THE PIONEER'S CURSE: SELECTION BIAS AND AGRICULTURAL LAND DEGRADATION

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Abstract

Expansion of agriculture into new regions has often been followed by land degradation. In this paper, it is argued that the process of land development involves the selection of pioneer's with optimistic expectations about the robustness and carrying capacity of new land. Hence, there is a systematic bias towards over-exploitation and land degradation. The argument is shown to be an extension of the winner's curse analysis in the theory of auctions.

Keywords: Risk, auctions, land degradation, property rights

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Expansion of agriculture into new regions has often turned out badly. The expansion of agriculture in Oklahoma, beginning with the land race of 1889, culminated in mass emigration from the Dustbowl of the 1920s and 1930s. A little earlier, South Australian farmers had pushed the frontiers of cultivation northward in the belief that "Rain follows the plow." This hypothesis was disproved by the 'Federation' drought of 1901 , which led both to crop failures and widespread erosion. Australian governments subsequently acted to limit the area in which cultivation would be permitted.

Unexpectedly rapid land degradation is a common reason for the failure of agriculture to prosper in areas which initially seemed promising. Similar problems, such as salinity and rising water tables have often affected irrigation schemes. Other new technologies such as pesticides and herbicides have also had unexpected adverse consequences, leading to degradation of natural resources.

The occurrence of some land degradation is an inevitable consequence of agriculture and the occurrence of some adverse outcomes is an inevitable consequence of choice under uncertainty. The purpose of this note is to show that, under private ownership, the process of pioneering has a systematic tendency to produce adverse outcomes involving high rates of land degradation. The central point is that pioneering will be undertaken by those with optimistic expectations about the productive capacity of new lands and new technologies, and will therefore be associated with over-exploitation. The phenomenon is analogous to the 'winner's curse' in auctions, where the winner will on average bid more than the value of the good under auction.

In the present paper, a model of pioneer's willingness-to-pay for undeveloped land is presented.

It is shown that willingness-to-pay is positively associated with estimates of carrying capacity, and hence that the winning bid will be based on a production plan involving a high rate of land degradation. This result holds even if pioneers adjust their bids to take account of the winners' curse in the auction. Some implications are derived for the theory of property rights and for public land management policies.

The Winner's Curse and the Pioneer's Curse

The basic winner's curse model may be summarized fairly simply. A group of N bidders participate in a sealed-bid second-price auction for a good x with an unknown monetary value $V(x)$. Each individual i makes an unbiased estimate

$$v_i = V(x) + \varepsilon_i \tag{1}$$

where ε_i is an independently and identically distributed error term, representing an observation on a random variable with cumulative distribution function F, such that $E[\varepsilon] = 0$.

If bidders ignore the errors in their value estimates, the optimal strategy is to bid v_i. However, this will on average lead to the good being sold at a price in excess of $V(x)$ whenever $N > 2$. For symmetrical distributions, the expected price may be approximated by $V(x) + F^{-1}((N\text{-}1)/N)$. This is the 'winner's curse'. More detailed discussion of the winner's curse problem is given by Milgrom (1989).

From the individual bidder's viewpoint, the problem may be explained as follows. "My private estimate is just as likely to be an over-estimate as to be an under-estimate. However, if everyone bids their own estimate, I am unlikely to win unless I have over-estimated the true

value." The correct strategy in auctions of this kind is to bid below your own valuation to take account of the winner's curse. The deduction will depend on the distribution F and on the number of competing bidders, N.

In place of an auction, consider now a situation where land becomes available for agricultural development. Such a situation may arise because of technological innovations which permit the extension of cultivation or grazing into new areas, or because previous gatherer-hunter populations have been dispossessed. The new settlers will be referred to as pioneers. New land may be made available by auction or by rationing procedures including races, queuing and establishment of occupancy. In all cases, potential pioneers must make a decision on the resources to invest in acquiring land, and this will depend on an estimate of the value of that land.

The winner's curse analysis may be extended to the case of the pioneer. Suppose that the productive potential of the land at time t is represented by L_t, the inputs applied to the land at time t are represented by X_t and output is given by

$$Y_t = f(X_t, L_t, \varepsilon_t) \tag{2}$$

where f_X, f_L, $f_{XL} > 0$, $f_{XX} < 0$ and ε_t is an unobservable random variable reflecting year-to-year climatic fluctuations. Profit is $pY - wX$, where p and w denote output and input prices. In the analysis which follows, it will be assumed that p and w are known with certainty.

The relationship (2) will not, in general, be stable over time or independent of previous values of X_t. Continuous cultivation tends to reduce the fertility of cropland. Application of irrigation may lead to rising water tables and salinity problems. Heavy grazing may lead to loss of soil cover and thence to erosion[1]. The vulnerability of land to degradation depends on a wide

[1] Not all impacts are negative. For example, crop rotations may be designed in such a way that nitrogen-

range of characteristics of soil, topography and climate. For example, mountainous areas with high rainfall are particularly vulnerable to erosion following deforestation. The details of the process of land degradation will not be considered here. Rather it will be assumed that all information concerning vulnerability of land to degradation may be summarized by a variable Θ .

The change in productive potential is represented by an equation of the form

$$\dot{L}_t = -\phi(X_t, \Theta) \tag{3}$$

where $\phi_X, \phi_\Theta, \phi_{\Theta X} > 0$. The pioneer does not know Θ, but possesses an unbiased prior distribution with cumulative distribution function F_i. For pioneer *i*, the mean value of the prior distribution is denoted θ_i. A posterior distribution is obtained by incorporating successive observations on X_t and Y_t according to Bayes' rule.

That is, as pioneers gain more experience with the land, they obtain successively better estimates of the carrying capacity, summarized by Θ. In particular, if the pioneer has initially overestimated carrying capacity, the productivity of land will decline over time, and the posterior distribution will represent a gradual downward revision of the initial optimistic estimates. The critical issue is whether this revision will take place before the land degradation is so severe that it is impossible, or very costly to reverse. If the true capacity of land is realized sufficiently early, the time-path of land-use turns out to be sub-optimal *ex post*, but the long-run equilibrium is fairly close to that which would have been reached with perfect knowledge. In many of the US Dustbowl areas, the land was sufficiently resilient to recover from initial over-use and return to

fixing leguminous crops are succeeded by cereals which depend on adequate nitrogen levels in soil. The development of appropriate techniques of this kind is typically not a characteristic of the pioneering phase of development, however.

less intensive cultivation. If the land is less resilient, or if the accumulation of information is very slow, it may be too late to reverse the damage by the time a correct estimate of capacity is reached. This seems to have been the case in North Africa, referred to in classical times as 'the granary of Europe', but now a largely desert food-importing region. Consideration of the conditions under which land degradation is reversible is beyond the scope of the present paper. The objective here is simply to show that there is a systematic tendency towards over-exploitation.

The crux of the argument is that the process which selects pioneer's will tend to favor those with low (optimistic) estimates of Θ. The pioneer must choose[2] a planned stream of inputs X_t to maximize an expected value function

$$(4) \qquad E[v_i] = \int\left[\int(e^{-\delta t} p\, f(X_t, L_t, \varepsilon_t) - wX_t)dt\right] dF_i$$

It is apparent that the lower is θ_i, the higher will be the optimal value of X_t and the higher the estimate v_i. More importantly for the purposes of the present paper, low values of θ_i and high values of X_t correspond to large negative values of $\dot{L}$, that is, to rapid rates of land degradation.

Since $E[v_i]$ is estimated with error, a winner's curse analysis is applicable here. If each pioneer makes a bid $E[v_i]$, then the expected auction price will exceed the true value of the land. More importantly, the land will always be allocated to the pioneer with the most optimistic expectations on Θ, and therefore the highest planned value of X_t and the lowest (most negative) observed value of $\dot{L}$. As the number of potential pioneers becomes larger, the probability that the winner's prior estimate θ_i exceeds the true value approaches 1.

[2] It may be noted (Levins 1990) that many pioneers lack the knowledge of probability theory and the calculus of variations required to formulate and solve problems of this kind. The arguments advanced here apply *a fortiori* to approximate and informal solutions of the problem, which typically take even less adequate account of the future than the solution derived here.

This is the pioneer's curse. By the act of outbidding rivals for land of unknown fragility, pioneers reveal themselves as holding optimistic expectations. In carrying out the optimal program derived from those expectations they will generate excessive land degradation.

This result holds even if pioneers adjust their bids to take account of the winners' curse in the auction. It is possible that bidders may adjust their expectations v_i to take account of unforeseen contingencies that might reduce the returns on new land. It seems less likely that they will incorporate the information generated by the fact that they have been successful in an auction to change their optimal plans.

There is no possibility that rational pioneers will adjust their production plans to account for the pioneer's curse unless they also adjust their bids to account for the standard winner's curse. Bidding v_i and then undertaking a conservative production plan would lead to expected returns from the new land insufficient to justify the bid. Hence it is possible to experience the pioneer's curse without the standard winner's curse, but not *vice versa.*

On the other hand, as with the standard winners' curse argument, the pioneers' curse may be offset when differences in the characteristics of potential pioneers are taken into consideration. To the extent that pioneers differ in their skill in handling frontier conditions, more skilled pioneers will tend to bid more and capture producer surplus.

Policy and welfare implications

Welfare analysis of the pioneer's curse problem is complicated by the fact that different participants in the economy have different beliefs about parameters such as Θ at the time decisions are made. Expected future welfare may be calculated in many different ways. First, each individual's welfare may be calculated according to their own expectations. Second, a mean

estimate of Θ may be used. Finally, welfare may be evaluated in the light of the revealed *ex post* value of Θ. There is no clear guidance from welfare theory on how to handle this problem. The recent literature on welfare analysis under uncertainty (Graham 1981, Smith 1987) has dealt primarily with the case of known probabilities.

The usual social practice is to let individuals make their own mistakes. However, it is not clear that this can be justified in the presence of a systematic tendency to over-use of fragile resources. It would seem preferable to make collective or governmental decisions so as to maximize expected social welfare based on a mean or median estimate of Θ, even though private decisions will be made on the basis of individual estimates (Mirrlees 1974). This argument has significant implications for choices between private, common and public property régimes.

A large strand of the literature on property rights, beginning with Coase (1960) and Demsetz (1967), has been devoted to the proposition that freely tradable private property rights constitute the best possible method of organizing the allocation of resources. Conversely, these writers have argued that communal ownership inevitably leads to degradation of resources, an argument popularized by Hardin's (1968) 'tragedy of the commons'. The second part of this argument has rested on a confusion between common property and open access (Ciriacy-Wantrup and Bishop 1975). The first has proved more resistant to critical analysis. The fact that episodes of rapid land degradation have occurred under private ownership has been recognized, but not adequately explained. The main attempts at explanation have been based on differences between private and social discount rates or other market imperfections, rather than on private property rights *per se*.

The phenomenon of the pioneer's curse provides grounds for the existence of a systematic tendency to over-exploitation of resources under freely tradable private ownership. This phenomenon arises only under uncertainty. Empirically, this accords with the observation that

rapid land degradation is most common in the early periods of agricultural development in a given region. However, it should be noted that the introduction of new technologies or the replacement of traditional subsistence crops with cash crops may engender new uncertainty concerning the robustness of the natural resource base. In particular, a change from communal to private ownership will normally involve changes in technology and production patterns, and these may be associated with increased land degradation (Jodha 1976).

The pioneer's curse argument may also prompt a re-evaluation of the relative merits of freehold and leasehold systems for fragile lands. In both the US and Australia, large areas of grazing land are publicly owned and leased to private farmers. A standard analysis suggests that lessees will have an incentive to adopt practices which increase short-term output at the expense of long-term resource degradation. Unless monitoring is costless, freehold ownership will result in less land degradation than leasehold.

The pioneer's curse analysis shows that freehold title may lead to higher rates of degradation than leasehold. Given that individuals differ only in their beliefs about carrying capacity, the same individuals will operate land under both régimes. In the freehold case, individual land use is unconstrained, but in the leasehold case, decisions are constrained by lease conditions. The argument presented above suggests that governments should impose lease conditions that reflect the best available estimates of the productive capacity of the land, rather than the upper bound estimates held by the pioneer. If the costs of monitoring and enforcement are not too great, these constraints will reduce the rate of land degradation and more than offset the incentive to increase short-run output at the expense of long-run capacity. This is an empirical question.

Concluding Comments

Contrary to the arguments of the Coasian school, the analysis presented here suggests that, in the absence of the stringent rationality conditions required to avoid the pioneer's curse, the creation and enforcement of well-defined property rights is not sufficient to yield an optimal outcome, even if transactions costs are small.

The phenomenon of the pioneer's curse has been observed in many instances of new settlement. The analysis presented here suggests a role for public management of fragile lands, at least until information on long-term carrying capacity has been accumulated. The pioneer's curse problem must be weighed against such well-known problems of public management as regulatory capture.

The pioneer's curse problem is likely to be particularly severe in cases where the environment is very fragile, but is capable of generating large initial yields. The Brazilian rainforests would appear to be an important contemporary example.

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