1. Introduction

The public provision of goods is often in the hands of officials who may be inclined to use their position to favor their own interests. Bribery and corruption are glaring examples of abuse of positions of power by government officials. Although bribery and corruption may occur in any country, it is often considered to be a particularly serious problem in developing countries. For instance, Gilbert (1990) informs us that corruption has plagued the provision of public services in Columbia. Similarly, Southall (2000) has noted that corruption has caused problems with succession in Kenya. Finally, Afza (2000) has pointed out that corruption has impeded the efficient allocation of a whole host of goods and services in Pakistan. Indeed, as Mookherjee and Png (1995) have noted, corruption does seem to have particularly severe impacts in developing countries. In this regard, the reader should note that although there are many kinds of corruption, the extant literature on this subject appears to have focused primarily on *enforcement* related corruption.[1]

There is no gainsaying the fact that enforcement related corruption is a salient problem. Even so, in many developing countries, there is a significant amount of corruption involving the public allocation of goods. As Batabyal and Yoo (2003) have pointed out, a basic feature of these goods allocation processes is that they involve *queuing* by citizens. Put differently, people have to wait in a queue to obtain the good that is being allocated by a government official. Now, in many cases there are scarcity problems in developing countries that prevent all citizens from obtaining a desired quantity of services simultaneously. This is often the case in the provision of medical care, social housing, and entrance to schools.[2] In these and other instances in which citizens have to queue to obtain a publically allocated good, it is quite likely that a corrupt government official will be willing to provide services to citizens at different rates. In other words, it is entirely possible that individuals with a high opportunity cost of time or with a high level of income will be willing to pay a bribe to obtain service relatively speedily. In contrast, individuals with a low opportunity cost of time or with a low level of income are more likely to not pay a bribe and to wait longer in queue for service.

Given the above possibility, it is pertinent to ask the following general question: What are the connections between bribery, favoritism, and wait times in the public allocation of goods in developing countries? Surprisingly, there is very little formal research on this question. In fact, we have been able to identify only two theoretical papers that have shed light on this important question.[3]

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For more information on this literature, we refer the reader to Alatas (1968), Basu *et al.* (1992), Besley and McLaren (1993), and Mookherjee and Png (1995).

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For specific examples of the public provision of goods that involve queuing, see Wood (1999) and Gunawardana (2000). Wood (1999) discusses the supply of groundwater by means of tubewells in the Indian state of Bihar and Gunawardana (2000) comments on the distribution of rice to consumers in Sri Lanka.

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It is noteworthy that there is a small literature—see in particular Stahl and Alexeev (1985) and Polterovich (1993)—that has analyzed queuing models of resource allocation in the context of black markets in centrally planned economies. However, the reader should note that this literature has not specifically studied the questions that we are analyzing in this note.

In an interesting paper, Lui (1985) uses a queuing model to demonstrate, *inter alia*, that it is not necessarily true that government officials will purposely cause delays in a queue to attract more bribes. To demonstrate this, Lui (1985) studies a Markovian queue.[4] Put differently, in Lui's (1985) model, citizens enter the queue in accordance with a Poisson process and the service time is exponentially distributed. Even though Lui (1985) does compute the expected wait time of citizens in the queue, he does not directly analyze the bribery/favoritism nexus that we are interested in studying in this note.

Recently, Batabyal and Yoo (2003) have used a more general queuing approach than Lui's (1985) to analyze the differential treatment by a government official of citizens who pay bribes and those who do not. These researchers have used the expected wait times in queue for citizens who pay bribes and for those who do not to show that bribery is profitable (less profitable) for citizens with a high (low) opportunity cost of time. Although their paper does shed light on salient issues concerning the value of preemption and the benefit from bribery, it leaves two pertinent questions unanswered. In particular, when goods are allocated publically by means of queuing processes in developing countries, which group of citizens should a corrupt government official favor? In addition, what should be the basis for this favoritism? To the best of our knowledge, these important questions have not been analyzed previously in the literature. Consequently, the present note has two objectives. First, we use queuing theory to show that when a good is allocated publically by means of a queuing process, a case can be made for favoring a particular group of citizens. Next, we show that the nature of this favoritism depends not only on the bribes received by the corrupt government official but also, in a specific sense, on the efficiency with which this official discharges his duties.

The rest of this note is organized as follows. Section 2 describes the theoretical framework in detail. Section 3 first provides evidence to substantiate our claim that when apportioning a good publically, a case can be made for favoring a particular group of citizens. Next, this section focuses on the connection between bribes and expected service times and shows that this connection constitutes the basis for favoritism. Finally, section 4 concludes and discusses ways in which the research of this note might be extended.

2. The Theoretical Framework

Consider a corrupt government official (the server)[5] who is in charge of allocating a specific homogeneous good to the citizens of some developing country. To obtain one unit of this good, citizens must first join a queue and then wait in this queue until it is their turn to be served by this government official. Any citizen can obtain quicker service by paying a bribe to the server. Further, citizens are heterogeneous and hence, to model this feature, we shall say that the population in the developing country under study consists of type I and type II citizens. Many interpretations are

[4] Textbook accounts of Markovian queues can be found in Ross (2002, chapter 8) and in Ross (2003, chapter 8).

[5] In the remainder of this note, we shall use the terms "corrupt government official" and "server" interchangeably.

possible for this two-part classification. For instance, in the Batabyal and Yoo (2003) classification scheme, type I citizens are high opportunity cost of time citizens and type II citizens are low opportunity cost of time citizens. Similarly, type I citizens could be those who have the right connections and hence are able to influence the corrupt government official. In this interpretation, type II citizens would be those who have little or no connections and hence are not able to influence the corrupt government official, or at least not to the same degree as type I citizens.

Type I and type II citizens arrive at the corrupt government official's service facility—where the homogeneous good in question is being distributed—in accordance with independent Poisson processes with rates β_I and β_{II}. A bribe B_i, $i=I,II$, per unit time is received by the server from each type i citizen who waits in queue to receive the homogeneous good. It takes a random amount of time to provide service to type I and to type II citizens. Let us denote the amount of time taken to serve type I and type II citizens by the random variables s_I and s_{II}.

Given B_I, B_{II}, s_I, and s_{II}, can we find a condition that determines which citizen type ought to be favored by the server? This is the basic question that we now propose to answer. However, before we move to the specifics of this question, let us first be clear about the sense in which we are using the word "favored." To this end, without loss of generality, we shall say that type I citizens are favored or given service priority over type II citizens if service never commences on a type II citizen when a type I citizen is waiting in queue. However, if a type II citizen is already being served and a type I citizen arrives, then the type II citizen continues to receive service until completion, i.e., until the good being allocated publically is received by this type II citizen. In other words, while type I citizens are favored or given service priority, there is no preemption once service on a type II citizen has commenced.[6] Finally, if a type I citizen and a type II citizen arrive at the service facility at exactly the same point in time then the type I citizen is served first. We are now ready to proceed with the answer to the question we posed in the first sentence of this paragraph.

3. Favoritism and the Public Allocation of Goods

3.1. Who to favor?

To answer the above question, we shall proceed by means of four steps. First, we shall mathematically characterize the *average* amount of time a citizen spends waiting in queue for our priority queue or queue with favoritism. Let us denote this expected wait time by T^N. For notational ease, let $a=\beta_I/(\beta_I+\beta_{II})$ denote the proportion of all citizens who are type I and let $(1-a)=\beta_{II}/(\beta_I+\beta_{II})$ denote the proportion of all citizens who are type II. Now recall that the corrupt government official's service times for the two types of citizens are random variables denoted by s_I and s_{II}. Consequently, let $E[s_i],=1/m_i$, $i=I,II$, represent the expected service times for these two types of citizens and let $r_I=\beta_I E[s_I]$ and let $r_{II}=\beta_{II}E[s_{II}]$.

The priority queuing system that we are studying has two types of citizens. Therefore, to

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In the queuing theory literature, this sort of a queue is sometimes called a non-preemptive priority queue. For more on priority queues, the reader should consult Ross (2002, chapter 8) and Ross (2003, chapter 8).

compute T^N, we must average over both types of citizens. This tells us that

$$T^N = aT_I^N + (1-a)T_{II}^N, \tag{1}$$

where T_i^N, $i=I,II$, is the average amount of time a type i citizen spends waiting in queue to obtain the homogeneous good in question. Now, from equations (3) and (5) in Batabyal and Yoo (2003), it follows that

$$T_I^N = \frac{\beta_I E[s_I^2] + \beta_{II} E[s_{II}^2]}{2(1-r_I)} \text{ and } T_{II}^N = \frac{\beta_I E[s_I^2] + \beta_{II} E[s_{II}^2]}{2(1-r_I)(1-r_I-r_{II})}. \tag{2}$$

Using equations (1) and (2) together, we conclude that

$$T^N = \frac{\{\beta_I E[s_I^2] + \beta_{II} E[s_{II}^2]\}\{a(1-r_I-r_{II}) + (1-a)\}}{2(1-r_I-r_{II})(1-r_I)}. \tag{3}$$

We now have a mathematical characterization of the expected amount of time a citizen spends waiting in queue. This also completes the first step in the four step procedure that we alluded to in the first paragraph of this section.

Our next task is to determine the average amount of time spent by a citizen waiting in queue when there is *no* favoritism demonstrated by the server. Although one can model the lack of favoritism in a variety of ways, the simplest way is to suppose that our server allocates the homogeneous good in question to citizens on a first-come-first-served or FIFO basis. When the good in question is allocated on a FIFO basis, the queuing model with favoritism that we have been analyzing thus far becomes the well known M/G/1 queue[7] in which the arrival rate of citizens is $\beta = \beta_I + \beta_{II}$. Therefore, using equation 8.36 in Ross (2002, p. 256) we can infer that the expected amount of time spent by citizens waiting in queue, T_{FIFO}^N, is

$$T_{FIFO}^N = \frac{\{\beta_I E[s_I^2] + \beta_{II} E[s_{II}^2]\}}{2(1-r_I-r_{II})} \cdot \frac{(1-r_I)}{(1-r_I)}. \tag{4}$$

With equation (4) in place, we have now completed the second step in the four step procedure that we alluded to earlier.

Our third task is to determine when the expected wait of citizens in queue with favoritism is

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In the notation M/G/1, the M means that the arrival process is Poisson and hence the time between successive arrivals is exponential or *Markovian*. The G refers to the fact that the service times have a *general* distribution function. Finally, the 1 refers to the fact that there is a *single* server. For more on M/G/1 queues, see Ross (2002, chapter 8) and Ross (2003, chapter 8).

less than the expected wait without any favoritism. In other words, with regard to the wait time in queue, we would like to know when it makes sense for the server to favor one or the other type of citizen. Mathematically, we want to determine when $T^N < T^N_{FIFO}$. To accomplish this task, let us use equations (3) and (4). Comparing these two equations, it is clear that

$$T^N < T^N_{FIFO} \Leftrightarrow a(-r_I - r_{II}) \leq -r_I \Leftrightarrow ar_{II} > (1-a)r_I \Leftrightarrow \frac{\beta_I \beta_{II} E[s_{II}]}{\beta_I + \beta_{II}} > \frac{\beta_{II} \beta_I E[s_I]}{\beta_I + \beta_{II}} \Leftrightarrow E[s_{II}] > E[s_I] \Leftrightarrow m_I > m_{II}. \quad (5)$$

Equation (5) provides the answer to the question we posed at the beginning of the previous paragraph. In particular, this equation tells us that the average wait of citizens in queue with favoritism is less than the average wait of citizens in queue without favoritism if and only if the mean time it takes to provide service to type II citizens is greater than the mean time it takes to provide service to type I citizens. Put differently, from a waiting time perspective, favoring type I citizens over type II citizens makes sense if and only if the expected service time for type II citizens is greater than the expected service time for type I citizens. We are now in a position to undertake the fourth and final step in the four step procedure that we have been following thus far.

Recall that a bribe B_i, $i=I,II$, per unit time is received by the server from each type i citizen who waits in queue to receive the homogeneous good. Equation (5) tells us that if $m_I > m_{II}$ then $T^N < T^N_{FIFO}$. In words, when $m_I > m_{II}$, it makes sense for the server to favor type I citizens because such favoritism minimizes the average wait time of citizens in queue. Now, without going through all the mathematical details, note that the argument that led to the above stated result from equation (5) also works when $B_I m_I > B_{II} m_{II}$. In other words, $B_I m_I > B_{II} m_{II}$ implies that $T^N < T^N_{FIFO}$. This gives us the answer to the "Who to favor?" question and we now state this answer as
LEMMA 1: In a situation of favoritism, if $E[s_I]/B_I < E[s_{II}]/B_{II}$ then the server ought to favor type I citizens over type II citizens when publically allocating the homogeneous good in question.

3.2. Why to favor?

We now address the second question of this note: Given B_I, B_{II}, s_I, and s_{II}, can we obtain a condition that specifies which citizen type ought to be favored by the server? This is the basic question that we had posed in section 2 and Lemma 1 provides the answer to this question. As we can see from this Lemma, type I citizens ought to be favored over type II citizens because, for type I citizens, the ratio of the expected service time to the received bribe is less than the corresponding ratio for type II citizens.

Looked at somewhat differently, because $E[s_I]/B_I < E[s_{II}]/B_{II} \Leftrightarrow B_I/E[s_I] > B_{II}/E[s_{II}]$, we can also say that an implication of Lemma 1 is that in the developing country under study in this note, the citizen type with the highest ratio of bribe to expected service time ought to be favored. The reader should note that this result holds because, in a sense, our corrupt government official is attempting to maximize his *private* monetary gain. Lemma 1 gives us a condition for favoritism when the two types of citizens pay dissimilar bribes, i.e., when $B_I \neq B_{II}$. Clearly, in the special case in which the bribes paid by the two types of citizens are identical, it is optimal to favor the citizen type with the shorter average service time.

It is not difficult to show that if the ratio of the expected service time to the received bribe for type I citizens is greater than the corresponding ratio for type II citizens then type II citizens ought to be favored in the public allocation of the homogeneous good. From a mathematical perspective, if $E[s_I]/B_I > E[s_{II}]/B_{II}$ then when allocating the homogeneous good publically, our corrupt government official should discriminate in favor of type II citizens over type I citizens.

In a more general model in which the focus is on the *socially* optimal way of distinguishing between citizen types, one would have to account for the benefit and the cost to society from bribery over and above the private gain to the corrupt government official. As a result, in this more general setting, a condition such as the one delineated in Lemma 1 would contain additional terms representing the benefit and the cost from bribery to the remaining members of society. Similarly, if the objective function of interest is a convex combination of *social* welfare and the server's private monetary gain then too the ensuing analysis would be more complicated because of the need to account for the impact of bribery on the presently unaccounted for members of society. One way to proceed in this latter situation would be to model the server explicitly and to partition the members of society into $n \in \mathbb{N}$ types of citizens, some of whom pay bribes and some who do not. One could then formulate and analyze an objective function with $n+1$ components. Our sense is that the methodology used in Batabyal and Yoo (2004) would be useful in this context.

4. Conclusions

In this note, we used a queuing theoretic approach to analyze two hitherto unstudied questions concerning favoritism in the public allocation of goods by means of queuing processes in developing countries. Specifically, we compared the ratios given in Lemma 1 and showed that a theoretical case can be made for favoring one type of citizen over the other. Our analysis showed that the nature of this favoritism depends not only on the bribes received by the corrupt government official, but also on the efficiency—measured by the expected service times—with which this official discharges his duties.

The analysis in this note can be extended in a number of different directions. In what follows, we suggest four potential extensions. First, we analyzed a model in which there are two types of citizens. Therefore, as indicated in section 3.2, one way to extend the analysis in this note would be to study a model in which there are *n* types of citizens where *n* is any positive integer. Second, in the queuing model of this note, we did not allow the magnitude of the bribes paid by citizens within a particular type to vary. Consequently, it would be useful to analyze a queuing theoretic framework in which this issue is explicitly modeled. Third, depending on the kind of good being allocated and the geographical location of the servers, it may be interesting to study bribery and corruption in multi-server queues. Finally, in any corruption regime, it is always possible that the "victims" of bribery will exert pressure on the server. In these sorts of situations, game-theoretic modeling approaches are likely to be useful. Studies that analyze these aspects of the problem will strengthen our understanding of the connections between bribery, favoritism, and wait times in the public allocation of goods by means of queuing processes in developing countries.

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