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An incentive compatible model for eliciting firms' production function in a development process

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Abstract. Development plans with projects are usually designed by developing countries including African countries as a major tool for carrying out their development activities. Yet in their market oriented economies the governments have problems of allocating their scarce resources in the tender process. Thus, an incentive model is formulated for more efficient resource allocation and within this framework; decisions taken could be evaluated based on the outcomes.
Keywords. Resource allocation, Tender process, Incentive compatible, Production technology, development plan, Public goods.
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1. Introduction

Many governments in developing countries formulate policies and use development plans which include projects as a major means of influencing and directing the development activities of their respective countries. The plans usually have a major impact on their economies and generally cover a period of one to five years or even longer depending on the development activities to execute. Certain development plans are simply a set of quantitative targets to be accomplished within a specific period of time. These sets of targets which may cover the whole economy or just a component of the economy tend to be apparently coherent. The structural adjustment programmes (SAP) implemented in several African countries in the 1980s, to some extent, suspended some of these development plans. The development plans, which often consist of projects in various sectors of the economy are generally translated into specific production targets like building of schools and hospitals, roads, dams and infrastructure or construction of bridges and public buildings, and providing certain goods for the military and government offices. These goods generally have attributes of public goods and generate huge positive externalities. Thus, such goods might not be adequately provided by the private sector, implying that the government should direct their provision regardless of whether they are included in the development plans. In this paper, we formulate an incentive model for a more efficient resource allocation in the development and tender process. The decision process brings out a method of eliciting information and examining the outcomes.

2. Limited Resources

Despite the relevance of plans to the development process, many of the plans are difficult to realize because of constraints which include limited human, financial and technical resources, such that the type of development plans designed

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are usually greatly influenced by the resource constraints facing the different countries. This makes it imperative to ensure the most effective and efficient utilization of the limited resources existing in the economy; this is important for the development process. In these countries, the government plays a critical role particularly in mobilizing and allocating resources, and in controlling and influencing development activities in the economy. It is worth noting that the goods are mainly public goods generating huge positive externalities. However, a majority of developing economies are largely market oriented with both the private and public sectors playing important roles in the economies. There is substantial reliance on private sector and private ownership as means of production and decentralized decision-making system for allocating resources underscoring the role of the public-private partnership. Material incentives are the principal bases of influencing individuals, agents and firms to participate in economic activities. This also highlights the important role of the private sector and in particularly firms in the economy. It is the private firms, which generally execute development plans producing goods and services with public sector partnership.

In many developing countries there is much deficit in the provision of public goods such as education and health facilities, road and transportation infrastructure, which are essential infrastructure with positive externalities. As countries developed more public goods with better quality tend to be provided to the population. Nevertheless, according to Banerjee, Lakshmi & Rohini (2007) the provision of public goods can be said to be a function of collective action of the population or inhabitants and the government. Hence the population and geographical settings are important in providing public goods and services. These factors do influence the demand for variety of public goods and the cost of supplying those public goods. The more forceful and demanding the population, the more the population would tend to obtain public goods. But the geographical features would also tend affect the cost of producing the goods.

Suppose Q is the public good that is produced including the quality in community j at time t, H is a set of inhabitants' characteristics in community j at time t and T is a vector of historical and geographical features of where the community is located. And letting output of the public good Q to depend on H and T, we can specify the following relation:

$$Q_{jkt} = f(H_{jt}, T_{jt}) \quad (1)$$

The population's characteristics include socio-economic homogeneity or heterogeneity; the more homogeneous the population is the more cohesive the population with less differences in preferences or power. Characteristics would also include the distribution of assets and income among the inhabitants. How equal or unequal is the distribution of income and assets tends to influence the type of public goods demand by the population.

3. Tender Board and Firms' Problem

The plans are generally designed with the consultation of the population by the governments and implemented by variety of firms. So that the success or failure of the plans may mainly depend on the way the firms receive and utilise the resources in operating the projects in the plans; and on the information the government, represented by the Tender Board, has on the firms and the economy.

Generally information is dispersed such that only the firms possess detailed knowledge about their production technology. While the Tender Board has a better insight on the interdependencies of the whole economy, the social objective function of the State, the available resources and the economy's general needs.

This is mainly because the Tender Board has more and better information on the whole economy. The major problem of the Tender Board is how to maximise the society's objective function (a set of activities in the plan) subject to the government's available resources or budget. So that if the resources are efficiently allocated, the social benefit function is also maximised.

On the other hand, the firm usually maximises the difference between what it receives from the Tender Board to operate a project (its revenues) and the amount it spends in operating the project (its expenditures). In its private calculation the firm's objective is to minimise the cost of operating or executing a project. Or the firm tries to maximise the net revenue (gross revenue minus total cost = profit) from executing a project. Generally, while the government (Tender Board) attempts to maximise the social welfare (benefit), the private firm attempts to maximise its profits. The firm would generally be encouraged to save on consumption of expensive inputs and to avoid waste. In a nutshell, it is in the firm's interest to obtain as large amount of receipts as possible and spend as little as possible for any given project to maximize profits. Each firm has better knowledge of its production function and technology. At the same time each firm in the economy has to compete against other firms in order to win a government's project or contract. In such a competitive environment, with the right incentives, firms strive to use cost saving inputs and efficient technologies to execute acquired projects.

4. Incentive Structure

The problem posed here is how to design an incentive structure that would make it in a firm's interest to send truthful messages to the Tender Board. The firm has private information which needs to be made known to the Tender Board for efficient allocation of resources. Without that, there is a mismatch between the State objective and that of the firm (De Parikshit, 2014). That is, the firm sends its true "cost estimates" that can reflect the true cost function, so that collectively the economy can perform efficiently by allocating its scarce resources efficiently. It is not easy to design an incentive compatible scheme. However, what we are proposing seems an improvement on the existing structure.

Some of the countries do not have, for example, a central Tender board responsible for awarding government projects or contracts; instead the government's budget for the planned period is shared among different government departments, sometimes arbitrarily or politically. Those departments in turn have offices responsible for giving out the different projects or awarding contracts. The criteria for selecting a firm for any particular project are not well known to the firms. This situation generally creates room for potential firms to carry on much rent seeking activities, since the ground rules are not well laid out. Even the limited skilled manpower (a common characteristic of many African countries) is spread throughout the different government departments. This reduces their performance as well as generates greater inefficiencies. In general the economy tends to incur great social costs from such situations. Hence, it is more efficient to centralise the contract granting department in not so large economies which is a characteristic of many developing economies.

The government as a whole knows little about the firm's production technology. So it cannot efficiently allocate the limited resources or carry out efficient planning. This situation is worsened by the fact that the firms tend to have little incentive to send true estimates to the Tender Board. The firms may benefit more by sending exaggerated estimated cost of the project to be executed. Thus making it very difficult for the government to know the true cost function of carrying out a

particular project in the economy and consequently the true total cost of the plan. The result is poor performance of public projects and consequently poor economic performance. Because the 'indicators' (which the Tender Board obtain from the different firms) may not be accurate, they may not be message desirable. Here, we propose a structure which can correct some of the defects and mainly elicit 'desirable messages' from the firms and equally make it possible for the Tender Board to gain a better knowledge of the economy. This can then put the economy in a better growth path. We believe development is enhanced if the government has a good knowledge of the economy, especially the cost structure and production function or production technology of the economy. The role of the government becomes very important in also improving the technology through public investment.

5. Formulating an Incentive Structure

The publishing of the offers and government contracts generate benefits to the society, the bidders and the government. The bidders have knowledge of the goods and services to be provided, and the government gain from the competition among the firms which bid to provide the goods and services. Competition means good quality of goods and services to be provided at the lowest cost.

Each firm or bidder put down a detailed bid including the length of time to complete the project, the amount of money and all its inputs necessary to execute the project or activity. Firms do not know what the other firms are bidding, nor the cost limits of the government (Tender Board). In all the Board should be able to select the bid of the firm that can generate the greatest benefits to the economy. The bidding process is one round after which the Tender Board gather all the bids, analyze the information on all the bids based on the criteria which include time and cost in realizing the respective projects. The Tender Board is interested in getting the work or project completed in a given time at the lowest cost possible, usually requesting shortest time at lowest cost. Usually changes in time and cost may tend to vary, the shorter the time limit the more the cost to execute a project.

Some models show where there are no payments with quasilinear utility, yet producing efficient resource allocation. Classic solutions are based on large payments to entity which are usually firms (Cavallo, 2014). Instead we base our settings on monetary payments to firms.

We are assuming one relevant well organized Tender Board in an economy responsible for all planning activities and implementation of the government's plan containing projects which have the characteristics of being public goods generating externalities. As a rule, plans are published with detailed specification of the different projects. The second step is that the Tender Board requests firms to submit their contingent estimates (which can be used to generate their cost functions). For convenience, we regard the estimates or costs as cost functions since we can derive the cost functions from their estimates, with the cost functions associated with different projects in the plan. The firms' estimates show their projected costs for the different projects within their given production technologies or production functions and time.

While the firms based their calculations on maximising private profits and so consider only those variables affecting their net profits - difference between receipts and expenditures, the Tender Board considers social costs and social profitability. Actually the firms are operating in a market oriented system and they regard the output which is a given project ($\overline{Q}$) as fixed. So the objective of the firm is minimising their costs or cost of production. In principle a typical firm chooses

its inputs x_i $(i = 1,2.....n)$ so, as to minimize its costs $\sum_{i=1}^{n} p_i x_i = PX$ subject to its technology $f(X) = \overline{Q}$ where *P, X, Q* are input price, input and output vectors respectively. That is minimize

$$\sum_{i=1}^{n} p_i x_i + \lambda\{\overline{Q - f(x)}\} \tag{2}$$

With given output, input prices, the cost minimizing values of the inputs are determined from the first order conditions of equation (2), assuming that an interior solution exists. With a given output, the rate of technical substitution gives the rate at which one input is substituted for another. And the factor price ratio gives the rate at which one output should be substituted for another with a given outlay. If this condition is not satisfied, outlay can be reduced by substituting one factor for another with a given output. Thus with given $\overline{Q}$, P_i , the input demand functions can be obtained as

$$x_i = x_i(p, \overline{Q}) \quad i = (1,2,.....n) \tag{3}$$

And from (3) the cost function is derived as

$$\hat{C}(P\overline{Q}) = \sum P_i x_i(p, \overline{Q}) \tag{4}$$

Equation (4) therefore gives the minimum cost of producing $\overline{Q}$ with input prices within the technological set. Hence, the cost function is obtained from the output-constrained minimization problem of the firm. The cost function therefore incorporates the production function of the firm. The cost function contains all the economic relevant information of a firm's technology; it is assumed to have all the desirable properties: non-decreasing, homogeneous, concave, and continuous in prices. Given these properties the cost function can be derived from the technology used.

The relevant information required by Tender Board is contained in equation (4) which can be rewritten as

$$\hat{C}_i = \hat{C}_i(p, \overline{Q}) \tag{4.1}$$

Note that Q includes X. (X is input factor as in equation 2.) For convenience, it is the firm's true cost function which the Tender Board wants to know among other things. The assumption of linearity of the cost structure may ensure efficient decision generating incentive compatibility, but this assumption may not be necessary, since the cost function is derived from the information given by the firms.

However when sending its estimates (implying the cost function) to the Tender Board, the firm may take into its calculations the number of firms it believes are competing for any given project in the plan. Firms generally may not know how many other firms are competing for a given project, although they know the number of projects as published. For any project, we can assume two situations: one in which there are many firms competing for a given project and the other when there are few firms competing for a given project. Many situations can exist in between. In the first case, because of competition, a firm cannot afford to exaggerate the cost of a project. While in the second case, with very few firms,

firms may be inclined to overestimate the cost of a project. There are many firms in a competitive market economy. So, generally, firm (i) would include the number of firms (m) competing for the project in its cost calculus. For any given project firm (i) would give an estimate of the following:

$$C_i = \hat{C}_i + \frac{a}{m}\hat{C}_i \tag{5}$$

Where $\hat{C}_i$ is the true estimate and α is chosen by the firm as its strategic variable for increasing its profits, $\alpha \in (0,1)$ and $\frac{a}{m}\hat{C}_i$ is what the firm makes additionally from the project depending on the number of firms (m). Equation (5) can be rewritten as

$$C_i = \left(1 + \frac{a}{m}\right)\hat{C}_i \tag{5.1}$$

So that $C_i \to \hat{C}_i$, as $m \to \infty$

When m is very large then, $C_i = \hat{C}_i$ and when the number is small this leads to equation (5). It therefore imply that revealing the cost function and consequently having better information on the economy's production function also depends on the number of firms in the economy. The greater the number of firms the better is the information set. Note that we are assuming transparency with no collusion among the firms. Information acquisition is very important in this process. Providing information or making all the necessary information publicly available so as to enhance transparency and efficiency is very important in reducing transaction cost in public tender. Given Adam Smith's Invisible Hand, economics has been able to "idealize competitive markets" as yielding best results in a decentralized ways with information transmission being incentive compatible in such situations, thus being efficient and incentive compatible. Incentive compatibility is possible when agents or firms are many especially in a large economy so that no one agent can influence market outcomes; that is, agents are price takers.

The Tender Board knows that generally a firm would like to submit cost based on equation (5) and the tender Board wants to know only $\hat{C}$ and not C. The Tender Board's problem is how to motivate firms to send the true cost function. Since the Tender Board's major problem is how to allocate the limited development funds efficiently so as to maximise the society's objective function, the Board can do this by coaxing the firms to supply their private held information especially concerning their production technology.

6. Eliciting the True Preference

Many incentive schemes may be proposed to induce agents to reveal their true preferences. Our structure is quite simple and easily applicable. The Tender Board can motivate firms to report their true cost functions, by giving them 'additional rewards'. That is Tender Board can include some 'side payments' in the awarding of projects. This side payment could be the minimum of estimated costs of the other firms. That is the firm with the lowest estimated cost would obtain the following for a given project:

$$C_i = \min\left[\hat{C}_i\right] \quad (6)$$

This should motivate firms to reveal their true cost ($\hat{C}$). With competition among the different firms for a project each firm knows that only the firm with the lowest cost or true cost, $\hat{C}$, would get the project. A serious problem to be avoided is for firms to reveal 'sub-estimates' and later ask for more funds. So there is a need to impose very heavy penalties and pursue them vigorously if any breach of contract occurs.

For the firm, if it submits higher estimates, it cannot win the government's project. If it reports its estimates, which are low (true estimates); it may win the project or offer. Safeguard are put in place to make sure any firm with lower estimates do so and are able complete the project. A firm cannot win the bid and later on not unable to complete due to insufficient funds. With a history of abandon or incomplete projects due to inadequate funds we must guard against such problems. So a firm's best strategy is to submit its true estimate, or cost function. The most efficient firm (with the lowest costs) wins the contract, which means that nationally the resources are allocated efficiently. It is quite important to note here that with this side payment based on the action of the other firms, each firm now faces a social decision instead of its private decision, and thus the need of the disclosure of desirable messages.

But because of the huge amounts involved, this type of side payment may be too costly as to make the whole plan infeasible. Instead extra 'payment' (positive or negative) could be added so as to change the total value of the payments. Hence the pay off for firm (i) can take the following form:

$$C_i = \min\left[\hat{C}_{j=i}\right] + G_i\left[C_{-i}\right] \quad (7)$$

where $G_i\left[C_{-i}\right]$ could be carefully chosen by the Tender Board's so as not to change very much the value of $\min\left[\hat{C}_{j=i}\right]$. In fact $G_i\left[C_{-i}\right] \leq 0$ or ≥ 0 depends on the Tender Board's calculation. It is important to note that $G_i\left[C_{-i}\right]$ G_i is independent on the firm (i)'s action; so it does not affect the non-co-operative action of the firm. It is in the firm's self-interest to submit its true cost function, since in principle it obtains 'more reward' by doing so and collectively the economy could function efficiently. This solves the incentive problem.

The results seem to imply that the revelation of the true cost function depends on the number of firms vying for a project. But the Tender Board could make a worldwide offer, calling for tenders or nationally the Tender Board could give out the projects at piecemeal. In order to elicit desirable messages; it is more difficult in a situation where there are few firms than where there are many firms. A problem with a developing economy is the thinness of the private sector; consequently the number of competent firms to execute the plan is very small. However, getting firms internationally across the border could be a positive way of transferring technologies into the domestic economy. The challenge is having the domestic firms absorb and adopt or acquire the technologies. On the other hand, there must be the willingness of the foreign firms to pass on the technologies to the domestic firms. The governments can play a very important role in the area of technology transfer or acquisition.

Thus having all the relevant information, the major problem facing Tender Board is choosing the minimum efficient cost for each project in the plan so as to minimize the total cost of the plan. Since the budget for the plan is fixed, the

Tender Board can maximise the social welfare function subject to the total fixed cost. This seems to be more difficult because of the problem of choosing a social welfare function. The Tender Board would then tend to minimise the costs of the projects. That is given $\hat{C}_i \overline{Q}_j$ and F as fixed budget to produce $\overline{Q}$ (Q is a vector of projects), the Tender Board

$$Min \sum_{i=1}^{n} \hat{C}_i Q \tag{8}$$

Subject to $\sum_{j=1}^{m} \hat{C}_j \leq F$ and the respective firms' technologies;

$$\Rightarrow F(Q, X, C) = F \tag{9}$$

where $i = 1,2,.....n$ and $j = 1,2,.....m$;
$m < n$ or $m > n$ and $F > 0$.

For simplicity the time (t) is not included in all the equations above. In choosing the minimum cost of producing each project, the Tender Board must make sure that the total minimum costs of all the projects do not exceed the total budget (F). This should not pose a big problem to the Tender Board . How is it known that a good decision has been taken? This depends on the outcome of a deliberate decision making process. The decisions made do produce outcomes. Hence one way of judging a given decision is by examining the outcomes.

7. Conclusion

Analysis is done for a single period, but it could be extended to multi periods. There are some advantages of this structure. The main advantage is that firms in the economy are motivated to be efficient in doing business with the public sector and also in revealing their true cost function to the government's Tender Board. There is, therefore, public private sector cooperation and partnership. This can have very profound impact on the economy, ceteris paribus. In fact, the Tender Board has better knowledge of the production technology of the economy, when firms submit their true cost functions. All this implies that future planning of setting of production targets could be used to describe efficient allocation of scarce resources among firms in the economy, and collectively the economy can function more efficiently. (Note that the Tender Board here is not the former Soviet type of planning board, since we are dealing with a market economy). However, this could be achieved if and only if each party 'play' according to the rules. Neither the Tender Board nor firms should break the rules because the breaking of the rules by either party may lead to disastrous consequences. An independent entity is usually established to enforce the contracts. Hence, very severe penalties are imposed on any breach of contract. Systems seem to function very poorly when there are no sanctions imposed for law breaking or breach of contract. Developing countries generally face the problem of not giving out the appropriate sanction or punishment for any wrong doing. The consequences of such laxity in law enforcement on African economies sometimes result to incomplete projects. So agents should be properly rewarded for their good actions and punished severely for their poor actions or impropriety. With appropriate incentives given for good performance,

the functioning of the economy is improved and firms continuously improve on their technologies, so generating productivity increase and growth.

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