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Conflict, Distribution and Population Growth

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Synopsis: This paper studies an optimal foraging model where distributive conflicts among foragers emerge from population growth. It investigates distributive rules set to resolve the conflicts. Efficient distributive rules are the ones associated with the most efficient productive decisions. Unequal societies, where the ruling class or King maximizes the surplus, engender the choice of more efficient productive combinations and to a smaller population relative to egalitarian societies.

Key words: organizational behavior, income distribution, inequality

JEL classification: D29, D39, D69

1. Introduction

Optimal foraging theory (OFT) had a huge impact in biology over the past decades becoming the dominant paradigm for explaining and predicting forager diets (Sih & Christensen 2001). The idea is quite simple and departs from the fact that animals have to eat, and those that can find and catch food efficiently should do better than those that can't. Animals that use less time in foraging can use more time for taking care of young, defending territories, etc. Therefore, animals should tend to forage optimally (Emlen 1966, MacArthur & Pianka 1966, Charnov 1976). The OFT is in line with the principle of optimality in biology that states that resources are limited and natural selection favor those organisms whose behavior and morphology enhance their access to those resources, relative to other organisms, and hence increase their reproductive output relative to others in the population (e.g., Pyke et al. 1977).

As humans have spent the bulk of their evolutionary history in foraging economies, the OFT turns out to be a promising source of insight into this topic. Indeed, the application of OFT in anthropology helped to revolutionize the field, mainly concerning the study of prehistoric archaeology and hunter-gathering societies (e.g., Hayden 1981, Hawkes et al. 1982, Smith 1983, Foley 1985, Ofek 2001). The key methodological contribution of OFT to anthropology is that foraging models focus on the per capita net rate of return of energy per unit of foraging time, therefore it focus its attention to individuals and how their decisions affect their chances of survival, fitness and reproductive success. By emphasizing the role of individuals, OFT avoids the group-benefit assumption and kin selection arguments so common in anthropology and sociobiology.

One of the main issues related to hunter-gathering societies that have caught the attention of economists is that effective territorial control is rarely present in non-sedentary hunter-gathering groups.[1] Consequently, effective conservation is almost impossible, what can lead to the tragedy-of-the-commons, that is, to resource depletion. Smith (1975), in a pioneering paper, showed how economic analysis may help in unifying and integrating theories and evidence concerning the overkill hypothesis[2] and the rise of agriculture. Brander & Taylor (1988) put forward a Ricardo-Malthus model of renewable resource use to explain natural depletion in Easter Island. Faria (2000) introduced human migration in Brander & Taylor model in order to analyze the body of evidence and conjecture concerning the demise of Neanderthals.

The objective of this paper is to analyze a simple optimal foraging model where conflicts of interests among foragers are present. Distributive conflict may emerge as a result of population growth. The paper investigates many distributive schemes that aim at resolving distributive conflicts. It shows that most efficient distributive rules are the ones associated with the most efficient productive decisions. In an equalitarian society, where total output is equally shared, productive and distributive efficiency leads to greater maximum population, defined as the total population living under subsistence level. In an unequal society, however, the ruling class or King has an incentive to maximize the surplus, which leads to a choice of more efficient productive and distributive rules and to a smaller population relative to equalitarian societies.

The paper is organized as follows. The next section presents a simple optimal foraging model and introduces a Malthusian like population growth, which generates distributive conflict after some threshold point. Some sharing rules and their consequences for maximum population are discussed. Then a comparison between equal and unequal output distribution sheds light on the relationship between economic efficiency and distribution. Section 3 brings the concluding remarks.

2. The model

The population of foragers shares a central base (camp, settlement, etc.) and make foraging trips of duration τ (which is normalized, without loss of generality, to 1) away from this base, foraging alone or in groups, and then returning to the camp, where the harvest may be shared or divided in various ways. In what follows the unit of analysis, the forager, can be an individual, a couple, a family, or even a clan. All individuals are equal, that is, they have the same technical skills, identical preferences and the same metabolism. If the catch is equally divided among the members of the group, the optimal foraging theory (OFT) establishes that each forager attempts to join groups that maximize the expected net energy return rate per capita $\pi(n)$, also called the representative forager payoff, defined as:

$$\pi(n) = F(n) - C(n) \tag{1}$$

where n is the group size, $F(.)$ is the per capita quantity of food energy acquired and $C(.)$ is per capita metabolic energy expended. It is assumed that F is an increased, concave and well behaved function of n, and that C is a linear function of n. For instance, let $F(n) = 2A\sqrt{n}$, where A is a positive constant, and $C(n) = n$.[3] Maximization of equation (1) yields:

$$n^* = A^2 \tag{2}$$

As a consequence, OFT generates an optimal group size, which is the n^* given in equation (2).

Assume that the initial population is equal to the optimal size n^*. What will happen if the population grows to $n^* + 1$? In order to answer this question, let us assume a Malthusian type population growth, according to which the size of the group increases with the difference between actual per capita availability of resources ($\pi(n)$), and the subsistence level (S) (e.g., Samuelson 1989):

$$\frac{dn}{dt} = \theta(\pi(n) - S) \tag{3}$$

It is clear that whenever equation (3) works, the population will always be greater than n^*, that is, the availability of resources provided by the optimal group size makes the population grow faster. Figure 1 illustrates this point. Equation (3) has two steady states, the first equilibrium (n_1) is smaller than n^* and the second (n_2) is greater than n^*. It is easy to note that the first equilibrium is unstable, given any perturbation in its neighborhood the population vanishes to zero or grows to the second equilibrium, which is stable.

Population growth generates a managerial problem, which consists in finding out the best way to employ the newcomers. In order to further investigate this problem, the following assumption will be made: When group size increases any extra foragers cannot migrate and the group cannot eliminate them.

Assuming that the initial size of the group is the optimal size, n^*, and one new member is born, the group has to decide how to allocate him. One alternative is to leave the new member as a solitary catcher, in this case his payoff will be: $\pi(1) = 2A\sqrt{1} - 1 = 2A - 1$. Another alternative is to allow him to enter the gang of catchers: $\pi(n^* + 1) = 2A\sqrt{n^* + 1} - (n^* + 1)$. Of course the forager prefers to join the gang

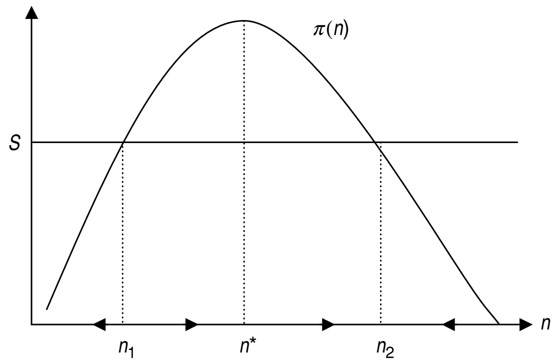

Figure 1.

when: $\pi(n^* + 1) > \pi(1)$. If this inequality holds true, notice that by the definition of n^* we have:

$$\pi(n^*) > \pi(n^* + 1) > \pi(1) \tag{4}$$

Therefore a conflict of interest will arise between members and joiners. This happens because the new member receives a higher per capita return from group foraging than from solitary foraging but his joining the gang would diminish the existing members' shares. Notice that inequality (4) can only happen if the actual population is above the optimal population size n^*. Inequality (4) will hold true whenever the payoff of a single forager is below the subsistence level S. As it is assumed that the group cannot eliminate this new forager, and he cannot achieve the subsistence level alone, he always prefers to join the gang of catchers of optimal size. This will necessarily generate a distributive conflict, and as a result the group has to find a way to solve this conflict.

Sharing or distributive rules are designed to resolve distributive conflicts. It is important to stress the fact that sharing rules are based on managerial (technical) decisions concerning how to employ, or combine, the excess number of foragers above n^*. That is, in the present setup distributive (sharing) rules are also productive decisions. The sharing rules are characterized by the fact that the output of foragers is brought to the central base and then it is divided. So the group first decides how to organize its members in gangs of catchers, and then decides how to divide the output of foraging activity.[4]

Sharing rules can produce many interesting outcomes, of which the most important is the effect on the maximum size of the population. The maximum size of the population is defined as the one in which the per capita payoff is equal to the subsistence level.

Let us tackle this issue using very simple sharing rules in a numerical example. Assume that the subsistence level is $S = 6$ and that $A = 3$. In this case $n^* = 9$. Let us start by examining sharing rules in which the output is brought to the central base and then it is equally divided.

1) The first and simplest sharing rule allocates every new forager to the same gang of foragers. As a consequence, the maximum population, as defined above, is 22, since $\pi_1(n_1) = \pi(22) = 6.14 > 6 > 5.77 = \pi(23)$, where π_1 denotes the per capita payoff of the first sharing rule.

Let us make 22 as the baseline figure for comparison with other forms of sharing rules.

2) Instead of incorporating each new member into the same gang, suppose foragers form 2 gangs with the optimal size of 9, and leave the remaining 4 foragers as solitary catchers. In this system each member will receive: $\pi_2 = [2(9)\pi(9) + 4\pi(1)]/22 = 8.27$

3) The third sharing rule forms 2 gangs of optimal size 9, and arranges the remaining 4 foragers in two gangs of 2 foragers each: $\pi_3 = [2(9)\pi(9) + 4\pi(2)]/22 = 8.54$

4) The fourth sharing rule is based on 2 gangs of optimal size, one gang with 3 foragers and one solitary catcher: $\pi_4 = [2(9)\pi(9) + 3\pi(3) + \pi(1)]/22 = 8.66$

5) The final sharing rule is based on 2 gangs of optimal size and one gang with 4 foragers: $\pi_5 = [2(9)\pi(9) + 4\pi(4)]/22 = 8.81$

It is easy to see that: $\pi_5 > \pi_4 > \pi_3 > \pi_2 > \pi_1$, as a consequence we have the first result of this paper:

Result 1: The maximum population increases when the sharing rule increases the per capita payoff.

Proof: Given equation (3) it is easy to see that greater π_{i} (n_{i}) leads to greater population growth.

So far equal division of output has characterized the sharing rules. What happens if there is inequality in the division of the output? In order to answer this question let us specify an unequal 'sharing rule' total output is brought to the central base and then it is divided in such a way that every forager receives enough to subsist and the excess is transferred *voluntarily* to the King (or the priest, or the political ruling class). Therefore, the King's extra revenue, or rent, corresponds to total excess (E) above the subsistence level: $E = n_i[\pi_i(n_i) - S]$.

Notice that under this unequal sharing rule, if every forager but the King is receiving a payoff equal to the subsistence level, the population will not grow.

For instance, if the 'institution' of the King emerges (or is created) under sharing rule one, where population is at maximum size 22, it provides as surplus for the King: $22 \times [6.14 - 6] = 22 \times 0.14 = 3.08$. This numerical example also illuminates one of the reasons why people would engage voluntarily in choosing a King, thereby establishing some kind of social inequality, it is because this 'institution' is cheap. Note that the contribution to the King corresponds to 0.14/6.14 = 2.28% of each forager's net income, and that the King's rent is below the subsistence level. One can only speculate why such social arrangement is made. One hypothesis is that the surpluses can be used as gifts in religious rituals and that the King is just a priest or shaman responsible for these rituals.

If we advance the argument and make a further assumption that the King is granted dictatorial powers to decide which productive scheme to follow, he will choose the one associated with the sharing rule that maximizes his surplus. In other words, the King has an incentive to make technical decisions which bring about the combination of foragers that maximize his rents.[5] The hypothesis of dictatorial powers is necessary here because foraging organization so far has been assumed to be voluntary. From the available technical menu seen above, the King will choose the productive scheme associated with sharing rule 5, which generates as rent: $22 \times 2.81 = 61.82$. The change in the combination of foragers does not change their individual payoff which is frozen at the subsistence level. The King's rents, however, will increase in [(61.82−3.08)/3.08] = 1907 % to an absolute level 10 fold the subsistence level. This discussion generates the following results.

Result 2: Given a technical combination of foragers, inequality in the distribution of output leads to a smaller population in comparison to systems based on equal distribution of output.

Result 3: Given a fixed population size, the King chooses the productive combinations with the highest payoff.

The model has interesting implications. Inequality reproduces itself by limiting the size of population and by choosing more efficient foraging combinations. Or put other way, inequality is an efficient device to limit population size and to achieve the best technical combination of foragers.

3. Concluding remarks

This paper analyzes a simple model based on optimal foraging theory where distributive conflicts result from population growth. Sharing (or distributive) rules are created to solve these conflicts. Sharing rules consist in technical combination of foragers. The more efficient distributive rules are the ones associated with higher individual payoff, for a given population. However, population grows whenever the individual payoff is above the subsistence level.

In egalitarian societies the output is equally divided while in unequal societies each forager is assumed to receive enough to subsist and the remainder is given to the King. Therefore, in unequal societies population does not grow. Moreover, the King, when granted dictatorial powers, has an incentive to maximize his rents, which can be achieved by choosing the most efficient combination of foragers. As a consequence, the model shows that given the combination of foragers, the population is larger in egalitarian societies than in unequal societies. In the same vein, it is shown that for a given population size, inequality leads to the choice of most efficient productive combinations of foragers. That is, inequality leads to a better allocation of resources.

It is interesting to notice that, although distributive rules are created to solve distributive conflicts, at the end of the day the most efficient solutions to distributive conflicts are the ones associated with inequality in the distribution of output.

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Notes

1. An exception is Baker (2003), he develops a model to explain the land tenure regimes in hunter-gatherer societies. He shows that land ownership would emerge when resources are relatively plentiful and occur predictably.
2. The overkill hypothesis (e.g., Martin 1967) suggests that great part of megafauna extinction in late Pleistocene in North America is associated with human hunting activity.
3. This assumption implies that a large band requires more energy per band member than a small band. This can be due to the presence of organizational costs, such as monitoring, coordination and supervision costs of band members that increase with its size.
4. In this model there are no security costs associated with the existence of individuals outside their community who pose a security threat. On this issue see Marceau & Myers (2000).
5. An implicit assumption is that the King does not have any offspring, or at least not more than as to affect negatively his rent maximization. This assumption is no longer appropriate to analyze early civilizations in which despotic rulers had large harems and often hundreds of offspring (on this issue see Lagerlof 2002).

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