Incentive mechanism for a sustainable public distribution system

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ABSTRACT

Efficient allocation of scarce resources through a public distribution system contributes significantly to the sustainable development of a nation. This is even more important when primarily the end consumers are below a benchmark poverty line and prevailing corruption practices prevent the resources from reaching them. More specifically, the rationed goods supplied by the government through a public distribution system do not often reach the deserving citizens primarily due to the practice of corruption. Bureaucrats who are empowered with distribution rights may indulge in other activities such as their own utility maximization, thereby distorting social optimality. The inherent moral hazard is identified as the potential cause of this deficiency. Through this research we design an incentive mechanism to curtail socially undesirable activities of the bureaucrats while distributing rationed goods. Such an incentive mechanism will cater to the development of a sustainable public distribution system and contribute towards the economic welfare of the less privileged citizens. We show that the mechanism designed will effectively reduce corruption and lead to social optimality.

KEYWORDS

public distribution system; incentive mechanism; information asymmetry; moral hazard; principal-agent model; social sustainability

1. Introduction

For the sustainable development of any nation, the government should ensure the poor get their fair share of the resources [Brundtland (1987)]. A Public Distribution System (PDS) is an instrument for the government to distribute basic amenities to the citizens below the poverty line. We introduce the concept of *sustainable PDS* as the one which achieves the dimensions of social sustainability, namely, health, welfare, and ethics among the stakeholders; such dimensions have been identified by Mani et al. (2016). The objective of this paper is to develop a sustainable PDS.

Very often rationed goods / essential commodities supplied by the government through a PDS do not reach the deserving citizens since the bureaucrats involved indulge in bribery to increase their utility. Hence, the government's objective is not realized to the fullest extent. In this paper we address the social welfare problem of maximizing the reachability of essential resources distributed by the government to the economically weaker citizens.

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In developing countries the government generally maintains a record of economically weaker citizens who primarily depend on the government for basic commodities for their livelihood. The government distributes such commodities to these citizens either free of cost or at prices well below the market-clearing level through PDS. Such benchmark/ class of citizens is referred to as *below the poverty line* (BPL) by the Government of India. A bureaucrat is employed by the government to achieve this task of distributing the commodities. Many times, these bureaucrats, instead of performing their duty diligently, accept bribe to maximize their own utility. The well to do citizens pay bribe to get these commodities as it will be still economical than buying from the market. Since the wage of the bureaucrat is assured by the government, they tend to be risk loving.

Evidence of several irregularities and corrupt practices leading to unreachability of the resources distributed through the PDS to the vulnerable has been reported by Mooij et al. (1999). This includes considerable profits from illegal sale of commodities, limited opening hours of the PDS shops and involvement in self enrichment activities of the bureaucrats. Khera (2011) identifies reasons for corrupt practices by the bureaucrat. The author observes low utilization of PDS among those who have access to it, i.e., purchasing less than the entitlement and purchasing from the market at a higher price, which has been referred to as 'under-purchase' puzzle. Ahluwalia (1993) observed *leakage* of commodities from PDS as high as a third of food grains and sugar, and over half of the edible oil. The consequence of leakage leading to costly income transfers and loss of social welfare has been pointed out by Dutta and Ramaswami (2001). Such practices are a major hindrance to a sustainable PDS in developing countries and through this work we design a mechanism to curtail such practices.

Be it a developing or developed country, the government requires an efficient PDS to achieve its objectives towards social welfare. Unlike developing countries where the motive is to distribute only scarce resources to the poor, in developed countries the government may desire to maximize the number of adopters of public interest goods, such as vaccines, products with less carbon emission, for social welfare. For example, the adoption of electric vehicles in California [Demirci and Erkip (2017)]. However, our study focuses on PDS in developing countries to distribute essential commodities.

Kulshreshtha (2007) analyzed the situation where the government usually distributes commodities at low prices to economically weaker citizens on first-come first-serve basis through bureaucrats who accept bribes. The author established that "if the rationed good and 'other' income are substitutes and bribery is present, the government should strictly enforce anti-corruption statutes in the bureaucracy and supervise bureaucrats strongly to reduce the scope of bribery in such situations". He also argued that if the rationed good and other income are substitutes or complements with the government charging a price below a particular threshold, then distributing the good free is socially optimal. Bardhan (1997) observed the inability of governments to reach the poor through subsidies in the presence of bribery. Justesen and Bjørnskov (2014) differentiate the propensity of rich and poor towards paying bribe for public services in the African context. Data from 18 African countries reveal poor people are three times (on average) more likely to pay bribes to government bureaucrats compared to wealthier people as the latter have viable exit options.

Contrasts in economists' versus non-economists' approach towards fighting corruption can be seen in Bardhan (2006). The author explains that non-economists adopt social movement or moral reform, whereas economists concentrate on incentive systems. Incentive mechanisms have been commonly applied by economists to improve worker productivity and morale [Klein (1965), Eilon (1966), Sander and Williams (2005)].

Incentives from employers such as promotion and bonuses encourage employee loyalty [Akerlof (1984), Malcomson (1984), Solow (1979)]. Abbink (2000) and van Veldhuizen (2013) find evidence from laboratory experiments that poorly paid public officials are less hesitant to accept bribes. An and Kweon (2017) quantify the marginal contribution of wages towards decrease in corruption. Gans-Morse et al. (2018) advocate the necessity of adequate wages to civil servants to control corruption. They examine seven categories of policies for controlling corruption such as monitoring, rewards, and penalties. Borcan, Lindahl, and Mitrut (2014) and Banuri and Eckel (2015) find crackdown to be ineffective in the long run to control corrupt behavior. Our study adopts an economist's approach to design an incentive mechanism to reduce the scope of bribery in a PDS by rewarding those who strive to achieve the government's objective of social welfare.

From the review of the literature it is evident that most of the researches analyze different policies to control corruption. To the best of our knowledge there is no study where a mechanism has been designed to prevent corruption in an environment where bribery prevails. This research is the first of its kind to provide a solution to the aforementioned problem using a quantitative approach. The incentive scheme designed in this paper discourages the corrupt practices of the bureaucrat by providing a high incentive to those who apply selfless effort to achieve the government's objective. Therefore, the model is of practical importance to governments, especially of developing countries in which bribery is prevalent and a large proportion of citizens fall under the BPL.

2. Problem Formulation

The proposed model is based on the fact that the government has the latest record of citizens in the BPL category such as their ration card number. The bureaucrat who supplies goods to the citizens in the BPL category verifies their identity and receives an acknowledgment duly attested by them against their respective ration card numbers at the time of distribution of the goods. Hence, we see that although the effort taken by the bureaucrat is not verifiable, the outcome of his effort is verifiable. This situation leads to *information asymmetry* in the form of *moral hazard* which arises typically in a principal-agent framework where the effort taken by the agent (appointed by the principal) to achieve a particular task cannot be verified [Macho-Stadler and Pérez-Castrillo (2001)]. We develop our model under this framework where the principal desires the agent to apply a specific level of effort which is not verifiable. Here the government plays the role of principal, bureaucrat being the agent.

Suppose the government allocates Q quantity of good for people in the BPL category and assumes that the distributed quantity in the absence of bribery lie in the range $[Q-q_1, Q-q_2]$ for some q_1, q_2 where $0 < q_2 < q_1 < Q$. It will be socially optimal if the agent distributes the goods in this desired range. The government anticipates three types of effort levels applied by the bureaucrat. The high level of effort H, desired by the government, is the one in which the bureaucrat supplies the desired quantity of good $[Q-q_1, Q-q_2]$ to the BPL category, without bothering about his own interest. Distribution of good below $Q-q_1$ indicates indulgence of the bureaucrat in some other activities to maximize his own welfare. This is represented by the undesired level of effort L_1. On the other hand, the quantity of the good distributed higher than $Q-q_2$ indicates selling of the good to people above the BPL category. Since it can be assumed that people above the BPL have paid bribe to buy these goods at a cheaper rate than the market, the distribution of goods beyond the estimated range indicates the bureaucrat has received bribe. Let L_2 denote this undesired effort level which is considered far more deviating from social optimality than L_1. While effort level L_2 refers to the corrupt behavior of bureaucrat, effort level L_1 hampers timely delivery of essentials to the needy.

To counter the bureaucrat's behavior of deviating from socially optimality, the government (principal) designs the following incentive mechanism - w_H to be the wage for the bureaucrat (agent) if he exerts effort level H, w_{L_1} for effort level L_1 and w_{L_2} for effort level L_2. To penalize the undesired effort levels, the wages should satisfy $w_H > w_{L_1}$ and $w_H > w_{L_2}$. By designing such a wage structure the government can enthuse the bureaucrat to apply the desired effort level H to achieve the following objectives — (i) maximize the distribution to the BPL category, (ii) timely delivery, and (iii) minimize bribery.

Table 1. Notations

Q	quantity of good allocated for people in BPL category
$[Q - q_1, Q - q_2]$	estimated range of quantity of good distributed to BPL people
q	actual quantity of good distributed by the bureaucrat
$f(q)$	utility to the government (in terms of monetary value) by distributing q units of good
L_1	low level of effort taken by the bureaucrat where quantity of good distributed is less than $Q - q_1$
H	high/ socially optimal level of effort taken by the bureaucrat where the quantity of good distributed is in the range $[Q - q_1, Q - q_2]$
L_2	low level of effort taken by the bureaucrat corresponding where the quantity of good distributed is more than $Q - q_2$
w_{L_1}	wage designed for the bureaucrat for effort level L_1
w_H	wage designed for the bureaucrat for effort level H
w_{L_2}	wage designed for the bureaucrat for effort level L_2
$p_q^{L_1}$	conditional probability that the bureaucrat applied effort level L_1 when the quantity of good distributed is q
p_q^H	conditional probability that the bureaucrat applied effort level H when the quantity of good distributed is q
$p_q^{L_2}$	conditional probability that the bureaucrat applied effort level L_2 when the quantity of good distributed is q
U	minimum expected utility for the bureaucrat to participate in the mechanism
P	external source of income the bureaucrat can achieve by applying effort level L_1
b	amount of bribe received by the bureaucrat for distributing per unit of good to people who are above the BPL category

The notations used in the paper are summarized in Table 1. The values $p_q^{L_1}$, p_q^H, $p_q^{L_2}$, U, P, b and Q being the parameters of the problem are considered to be common knowledge. We assume that the principal who designs the contract desires to maximize his expected utility which increases with the quantity of good distributed and decreases with the wages paid to the agent. Further, we assume that the principal is risk-neutral and the agent is risk-loving. Hence it is valid to assume that the monetary value, $f(q)$ of distributing q units of the good for the government is q, i.e., $f(q) = q$. While traditional models assume the agent to be risk averse, we assume the agent is risk-loving primarily due to the fact that agent by nature of his position as a government employee is already assured of his income and position. This generates scope for moral hazard to occur.

Convex functions model risk loving nature of players in a given situation (Mas-Colell et al., 1995). In this study we consider the convex function w^2 to be appropriate to the problem setting since these incentives are perceived as awards or recognitions by the agents for excellence in service. Thus the incentives described in the model do not imply the conventional salary. The agent will associate a utility of w^2 for a wage of w.

Evidence about the existence of risk-loving agents exists in literature. Kahneman and Lovallo (1993) explain two exceptions to risk aversion – (i) many people are willing to pay more for lottery tickets than their expected values, and (ii) studies of individual choice have shown that managers are risk seeking in the domain of losses. Shleifer and Vishny (1993) in their model to describe corruption assume that the good is sold for the government by an official who has the opportunity to restrict the quantity of the good that is sold. The authors describe that corrupt officials go unpunished because their bosses often share the proceeds. Moreover, public pressure to stop corruption in most countries is weak. Chakravarty et al. (2011) find that there is a tendency to exhibit less risk aversion when an individual makes a decision for a stranger. This reduction in risk aversion is relative to his or her preferences and it is also relative to his or her belief about the preference of others. This result has significant implications for the design of contracts between principals and agents.

The model is formulated mathematically as the follows.

$$\underset{\{w_{L_1},w_H,w_{L_2}\}}{\text{Maximize}} \quad \sum_{q=1}^{Q-q_1-1} p_q^H(q-w_{L_1}) + \sum_{q=Q-q_1}^{Q-q_2} p_q^H(q-w_H) + \sum_{q=Q-q_2+1}^{Q} p_q^H(q-w_{L_2}) \quad (1)$$

subject to

$$\sum_{q=1}^{Q-q_1-1} p_q^H w_{L_1}^2 + \sum_{q=Q-q_1}^{Q-q_2} p_q^H w_H^2 + \sum_{q=Q-q_2+1}^{Q} p_q^H w_{L_2}^2 \geq U \quad (2)$$

$$\sum_{q=1}^{Q-q_1-1} p_q^H w_{L_1}^2 + \sum_{q=Q-q_1}^{Q-q_2} p_q^H w_H^2 + \sum_{q=Q-q_2+1}^{Q} p_q^H w_{L_2}^2 \geq$$
$$\sum_{q=1}^{Q-q_1-1} p_q^{L_1} w_{L_1}^2 + \sum_{q=Q-q_1}^{Q-q_2} p_q^{L_1} w_H^2 + \sum_{q=Q-q_2+1}^{Q} p_q^{L_1} w_{L_2}^2 + P \quad (3)$$

$$\sum_{q=1}^{Q-q_1-1} p_q^H w_{L_1}^2 + \sum_{q=Q-q_1}^{Q-q_2} p_q^H w_H^2 + \sum_{q=Q-q_2+1}^{Q} p_q^H w_{L_2}^2 \geq$$
$$\sum_{q=1}^{Q-q_1-1} p_q^{L_2} w_{L_1}^2 + \sum_{q=Q-q_1}^{Q-q_2} p_q^{L_2} w_H^2 + \sum_{q=Q-q_2+1}^{Q} p_q^{L_2} (w_{L_2}^2 + bq) \quad (4)$$

$$w_{L_1}, w_H, w_{L_2} \geq 0$$

The principal maximizes his objective subject to the participation and incentive compatibility constraints of the agent. The principal's expected utility is his expected difference between the quantity distributed and the respective wage paid, given by (1). The agent will participate in the mechanism if his expected utility in participating in the mechanism is at least as high as that which can be achieved through outside means. For a bureaucrat with high effort level, to participate in the mechanism, the expected utility through participation given by LHS of (2) must be at least as high as his minimum requirement of U. Hence the participation constraint (2). The incentive compatibility constraint implies that the utility achieved in exerting a high effort is at least as high as that achieved by exerting a low effort. The effort level of L_1 provides the bureaucrat with an additional income of P while effort level of L_2 provides an additional income of $\sum_{q=Q-q_2+1}^{Q} p_q^{L_2} bq$. Hence the incentive compatibility constraints corresponding to the two low levels of effort L_1 and L_2 are (3) and (4) respectively. The principal then evaluates the values of the wages w_{L_1}, w_H, and w_{L_2} under which the agent is incentivized to choose high effort level.

3. Model Solution

Let $\alpha^H = \sum_{q=1}^{Q-q_1-1} p_q^H$, $\beta^H = \sum_{q=Q-q_1}^{Q-q_2} p_q^H$ and $\gamma^H = \sum_{q=Q-q_2+1}^{Q} p_q^H$. Similarly, we define α^{L_1}, β^{L_1}, γ^{L_1}, α^{L_2}, β^{L_2} and γ^{L_2}. Thus, α^{L_1}, β^H and γ^{L_2} denote the maximum probability to reflect the actual effort levels L_1, H, L_2 respectively applied by the agent.

To solve the above optimization problem we set up Lagrangian L as follows and associate multipliers λ, μ_1 and μ_2 with constraints (2), (3) and (4) respectively.

$$\begin{aligned} L = \quad & \alpha^H(q - w_{L_1}) + \beta^H(q - w_H) + \gamma^H(q - w_{L_2}) + \lambda[\alpha^H w_{L_1}^2 + \beta^H w_H^2 + \gamma^H w_{L_2}^2 - U] \\ & + \mu_1[\alpha^H w_{L_1}^2 + \beta^H w_H^2 + \gamma^H w_{L_2}^2 - \alpha^{L_1} w_{L_1}^2 - \beta^{L_1} w_H^2 - \gamma^{L_1} w_{L_2}^2 - P] + \mu_2[\alpha^H w_{L_1}^2 \\ & + \beta^H w_H^2 + \gamma^H w_{L_2}^2 - \alpha^{L_2} w_{L_1}^2 - \beta^{L_2} w_H^2 - \gamma^{L_2}(w_{L_2}^2 + bq)] \end{aligned} \tag{5}$$

Lemma 1. *At optimality the participation constraint (2) of the agent is satisfied with equality.*

Proof. The first order conditions of optimality imply $\frac{\partial L}{\partial w_{L_1}} = 0$, $\frac{\partial L}{\partial w_H} = 0$ and $\frac{\partial L}{\partial w_{L_2}} = 0$. This gives

$$\alpha^H(-1 + 2\lambda w_{L_1} + 2\mu_1 w_{L_1} + 2\mu_2 w_{L_1}) = 2\alpha^{L_1}\mu_1 w_{L_1} + 2\alpha^{L_2}\mu_2 w_{L_1} \tag{6}$$

$$\beta^H(-1 + 2\lambda w_H + 2\mu_1 w_H + 2\mu_2 w_H) = 2\beta^{L_1}\mu_1 w_H + 2\beta^{L_2}\mu_2 w_H \tag{7}$$

$$\gamma^H(-1 + 2\lambda w_{L_2} + 2\mu_1 w_{L_2} + 2\mu_2 w_{L_2}) = 2\gamma^{L_1}\mu_1 w_{L_2} + 2\gamma^{L_2}\mu_2 w_{L_2} \tag{8}$$

Dividing (6), (7) and (8) by w_{L_1}, w_H and w_{L_2} respectively and then adding them we get

$$-\frac{\alpha^H}{2w_{L_1}} - \frac{\beta^H}{2w_H} - \frac{\gamma^H}{2w_{L_2}} + \lambda + \mu_1 + \mu_2 = \mu_1 + \mu_2$$

since $\alpha^{L_1} + \beta^{L_1} + \gamma^{L_1} = 1$, $\alpha^H + \beta^H + \gamma^H = 1$ and $\alpha^{L_2} + \beta^{L_2} + \gamma^{L_2} = 1$. Therefore,

$$\lambda = \frac{\alpha^H}{2w_{L_1}} + \frac{\beta^H}{2w_H} + \frac{\gamma^H}{2w_{L_2}} > 0 \tag{9}$$

since α^H, β^H, $\gamma^H > 0$ and w_{L_1}, w_H, $w_{L_2} \geq 0$. Now $\lambda > 0$ implies the corresponding constraint binds. □

Lemma 2. *At optimality the incentive constraints (3) and (4) of the agent are satisfied with equality.*

Proof. Dividing (6), (7) and (8) by w_{L_1}, w_H and w_{L_2} respectively, we get

$$\begin{aligned}\frac{1}{2w_{L_1}} &= \lambda + \mu_1[1 - \frac{\alpha^{L_1}}{\alpha^H}] + \mu_2[1 - \frac{\alpha^{L_2}}{\alpha^H}] \\ \frac{1}{2w_H} &= \lambda + \mu_1[1 - \frac{\beta^{L_1}}{\beta^H}] + \mu_2[1 - \frac{\beta^{L_2}}{\beta^H}] \\ \frac{1}{2w_{L_2}} &= \lambda + \mu_1[1 - \frac{\gamma^{L_1}}{\gamma^H}] + \mu_2[1 - \frac{\gamma^{L_2}}{\gamma^H}]\end{aligned}$$

From the above, it is easy to observe that μ_1 and μ_2 cannot be zero simultaneously; otherwise, $w_{L_1} = w_H = w_{L_2}$ and constraints (3) and (4) will be violated. We also observe that:

(1) $\mu_1 = 0$ and $\mu_2 > 0$ cannot occur simultaneously. Otherwise, $w_H < w_{L_2}$ (since $\beta^{L_2} < \beta^H$ and $\gamma^{L_2} > \gamma^H$) which contradicts the incentive designed.
(2) $\mu_1 > 0$ and $\mu_2 = 0$ cannot occur simultaneously. This can be proved using a similar argument as in 1.

Hence, $\mu_1 > 0$ and $\mu_2 > 0$ implying the incentive constraints (3) and (4) bind at optimality. □

Proposition 1. *If* $\alpha^H(\beta^{L_1}\gamma^{L_2} - \beta^{L_2}\gamma^{L_1}) - \beta^H(\alpha^{L_1}\gamma^{L_2} - \alpha^{L_2}\gamma^{L_1}) + \gamma^H(\alpha^{L_1}\beta^{L_2} - \alpha^{L_2}\beta^{L_1}) \neq 0$, *there exists a unique optimal solution* $(w^2_{L_1}, w^2_H, w^2_{L_2})$ *which satisfies constraints (2), (3) and (4) with equality.*

Proof. From Lemmas 1 and 2, we know that constraints (2), (3) and (4) hold with equality at optimality. This generates a unique solution $(w^2_{L_1}, w^2_H, w^2_{L_2})$, provided the determinant of the coefficients of $w^2_{L_1}$, w^2_H and $w^2_{L_2}$ (given by the above condition) is non-zero. □

Under the conditions of Proposition 1 we infer that a closed form solution $(w^2_{L_1}, w^2_H, w^2_{L_2})$ can be obtained by solving constraints (2), (3) and (4) as simultaneous equations.

4. Model Analysis

The principal considers $[Q - q_1, Q - q_2]$ to be the desired quantity of the good to be distributed, whereas distribution below or above this range is considered undesirable. Since L_1 corresponds to an effort level often leading to the good being distributed in the range $[1, Q - q_1 - 1]$, the probability will be highest for such an outcome to be realized when an effort of L_1 is exerted. Moreover, for the effort level L_1, the outcome in the range $[Q - q_1, Q - q_2]$ will be realized with a higher probability than in the range $[Q - q_2 + 1, Q]$. Thus, a reasonable assumption can be taken as $\alpha^{L_1} \geq 0.5$, $\beta^{L_1} = 3(1 - \alpha^{L_1})/4$ and $\gamma^{L_1} = (1 - \alpha^{L_1})/4$. Using a similar argument it is assumed that $\gamma^{L_2} \geq 0.5$, $\beta^{L_2} = 3(1-\gamma^{L_2})/4$ and $\alpha^{L_2} = (1-\gamma^{L_2})/4$. Effort level H often leads to good distributed in the range $[Q-q_1, Q-q_2]$, and therefore the probability will be the highest for this outcome to be realized when an effort level of H is exerted. Further, we observe that realizing outcomes in the ranges $[1, Q - q_1 - 1]$ and $[Q - q_1, Q - q_2]$ is low for such an effort level. Hence, we assume that $\beta^H \geq 0.5$, $\alpha^H = \gamma^H = (1 - \beta^H)/2$.

Further, we assume the maximum probability to reflect the actual effort levels L_1, H, L_2 respectively applied by the agent are all equal, i.e., $\alpha^{L_1} = \beta^H = \gamma^{L_2} = k$ (say). Note that from pervious discussion $k \geq 0.5$. Therefore, we establish our propositions under the assumptions: $\alpha^{L_1} = \beta^H = \gamma^{L_2} = k \geq 0.5$, $\alpha^H = \gamma^H = (1-k)/2$, $\beta^{L_1} = \beta^{L_2} = 3(1-k)/4$, $\gamma^{L_1} = \alpha^{L_2} = (1-k)/4$.

From Proposition 1, we immediately observe that the closed form solution of the required model can be determined as below.

$$w^2_{L_1} = \frac{(7k-3)\{U(1-5k)+2(1-k)(P-B)\} - 4k\{2P(1-3k) - B(1-k)\}}{-35k^2+22k-3} \tag{10}$$

$$w^2_H = \frac{2(1-k)(1-5k)(P+B) - U\{4(1-3k)^2 - (1-k)^2\}}{-35k^2+22k-3} \tag{11}$$

$$w^2_{L_2} = \frac{(7k-3)\{U(1-5k)+2(1-k)(B-P)\} - 4k\{2B(1-3k) - P(1-k)\}}{-35k^2+22k-3} \tag{12}$$

where $B = \sum_{q=Q-q_2+1}^{Q} p_q^{L_2} bq$.

Proposition 2. *$w^2_{L_1}$ monotonically increases with α^{L_1} in [0.5,1.0].*

Proof. From (10), $w^2_{L_1} \to U - 10P/3 - 2B/3$ as $k \to 0.5$, and $w^2_{L_1} \to U - P$ as $k \to 1.0$, hence the result. □

Proposition 3. *$w^2_{L_2}$ monotonically increases with γ^{L_2} in [0.5,1.0].*

Proof. From (12), $w^2_{L_2} \to U - 10B/3 - 2P/3$ as $k \to 0.5$, and $w^2_{L_2} \to U - B$ as $k \to 1.0$. This establishes the proposition. □

Proposition 4. *w^2_H monotonically decreases with β^H in [0.5,1.0].*

Proof. From (11), $w^2_H \to U + 2(P+B)$ as $k \to 0.5$, and $w^2_H \to U$ as $k \to 1.0$. This establishes the proposition. □

The nature of the distribution of the wages w_{L_1}, w_H, w_{L_2} as a function of k (explained by Propositions 2 - 4) is depicted in Figure 1. The utility of wages, $w^2_{L_1}$ and $w^2_{L_2}$, are increasing while w^2_H decreases with k in order to achieve expected utility of at least U. However, it may be observed that participation of the players is *ex-interim* only, i.e. players participate if their expected utility is at least as high as their reservation price. *Ex-post* individual rational constraint need not be satisfied, i.e. after the realization of the outcome the utility received by an agent need not be at least as high as U.

We next describe the relationship among the wages w_{L_1}, w_H and w_{L_2} evaluated from the incentive mechanism.

Proposition 5. *For $\alpha^{L_1} = \beta^H = \gamma^{L_2} = k \in [0.5, 1.0]$, $w^2_H > w^2_{L_1}$ and $w^2_H > w^2_{L_2}$. Further $w^2_{L_1} > w^2_{L_2}$ if $B > P$.*

Proof. The relation follows from equations (10), (11) and (12) by evaluating $w^2_{L_1}$, w^2_H and $w^2_{L_2}$ when $k \to 0.5$ and $k \to 1.0$. □

The scope of this study is limited to the conditions specified in Proposition 5. It is easy to observe from the above proposition that the agent applying effort H is better incentivized than the others. The model penalizes the agent applying effort L_2 by offering the least wage.

Numerical illustration of the above propositions is provided in Table 2. The model parameters Q, q_1 and q_2 are set to 100, 50 and 90 respectively, whereas P, U and b are varied. It is easy to observe that $w_H^2 > w_{L_1}^2 > w_{L_2}^2$ for all cases. Let $\theta_{L_1} = (w_H - w_{L_1})/w_H \times 100$ and $\theta_{L_2} = (w_H - w_{L_2})/w_H \times 100$ denote the percentage decrease in the wage from w_H for agents applying effort levels L_1 and L_2 respectively. Values of θ_{L_1} and θ_{L_2} from computational results indicate that the model disincentivizes the agent adopting effort level L_2.

Table 2. Numerical illustration

	B	$\alpha^{L_1} = \beta^H = \gamma^{L_2}$	w_{L_1}	w_H	w_{L_2}	θ_{L_1}	θ_{L_2}
		$U = 2500,\ P = 500,\ b = 12$					
(a)	573.0	0.5	21.2	68.2	16.0	68.8	76.5
	687.6	0.6	38.7	57.4	33.5	32.5	41.5
	802.2	0.7	42.2	54.0	36.0	21.8	33.2
	916.8	0.8	43.7	52.1	36.7	16.3	29.5
	1031.4	0.9	44.4	50.9	36.9	12.9	27.5
	1146.0	1.0	44.7	50.0	36.8	10.6	26.4
		$U = 3000,\ P = 500,\ b = 12$					
(b)	573.0	0.5	30.8	71.7	27.5	57.0	61.7
	687.6	0.6	44.7	61.6	40.3	27.4	34.5
	802.2	0.7	47.8	58.4	42.4	18.2	27.4
	916.8	0.8	49.1	56.7	43.0	13.5	24.2
	1031.4	0.9	49.7	55.6	43.1	10.7	22.4
	1146.0	1.0	50.0	54.8	43.1	8.7	21.4
		$U = 5000,\ P = 500,\ b = 12$					
(c)	573.0	0.5	54.3	84.5	52.5	35.7	37.9
	687.6	0.6	63.2	76.1	60.2	16.9	20.9
	802.2	0.7	65.4	73.6	61.6	11.0	16.2
	916.8	0.8	66.4	72.2	62.1	8.1	14.1
	1031.4	0.9	66.8	71.4	62.1	6.3	12.9
	1146.0	1.0	67.1	70.7	62.1	5.1	12.2
		$U = 3000,\ P = 500,\ b = 14$					
(d)	668.5	0.5	29.8	73.1	20.9	59.2	71.3
	802.2	0.6	44.7	62.2	37.4	28.1	39.9
	935.9	0.7	47.9	58.8	39.9	18.6	32.1
	1069.6	0.8	49.1	56.9	40.7	13.7	28.6
	1203.3	0.9	49.7	55.7	40.9	10.7	26.7
	1337.0	1.0	50.0	54.8	40.8	8.7	25.5
		$U = 3000,\ P = 580,\ b = 12$					
(e)	573.0	0.5	26.2	72.8	26.5	64.1	63.6
	687.6	0.6	42.9	62.0	40.3	30.8	35.0
	802.2	0.7	46.5	58.6	42.5	20.7	27.6
	916.8	0.8	48.0	56.8	43.1	15.6	24.2
	1031.4	0.9	48.8	55.7	43.2	12.4	22.4
	1146.0	1.0	49.2	54.8	43.1	10.2	21.4

4.1. *Some Observations*

(1) When the minimum expected utility U increases, keeping all other parameters fixed, the marginal increase in w_H is smaller than that of w_{L_1} and w_{L_2} (Table 2,

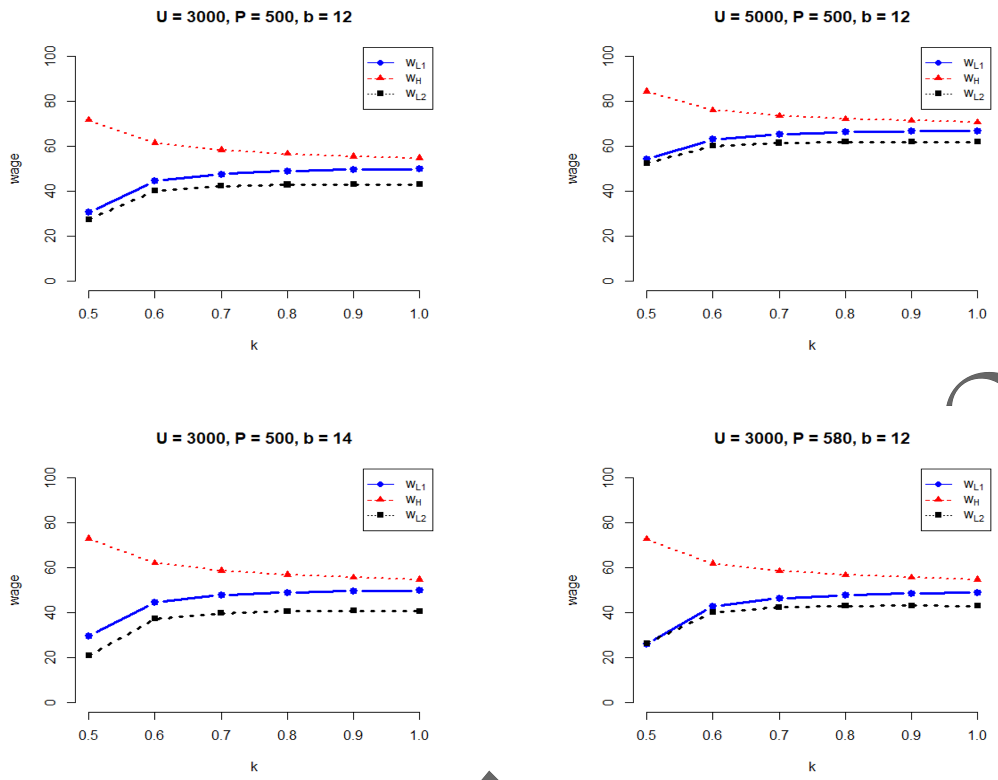

Figure 1. Sensitivity analysis of the wages

cases (a), (b) and (c)). This can be attributed to the fact that the agent applying effort level H has already been highly incentivized and any further increase in U should only improve the wages of agents applying effort levels L_1 and L_2 to ensure participation.

(2) When the source of income through bribery B increases, all other parameters being fixed, w_H increases to incentivize high level of effort and w_{L_2} decreases significantly to disincentivize the agent from receiving bribe (cases (b) and (d)). A similar phenomenon occurs when P increases and w_{L_1} decreases significantly.

(3) For equal percentage increase in B or P, the decrease in w_{L_2} is more significant than that of w_{L_1}, indicating that the model penalizes the agent receiving bribe more severely. For example (referring to cases (b), (d) and (e) in Table 2), for an increase of 16% in P (from 500 to 580), $w^2_{L_1}$ decreases by 15% (from 30.8 to 26.2). On the other hand, for an increase of 16.7% in B (from 573.0 to 668.5), $w^2_{L_2}$ decreases by 24% (from 27.5 to 20.9). Our model is designed with the assumption that effort level L_2 is worse than L_1, hence this observation.

(4) If the type of effort of the agent can be determined with certainty, the variation in the wages is minimal. This can be verified from Figure 1 (all cases) that as $k \to 1.0$, the wages are close to each other.

The sensitivity analysis and the above observations indicate that incentives are directed towards effort H and not towards L_1 or L_2. This is in line with the principle of our model framework.

5. Implications of our Study

According to a study by World Bank (2019), 800 million citizens in India are covered through half a million fair price shops (FPS). Logistic challenges (such as long waiting lines, etc.) in the distribution of essential commodities through PDS shall often prevail. With corrupt practices prevalent, it will make the reachability to the needy all the more difficult. This is evident from the fact that only three out of ten of India's poorest households bought grains from FPS in 2005 [World Bank (2019)]. Hence there is a dire need to eliminate corrupt practices in the distribution system. The incentive mechanism designed through this research shall deter the corrupt bureaucrats from receiving bribes as it incentivizes only those who apply effort towards social welfare. We strongly believe that more of the vulnerable class shall benefit if the mechanism is in place.

In situations of crisis, such as the pandemic caused by Covid-19, most of the needy class are deprived of the opportunity to earn their livelihood and depend on the PDS as the only source of sustenance. To ensure reachability of essential commodities to the needy at the right time an incentive mechanism such as the one developed in this study should be a guiding principle for the government. Our model can be adjusted to design incentives with $w_H^2 > w_{L_2}^2 > w_{L_1}^2$ for timely delivery of essential commodities. This can be achieved through the condition $P > B$ as the model is symmetric to effort level L_1 and L_2 (refer equations (10) and (12)), thus, adaptable to the government's priority.

6. Conclusion

This research focussed on the design of an incentive mechanism to curtail bribery prevalent in a PDS as a step towards sustainability. The model is set in a principal-agent framework and studied as a problem of moral hazard. The mechanism designed through this study sufficiently penalizes the agent who receives bribe, whereas incentivizes him if the desired level of effort is applied to attain social optimality. Most researchers have analyzed different kinds of corruption, reasons and the evidence of existence and its consequences. This paper differs in its attempt to develop an incentive mechanism to prevent bureaucratic corruption. The developed model may be extended further to study situations where the government's monetary value towards the distribution of goods assumes a more general linear form. It will also be interesting to study the mechanism by parameterizing the risk preference of the agent.

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