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THE IMPACT OF INFORMATION ON LAND DEVELOPMENT:

A DYNAMIC AND STOCHASTIC ANALYSIS

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ABSTRACT

In a two-period model, economists such as K.J. Arrow, A.C. Fisher, and C. Henry, have shown that when development is both indivisible and irreversible, a developer who ignores the possibility of obtaining new information about the outcome of such development will invariably underestimate the benefits of preservation and hence favor development. In this note, I extend the AFH analysis in two directions. I model the land development problem in a dynamic framework, explicitly specifying an information production function. In such a setting, I then ask and answer the question concerning when development should take place.

JEL Classification: D82, Q20

Key words: development, dynamic, information, uncertainty

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1. Introduction

Since the seminal papers of Weisbrod (1964), Arrow and Fisher (1974), and Henry (1974), resource economists have been interested in the concept of option value. The so-called AFH concept of option value tells us that when development is both indivisible and irreversible, a developer who ignores the possibility of obtaining new information about the consequences of such development will invariably underestimate the benefits of preservation and hence skew the binary choice development decision in favor of development.

This simple and yet powerful result has been shown to hold in its most general form in a two-period setting. However, the result typically does not hold in more general settings. It has already been shown by Epstein (1980) and Hanemann (1989) that when the development decision is *divisible*, this bias toward development need not arise; indeed, it will not arise unless the development benefit function is of a rather specific form. Similarly, one can ask about the nature of the development decision when this decision is made in an intertemporal setting. Because the AFH analysis is conducted in a two-period model, the relevant development question is "Do I develop today or tomorrow?" In a dynamic setting, this question must be changed to "When do I develop?" This follows from the fact that the decision problem is not over two periods but over a much longer time horizon. A purpose of this note is to extend the AFH analysis and answer the "When do I develop?" question.

As Hanemann (1989) has noted, the AFH option value is a *conditional* value of perfect information. In other words, it is the informational gain achieved when choosing the second period development level, conditional on not having developed, i.e., preserved in the first period. Given this intimate connection between option value and the value of information, it would appear to be necessary to specify how information is generated in the development choice problem. However, this has typically not been done. As a result, Hanemann (1989, p. 36) has remarked that ". . . the specification of the information production function is certainly an interesting area for further research." Given this, the second purpose of this note is to specify an information production function.

I now follow Ross (1970, pp. 180-90; 1983, pp. 51-7) and discuss the optimal stopping framework which I shall use to analyze the "When do I develop?" question posed above.

2. The Theoretical Framework

I shall first describe the infinitesmal look ahead stopping rule (ILASR) and a theorem which provides conditions under which it is optimal to stop using ILASR. As Ross (1970, p. 188) has noted, the ILASR can be thought of as a policy which stops a stochastic process precisely in those states for which stopping immediately yields a higher payoff than waiting an additional time h. Let S be the set of states for which stopping immediately yields a higher payoff than waiting an additional time h. It can be shown that

Theorem 1: (Ross, 1970, p. 188): If S is closed, i.e., once a stochastic process enters S, the process cannot exit S, then under certain regularity conditions, the ILASR is optimal.

The land development problem can now be cast in an optimal stopping framework. This will enable me to use *Theorem 1* to determine when development should take place. I proceed as in Ross (1970, pp. 189-90). The decision problem faced by a developer concerns when to develop a certain parcel of land. Following AFH, I assume that this development decision is indivisible. The developer solves his problem in a dynamic and stochastic framework. The framework is stochastic because the decision to develop depends fundamentally on the availability of information regarding the consequences of development; this information is produced according to a nonhomogeneous Poisson process $\{I(t): t \geq 0\}$, with a continuous, nonincreasing intensity function $\gamma(t)$. Information is acquired independently, and this information has a common cumulative distribution function $F(\bullet)$, with finite mean. By allowing the information acquisition process to follow a nonhomogeneous Poisson process, I am leaving open the possibility that it is more likely that information will be received at certain times than at other times. Since the production of information is typically the result of R&D activities which generate results in an unpredictable manner, allowing for the above possibility would appear to be necessary. I make the natural assumption that any information that is not used immediately in deciding whether or not to develop, can be stored and used subsequently. The specific source of information production is not critical to my analysis. It could be the result of in-house R&D activities by the developer or it could be the result of research undertaken by other public or private agencies. In any event, from the perspective of the developer, information is costly to acquire; as such, in what follows, I will incorporate this cost in the overall decision problem faced by the developer.

Upon acquiring information, the developer decides whether to develop his land or to preserve it and wait for additional information. Let $f(\bullet)$ be the continuous and strictly monotone function which maps information to revenue from development. That is, if $i(t)$ is the information acquired by time t, then $f = f\{i(t)\}$ denotes the revenue from developing, given that a decision to develop has been made. Further, since $f(\bullet)$ is a continuous and strictly monotone transformation of $I(t)$, $\forall t$, it follows that f is itself a nonhomogeneous Poisson process with a continuous and nonincreasing intensity function, say, $\theta(t)$ (see Wolff, 1989, p. 26 for details). Further, the "revenues" are independent, with cumulative distribution function $G(\bullet)$. This distribution function also has a finite mean.

Should the developer choose not to develop his parcel of land, he incurs benefits and costs. The benefits are the obvious AFH type benefits; the developer preserves the flexibility to acquire new information in the future. The costs arise from the fact that the developer has to pay to obtain information, and he loses the revenue from development. I will denote the net benefit per unit of time from not developing (preserving) by β.

The state of the process at any time is denoted by the pair $[t,\ f\{i(t)\}]$, where t is the time, i is the highest quality information received by time t, and $f = f(i)$ is the revenue that would be received if the developer chooses to develop upon receiving i. Thus, it is clear that if the developer develops in state $[t,\ f\{i(t)\}]$, the developer's receipts from t onwards are f. On the other hand, if the developer preserves his land and waits an additional time h, then his expected receipts are

$$\left\{1 - \int_t^{t+h} \theta(r)dr\right\} \bullet f + \int_t^{t+h} \theta(r)dr \bullet E[\max(Y,\ f)] + Bh + o(h)\,, \tag{1}$$

where $E[\bullet]$ is the expectation operator and Y is a random variable representing the development revenue from information acquired in $[t,\ t+h]$. Equation (1) can be simplified to

$$f + \int_t^{t+h} \theta(r)dr \int_f^{\infty} (y - f)dG(y) + Bh + o(h)\ . \tag{2}$$

Given (2), it follows that the developer should cease to preserve his land and develop it upon acquiring information *i* if and only if the revenue from developing now, i.e., at time *t*, exceeds the expected revenue from postponing development by an additional time *h*. In other words, development should proceed now if and only if

$$f + \int_t^{t+h} \theta(r)\,dr \int_f^{\infty} (y - f)\,dG(y) + Bh + o(h) \leq f\,. \tag{3}$$

Canceling the common terms on both sides of (3), dividing both sides of (3) by *h* and then letting $h \to 0$ yields

$$\theta(t) \int_f^{\infty} (y - f)\,dG(y) + B \leq 0 \tag{4}$$

as the condition for determining whether development should proceed immediately. From (4), I can define the set *S*, i.e., the set of all states for which stopping immediately (developing now) yields a higher payoff than waiting an incremental time *h* (developing later/preserving). This set is

$$S = \{(t, f): \theta(t) \int_f^{\infty} (y - f)\,dG(y) \leq 0\}\,. \tag{5}$$

Note that *S* is closed because as *t* increases, $\theta(t)$ does not increase and the integral does not increase as well. I can now apply Theorem 1 and conclude that the developer should develop at time *t* if and only if the revenue from developing is *f*, where $f = f(i)$, and *f* solves

$$\theta(t) \int_f^{\infty} \{y - f\}\,dG(y) = 0\,. \tag{6}$$

In other words, development should take place at *t*, if, probabilistically speaking, it does not pay to wait and learn for an additional period of time.

3. Conclusions

In this note I modeled the land development question in a dynamic and stochastic framework. In this setting, I provided an answer to the "When do I develop?" question. This answer involved a comparison of the returns obtainable from developing at time t, i.e., $f\{i(t)\}$, with the expected returns to be obtained by preserving and waiting for new information beyond time t.

The analysis of this note can be generalized in a number of directions. I suggest two possible extensions. First, one could consider the divisible development question in a context similar to that of this note. This extension will enable one to determine whether the possibility of acquiring new information (learning) truely skews the development decision in favor of increased preservation in the most general case. Second, one could consider alternate specifications of the information production function. In this note, I have provided a simple specification for the information production function in which information is produced in accordance with a nonhomogeneous Poisson process. More general specifications will permit more elaborate analyses of the connections between information production and land development.

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