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Scarcity and Appropriative Competition

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Abstract

This paper formalizes the commonsensical hypothesis that resource scarcity causes a large allocation of time and effort to appropriative competition. Our main innovation is to model explicitly the positive intertemporal effect of consumption on the probability of survival. The critical assumption is that this effect becomes stronger as resources become scarcer. We also show that anticipated future resource abundance increases the incremental value of survival and, consequently, amplifies the current allocation of time and effort to appropriative competition. Interestingly, if resources are currently scarce, then larger anticipated future abundance can cause people to allocate sufficiently more time and effort to appropriative competition to result in a decrease in the sum of current and expected future utility, a "paradox of anticipated abundance".

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> As Malthusian pressures depress per capita incomes, it comes to a choice between fighting and starving. (Jack Hirshleifer, 1995, page 44)

Surprisingly, the commonsensical hypothesis that resource scarcity causes a large allocation of time and effort to appropriative competition is not easy to formalize. Notably, although Jack Hirshleifer, who has made seminal contributions to the economic analysis of appropriative competition, acknowledges this commonsensical hypothesis, he does not explicitly model "a choice between fighting and starving".

The essential analytical problem is that it is natural to assume that both the return to time and effort allocated to appropriative competition and the return to time and effort allocated to productive activities depend positively on the resource endowment. But, under this assumption there is no presumption that resource scarcity affects the allocation of time and effort to appropriative competition in one way or the other. Allowing for the allocation of time and effort to leisure activities, as an alternative to both appropriative competition and productive activities, does not by itself resolve this ambiguity, because the resource endowment has offsetting substitution and income effects on the allocation of time to leisure, and we have no reason to presume that one effect or the other is dominant. For example, under the common assumptions that the production of consumables is a Cobb-Douglas function of the resource endowment and the time and effort allocated to productive activities and that utility is a logarithmic function of consumption, the allocation of time and effort to appropriative competition is independent of the resource endowment.[1]

The present paper suggests a modeling innovation that enables us to formalize the hy-

[1] Some models in the literature assume that either production or utility is a linear function of the appropriable endowment. Examples include Herschel Grossman (1992) and Kai Konrad and Stergios Skaperdas (1998). With linearity the substitution effect of the appropriable endowment on the allocation of time and effort dominates the income effect. Consequently, these models imply that the allocation of time and effort to appropriative competition is everywhere an increasing function of the appropriable endowment. In these models resource scarcity causes a small allocation of time and effort to appropriative competition.

pothesis that resource scarcity causes a large allocation of time and effort to appropriative competition. This innovation is to introduce explicitly a positive intertemporal effect of consumption on the probability of survival. The critical assumption is that this effect becomes stronger as resources become scarcer. Given this assumption, in addition to yielding a negative relation between the resource endowment and the amount of time and effort allocated to appropriative competition, our analysis implies that anticipated future resource abundance amplifies the current allocation of time and effort to appropriative competition, and that resource scarcity creates the possibility of a "paradox of anticipated abundance".[2]

1. The Struggle for Survival

The struggle for survival has been for most of history, and even today in many parts of the world continues to be, the first priority of human life. This struggle has pitted both man against nature in an effort to produce the necessities for survival and man against man in an effort to appropriate the resources from which these necessities are produced. This paper focuses on the appropriative aspect of the struggle for survival.

In their fascinating account of the economic history of Easter Island, James A. Brander and M. Scott Taylor (1998) report evidence that, after population on the island had peaked sometime around 1400 A.D., the following century witnessed three forms of socioeconomic decline: Resource scarcity, attributable primarily to the depletion of the stock of coconut palms, resulted in decreasing food consumption. Engagement in the principal leisure activity, which was the carving and erecting of stone statues, also decreased. And, "the island entered a period of violent internecine competition", with even "strong evidence of cannibalism". Brander and Taylor tell us that this evidence supports a historical interpretation that claims

[2] In related work Skaperdas and Constantinos Syropoulos (1996) model a repeated appropriative competition for an appreciating asset. They show that either a larger discount factor or a higher rate of appreciation can result in a larger allocation of resources to appropriative competition. Our analysis differs from their analysis in two ways: First, we consider the recurring arrival of a nonstorable resource. Second, we endogenize the discount factor in the form of a survival probability.

that "rather than being the cause of decline, violent conflict is commonly the result of resource degradation and occurs after the civilization has started to decline."

Easter Island, of course, is not a unique example of resource scarcity apparently causing an intensification of appropriative competition. James Tong (1988) provides convincing evidence that periodic famines caused recurring episodes of intense appropriative competition in premodern China. Jack Goldstone (1991) blames the pressure of population on resources for the widespread revolts, a symptom of intensified appropriative competition, that plagued both the Ottoman Empire and the Ming dynasty in the first half of the seventeenth century. Brander and Taylor claim further that the idea that resource scarcity relative to population causes an intensification of appropriative competition is also applicable to modern history, and they offer recent events in Rwanda as an example.[3]

As presented by Brander and Taylor, as well as by Tong and by Goldstone, the idea that resource scarcity causes appropriative competition to become more intense is a purely empirical hypothesis. These authors do not offer a theory that implies this causal link. The present paper develops such a theory.[4]

2. Appropriative Competition

Consider a large population of $n+1$ identical people that receives in each period a positive nonstorable endowment of productive resources. The size of the endowment received in the current period is $(n+1)E$ units, where $E \geq 1$. This endowment, like the fish in the sea

[3]Michael Renner (1996) provides a more complete account of the effect of increasing population pressure on agricultural land in causing conflict in Rwanda. Renner offers a similar analysis of ongoing conflict in the Mexican state of Chiapas.

[4]Brander and Taylor develop a theoretical model of the dynamic interaction between population and a resource stock, but their assumptions imply that the allocation of time and effort between leisure activities and resource harvesting, which we can interpret to be a form of appropriative competition, is independent of the size of the resource stock. Tong asserts that his account of appropriative competition in premodern China is consistent with a rational choice model, but he does not formalize such a model.

or the coconut palms on Easter Island, is initially in a common pool over which the people engage in appropriative competition.[5] Our objective is to understand how the current per capita resource endowment, E, as well as the anticipated future size of the per capita resource endowment affects the allocation of time and effort to appropriative competition.

To model the outcome of the appropriative competition we specify a standard "contest-success function", according to which a person appropriates e units of resources, where

$$e = \frac{r}{r + nR}\,(n+1)E. \tag{1}$$

In equation (1) r is the non-negative fraction of his time and effort that this person allocates to appropriative competition, and R is the fraction of time and effort that other people on average allocate to appropriative competition. Equation (1) says that a person appropriates a fraction of the resources in the common pool that equals the fraction that this person contributes to the total time and effort that the $n+1$ people together allocate to the appropriative competition.[6]

For our purposes equation (1) has the following important properties: Given that R is

[5]Alternatively, individual agents can initially have nonoverlapping claims to the resources that are subject to appropriative competition. In addition, the resources to which individuals have claims can be either alienable, like land or livestock, and, hence, subject to appropriative competition, or inalienable, like human capital. With inalienable resources appropriative competition can take place over the consumables that are produced from the resource endowment. We can show that the main qualitative results that we derive about the effects of resource scarcity on appropriative competition do not depend either on the assumption that the endowment is initially in a common pool or on whether appropriative competition takes place over the productive resources or over the consumables produced from the resources.

[6]Following Hirshleifer (1995) a possible generalization of equation (1) would be to raise r and R to the power m, $m > 0$, where m is the "decisiveness parameter". The qualitative implications of the present model are independent of the value of m. More ambitiously, but with some difficulty, we could introduce differences among people in their ability to appropriate resources. This extension would allow us to consider the possibility that in equilibrium, while some people appropriate more than enough resources for survival, other people appropriate insufficient resources to survive.

positive, e is positive if and only if r is positive. If r equals R, then e equals E. Also, e is an increasing concave function of the ratio r/R.

These properties notwithstanding, equation (1) is a generic black box that does not specify the process of appropriative competition, just as the standard generic production function does not specify the process of production. Our analysis does not distinguish among such disparate appropriative processes as a nonviolent scramble, a division under the threat of force, or a violent struggle. If we wanted to focus on violent conflict, then we could easily extend the analysis to allow appropriative competition to destroy some of the resource endowment or even, as noted below, to cause the death of some of the participants.

Assume for now that a person effortlessly converts his e units of resources into c units of consumables. Later on we extend the analysis to allow for a nontrivial production technology according to which time and effort is required to convert resources into consumables. We also assume that consumables are nonstorable and inalienable.

3. Current Utility and Expected Future Utility

As is standard, we assume that a person maximizes the sum of his current utility and his expected future utility, and that he obtains current utility from both his current consumption and his current leisure, allowing that leisure can be devoted to such activities as the carving and erecting of stone statues. Abstracting from pure time discounting, we specify the maximand, denoted by u, as

$$u = \alpha \ln(c) + \gamma h + sv + (1-s)x, \quad \text{where} \quad \gamma > \alpha > 0. \tag{2}$$

In equation (2) a person currently consumes c units of consumables, currently allocates the fraction h of his time and effort to leisure activities, survives to the next period with probability s, $0 \leq s \leq 1$, and attaches the value v to survival and the smaller, possibly negative, value x to death. The assumption that the parameter γ is larger than the parameter α allows the possibility that a person allocates a positive fraction of his time and effort to leisure activities.[7]

According to equation (2), u has two components: the sum $\alpha \ln(c) + \gamma h$, which represents current utility, and the sum $sv + (1-s)x$, which represents expected future utility. The difference $v - x$ is the incremental value attached to survival. We treat x as a parameter. The value v attached to survival equals the discounted value of utility from future consumption and future leisure activity, conditional on surviving until the next period. In choosing how to allocate his current time and effort, a person takes v as given. But, when we analyze the equilibrium allocation of time and effort, we have to recognize that in a steady state v equals u.

Given that production is effortless, any time and effort not allocated to appropriative competition is available for leisure activity. Thus, h is equal to $1 - r$. Furthermore, the logarithmic function in equation (2) implies that, for a given value of expected future utility, the substitution effect and the income effect of a person's resources on his allocation of time and effort between appropriative competition and leisure activities are exactly offsetting. In this model the dependence of the allocation of time and effort on the resource endowment does not derive from one of these effects being dominant.

As mentioned above, our main innovation is to model explicitly the positive intertemporal effect of consumption on the probability of survival.[8] Specifically, assume that in the range

[7]This model assumes that leisure activities use only time and effort. Jared Diamond (1992) tells us that the carving and erecting of stone statues on Easter Island also used productive resources, which were the tree trunks used to roll the statues from the quarries to their platforms and to erect them. With this more complex technology the effect of resource scarcity on the allocation of time and effort to appropriative competition would be amplified.

[8]As we have noted, appropriative competition can be nonviolent or violent. Dan Usher (1992, Chapter III) suggests a model of violent appropriative conflict in which the probability of survival depends positively on the level of consumption and, also, negatively on the amount of time and effort that people allocate to appropriative competition. Adding such a dependence to our model would decrease the equilibrium amount of time and effort allocated to appropriative competition.

of relevant consumption possibilities a person's probability of surviving until the next period depends on his consumption according to

$$s = max\{q(c),\ 0\}, \tag{3}$$

where $q(\underline{c}) = 0$, $q'(c) > 0$, $q''(c) < 0$, $\lim_{c \to \underline{c}} q'(c) = \infty$, and $\lim_{c \to \infty} q(c) < 1$. We also assume that the product $q'(c)\ c$ is a decreasing function of c, at least for values of $q(c)$ that are not close to one.

In equation (3) $\underline{c}$ is the level of consumption at the threshold of starvation. A person has a positive survival probability if and only if he consumes more than $\underline{c}$.[9] We choose units of consumption such that $\underline{c}$ is larger than one. Given this choice of units, for any value of c larger than $\underline{c}$, current utility is positive, and in a steady state the incremental value attached to survival is also positive.

For values of c larger than $\underline{c}$, s is an increasing concave function of c.[10] Also, as c approaches $\underline{c}$ from above, the derivative of s with respect to c becomes infinitely large. The assumption that the product $q'(c)\ c$ is a decreasing function of c implies that the absolute value of the elasticity of $q'(c)$ with respect to c, defined as $-c\ q''(c)/q'(c)$, is larger than one. As we shall see, this property is critical for the result that current resource scarcity causes a large allocation of time and effort to appropriative competition.[11]

[9] The individual consumption level $\underline{c}$ is distinct from the Malthusian concept of subsistence consumption, which Malthus defined in his analysis of population growth to be the average level of consumption at which the death rate equals the birth rate.

[10] The assumption that the probability of survival is an increasing function of homogeneous consumption seems appropriate for an economy in which people are engaged in the struggle for survival. In modeling a more affluent economy we might want to distinguish the consumption of necessities, defined as an activity that increases the probability of survival, from the consumption of luxuries, defined as an activity that increases current utility but does not increase the probability of survival.

[11] Given that we do not assume that this property necessarily obtains for values of $q(c)$ that are close to one, the model does not rule out the possibility that a negative relation between the resource endowment

4. Allocation of Time and Effort

A person takes E, R, and v as given and allocates his time and effort between r and h to maximize the sum of his current utility and his expected future utility, as given by equation (2), subject to equations (1) and (3). Given $h = 1 - r$, the solution to this choice problem is

$$\text{(4)} \qquad \begin{aligned} &\text{either} \quad \frac{du}{dr} > 0 \quad \text{and} \quad r = 1 \\ &\text{or} \qquad \frac{du}{dr} = 0 \quad \text{and} \quad r \leq 1, \end{aligned}$$

where, assuming that e is larger than $\underline{c}$, we have

$$\text{(5)} \qquad \frac{du}{dr} = \frac{\alpha}{c}\,\frac{dc}{dr} - \gamma + q'(c)\,\frac{dc}{dr}\,(v - x),$$

and where, from equation (1), we have

$$\frac{dc}{dr} = \frac{nR}{(r + nR)^2}\,(n+1)\,E.$$

The assumption that e is larger than $\underline{c}$ implies that the endowment per capita, E, is large enough that in equilibrium every identical person has a positive probability of surviving.

These first-order conditions imply a unique, symmetrical equilibrium in which every person makes the same choices of r and h. In such an equilibrium we have for every person $r = R$ and, hence, from equation (1), $e = E$. Accordingly, equation (5) becomes

$$\text{(6)} \qquad \frac{du}{dr} = \frac{n}{n+1}\,\frac{\alpha}{R} - \gamma + q'(E)\,\frac{n}{n+1}\,\frac{E}{R}\,(v - x).$$

Combining conditions (4) with equation (6) yields the equilibrium condition,

$$\text{(7)} \qquad R = min\{\frac{n}{n+1}\,\frac{\alpha + q'(E)\,E\,(v-x)}{\gamma}, \quad 1\}.$$

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and the allocation of time and effort to appropriative competition obtains only for values of E that are not too large.

For large values of n equation (7) becomes in the limit

$$R = min\{\frac{\alpha + q'(E)\ E\ (v - x)}{\gamma},\ \ 1\}. \tag{8}$$

Equation (8) captures the main results of the analysis. This equation implies that R, the amount of time and effort allocated to appropriative competition, depends both on the current per capita resource endowment, E, and on the incremental value, $v - x$, that a person attaches to survival.

Consider these two effects in turn. First, for R smaller than one, holding E fixed, R is positively related to $v - x$. In other words, the more valuable is survival the more time and effort a person allocates to competition over the scarce resources that increase the probability of survival.

Second, for R smaller than one, holding $v - x$ fixed, the relation between E and R involves the product of two factors, $q'(E)$ and E. The factor $q'(E)$ enters because the marginal effect of a person's consumption on his probability of survival is a decreasing function of his consumption. The factor E enters because the marginal effect of the time and effort that a person allocates to appropriative competition on the units of resources that he appropriates is an increasing function of the average endowment. The assumption that the product $q'(c)\ c$ is a decreasing function of c, at least for values of $q(c)$ that are not close to one, implies that the first factor dominates the second factor. Thus, holding $v - x$ fixed, R is negatively related to E, at least for values of E that are not too large.[12]

Equation (8) also implies that R equals one for values of E and v such that

$$q'(E)\ \ E\ \ (v - x)\ \ \geq\ \ \gamma - \alpha. \tag{9}$$

[12]Equation (7) implies that R also is positively related to n. Thus, if a smaller endowment per capita were associated with a larger population, then R would be larger both because E is smaller and because n is larger. But, for large values of n the effect of n on R is small and vanishes in the limit. Also, from equation (8) we see that, if the survival probability did not depend on consumption, then R would not depend on E. Specifically, if $q^{\theta}(c)$ were zero, then R would equal α/γ for all values of E.

Given that γ is larger than α, condition (9) is satisfied for combinations of sufficiently small values of E and sufficiently large values of $v - x$. In other words, if resources are sufficiently scarce and the incremental value of survival is sufficiently large, then every person allocates all of his time and effort to appropriative competition.

5. Transitory Resource Scarcity

Using equation (8) and condition (9) consider the effect of transitory resource scarcity on the allocation of time and effort to appropriative competition. Transitory resource scarcity means that the current per capita resource endowment, E, is both small and smaller than the permanent per capita resource endowment. Accordingly, with transitory resource scarcity current consumption is both small and smaller than future consumption possibilities. Because transitory resource scarcity does not affect future consumption, transitory resource scarcity does not affect the incremental value, $v - x$, that a person attaches to survival.

We have just seen in equation (8) that, holding $v - x$ fixed, for R smaller than one, R is negatively related to E, at least for values of E that are not too large. Thus, equation (8) implies that transitory resource scarcity causes a temporary increase in the allocation of time and effort to appropriative competition. In fact, as we have seen, condition (9) implies that a small enough transitory realization of E causes people to allocate all of their current time and effort to appropriative competition. These results obtain because the dominant effect of transitory resource scarcity is to increase the current marginal effect of consumption on the probability of survival.

6. Anticipated Future Resource Abundance

Again using equation (8) and condition (9), consider the effect of anticipated future resource abundance on the current allocation of time and effort to appropriative competition. Larger future resource abundance would imply larger future consumption and, hence, would cause people to attach a larger incremental value, $v - x$, to survival.

We have seen in equation (8) that, holding E fixed, for R smaller than one, R

is positively related to $v - x$. Thus, equation (8) implies that larger anticipated future resource abundance causes people currently to allocate more time and effort to appropriative competition. In this respect, the effect of larger anticipated future resource abundance is similar to the effect of transitory resource scarcity. In fact, condition (9) implies that, given E, a large enough value of $v - x$ causes people to allocate all of their current time and effort to appropriative competition.

The effect of larger anticipated future resource abundance in causing people to allocate more time and effort to appropriative competition creates the possibility of a "paradox of anticipated abundance", by which we mean a negative effect of anticipated future resource abundance on the sum of current and expected future utility. Using equations (2) and (8) we calculate that, for $R < 1$,

$$(10) \qquad \left.\frac{du}{d(v-x)}\right|_E = -\gamma \left.\frac{dR}{d(v-x)}\right|_E + q(E) = -q'(E)\ E + q(E).$$

Given that the product $q'(c)\ c$ is a decreasing function of c, that $q(c)$ is an increasing function of c, and that $q(\underline{c}) = 0$, equation (10) implies that $du/d(v-x)$ is negative for small enough values of E and that $du/d(v-x)$ is positive for large enough values of E.

These results say that, if resources are currently sufficiently abundant, then larger anticipated future resource abundance increases the sum of current and expected future utility. But, if resources are currently sufficiently scarce, then larger anticipated future resource abundance decreases the sum of current and expected future utility. This paradoxical outcome obtains because, with current resource scarcity, the marginal effect of consumption on the probability of survival is large. Hence, larger anticipated future resource abundance causes a large increase in the current allocation of time and effort to appropriative competition.

7. Appropriative Competition in a Steady State

Finally, consider the effect of the resource endowment on the allocation of time and effort to appropriative competition in a steady state in which the per capita resource endowment is constant over time. Let $*$ denote a value that obtains in the steady state. As mentioned above, in a steady state the value, v^*, that a person attaches to survival equals u^*, the sum of his current utility and his expected future utility. Equating v^* and u^*, equation (2) implies that

$$v^* - x = u^* - x = \frac{\alpha \ln(E^*) + \gamma(1-R)}{1-s}. \tag{11}$$

Solving equations (8) and (11) together for v^* and u^*, we obtain

$$v^* - x = u^* - x = max\{\frac{\alpha \ln(E^*) + \gamma - \alpha}{1 - q(E^*) + q'(E^*)\ E^*},\ \frac{\alpha \ln(E^*)}{1-q(E^*)}\}. \tag{12}$$

Given that the product $q'(c)\ c$ is a decreasing function of c, at least for values of $q(c)$ that are not close to one, and that $q(c)$ is an increasing function of c, the denominators of both of the fractions in equation (12) are negatively related to E^*. Thus, equation (12) implies that v^* and u^* are positively related to E^*, at least for values of E^* that are not too large. This result precludes a "paradox of abundance" in a steady state.

Equation (8) implies that the direction of the effect of E^* on R^* depends on the net of the negative effect of E^* on the product $q'(E^*)\ E^*$ and the positive effect of E^* on the difference $v^* - x$. Solving equations (8) and (11) together for R^*, we obtain

$$R^* = min\{\frac{\alpha[1-q(E^*)] + [\alpha \ln(E^*) + \gamma]\ q'(E^*)\ E^*}{\gamma[1 - q(E^*) + q'(E^*)\ E^*]},\ 1\}. \tag{13}$$

Equation (13) implies that R^* equals one for values of E^* such that

$$q'(E^*)\ E^*\ \frac{\alpha \ln(E^*)}{1-q(E^*)} \geq \gamma - \alpha. \tag{14}$$

Given that $\underline{c} > 1$ and that $\lim_{c \to \underline{c}} q'(c) = \infty$, condition (14) is satisfied for sufficiently small values of E^* — that is, for values of E^* sufficiently close to $\underline{c}$. Conversely, if γ is sufficiently large relative to α, then condition (14) is violated for values of E^* that are not too small. In other words, condition (14) implies that in a steady state, if resources are sufficiently scarce, then people allocate all of their time and effort to appropriative competition. But, if the utility derived from leisure activities is sufficiently large relative to the utility derived from consumption, and if resources are not extremely scarce, then in a steady state people allocate some of their time and effort to leisure activities rather than to appropriative competition.

8. A Production Economy

This section extends the analysis to allow for the allocation of time and effort to production. Specifically, in place of $c = e$, assume that the conversion of resources into consumables involves a Cobb-Douglas technology, $c = \ell^{\beta} e^{1-\beta}$, $0 < \beta < 1$, where ℓ is the fraction of his time and effort that a person allocates to the production of consumables. Now, instead of $h = 1 - r$, we have $h = 1 - \ell - r$. In the limit as β approaches zero, the analysis that follows becomes identical to the analysis in the preceding sections.

A person again takes R and E as given and now chooses r, ℓ, and h to maximize the sum of his current utility and his expected future utility as given by equation (2), subject to equations (1) and (3). Given $c = \ell^{\beta} e^{1-\beta}$ and $h = 1 - \ell - r$, the solution to this choice problem is

$$\text{(15)} \qquad \begin{aligned} &\text{either} \quad \frac{\partial u}{\partial r} = \frac{\partial u}{\partial \ell} > 0 \quad \text{and} \quad r + \ell = 1 \\ &\text{or} \qquad \frac{\partial u}{\partial r} = \frac{\partial u}{\partial \ell} = 0 \quad \text{and} \quad r + \ell \leq 1, \end{aligned}$$

where, assuming that c is larger than $\underline{c}$, we have

$$\text{(16)} \qquad \frac{\partial u}{\partial r} = \frac{\alpha}{c} \frac{\partial c}{\partial r} - \gamma + q'(c) \frac{\partial c}{\partial r} (v - x),$$

and

$$\text{(17)} \qquad \frac{\partial u}{\partial \ell} = \frac{\alpha}{c} \frac{\partial c}{\partial \ell} - \gamma + q'(c) \frac{\partial c}{\partial \ell} (v - x),$$

and where, from equation (1) and $c = \ell^{\beta} e^{1-\beta}$, we have

$$\frac{\partial c}{\partial r} = (1 - \beta)\ (\ell/e)^{\beta}\ \frac{nR}{(r + nR)^2}\ (n + 1)\ E,$$

and

$$\frac{\partial c}{\partial \ell} = \beta \ (e/\ell)^{1-\beta}.$$

These first-order conditions imply again a unique, symmetrical equilibrium in which every person makes the same choices. In such an equilibrium we have for every person $r = R$ and, hence, from equation (1), $e = E$, and also $\ell = L$, where L is the fraction of time and effort that people on average allocate to the production of consumables. Accordingly, in equilibrium, we have $c = L^{\beta} E^{1-\beta}$, and for large values of n equations (16) and (17) become in the limit

$$\frac{\partial u}{\partial r} = \frac{\alpha(1-\beta)}{R} - \gamma + (1-\beta)\ q'(c)\ \frac{c}{R}\ (v-x), \tag{18}$$

and

$$\frac{\partial u}{\partial \ell} = \frac{\alpha\beta}{L} - \gamma + \beta\ q'(c)\ \frac{c}{L}\ (v-x). \tag{19}$$

Combining conditions (15) with equations (18) and (19) yields the equilibrium conditions,

$$L = \beta \ \ min\{\frac{\alpha + q'(c)\ c\ (v-x)}{\gamma},\ 1\} \tag{20}$$

and

$$R = (1-\beta) \ \ min\{\frac{\alpha + q'(c)\ c\ (v-x)}{\gamma},\ 1\}. \tag{21}$$

Equation (21) is identical to equation (8) above, except for the factor $1-\beta$ in equation (21) and for the fact that c, which equals $L^{\beta} E^{1-\beta}$, appears in equation (21) in place of E. Similarly, in a steady state we now would have an equation for v^* that is identical to equation (11), except that c^* would appear in place of E^* and that $1 - L^* - R^*$ would appear in place of $1 - R^*$. Also, equation (20) implies that L can depend either positively or negatively on E, but that in either case c depends positively on E.[13] Thus, using

[13] To confirm this result observe that, because the product $q'(c)\ c$ is a decreasing function of c, equation (20) implies that L is inversely related to c. Consequently, with a larger value of E, L cannot be sufficiently smaller to cause c to be smaller.

equation (21), and equation (21) together with the equation for v^*, we obtain the same qualitative implications for the relations between R, E, and v as we did from equation (8) and from equation (8) and equation (11) together. The main new implication from extending the analysis to allow for a nontrivial production technology is that time and effort allocated to appropriative competition and time and effort allocated to producing consumables are complementary alternatives to the allocation of time and effort to leisure activities.

9. Summary

This paper has formalized the commonsensical hypothesis that resource scarcity causes people to allocate a large amount of time and effort to appropriative competition. Our main innovation was to model explicitly the positive intertemporal effect of consumption on the probability of survival. The critical assumption was that this effect becomes stronger as resources become scarcer.

We found that the effect of resource scarcity in causing a large allocation of time and effort to appropriative competition obtains whether resource scarcity is transitory or permanent, but that this effect is larger if resource scarcity is transitory. Also, anticipated future resource abundance increases the incremental value attached to survival and, consequently, amplifies the current allocation of time and effort to appropriative competition. Interestingly, if resources are currently scarce, and, accordingly, current consumption has a strong marginal effect on the probability of survival, then larger anticipated future abundance can cause people to allocate sufficiently more time and effort to appropriative competition to result in a decrease in the sum of current and expected future utility, a “paradox of anticipated abundance”.

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