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Essays in valuation in law and economics

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ESSAYS IN VALUATION IN LAW AND ECONOMICS

by

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PREFACE

The central theme of these essays is valuation, both in theoretical and applied contexts. Experience of lawyers and courts quickly reveals that cases in certain areas of the law are often decided wrongly or on the wrong grounds because statistical evidence has been misunderstood. Too often, it is credited with far more persuasive power than it is properly entitled to enjoy. The first essay concerns applications of statistical technique to the valuation of claims for damages stemming from employment discrimination or other wrongful hiring, promotion, or pay practices. Careful attention is paid to analysis of the traps for the unwary in the use of this kind of evidence.

The other two essays concern a problem of current controversy. It is whether, to what extent, and how to preserve tropical rain forests. The first of these latter two essays is a critical analysis of a line of research that has become popular among many biologists and some economists in recent years. The plan of this research begins by gathering the "sustainable yield" products of a plot of rain forest land, selling them to arrive at a net revenue, and calculating the present value a perpetual stream of installments of the net revenue. The researcher then compares the present value thus found to the present value of rain forest land in other uses. The usual finding is that the "sustainable yield" use is superior to all others on financial grounds. Typically, none of the many difficulties with this procedure are recognized. The essay points them out.

The final essay is an analysis of another aspect of the attention being paid to identifying the conditions under which preservation of the rain forest can be practicably guaranteed. Again, this essay is motivated by the wide variety of unfounded opinions regularly heard on this subject. It consists of analysis of the question of whether rain forest land is a public good whose preservation requires collective intervention. It is critical of the usual recommendations in this regard and makes an argument in favor of the use of Clarke taxes to solve the public goods problem.

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STATISTICAL ANALYSIS IN WRONGFUL DISCHARGE/TITLE VII LITIGATION

Introduction

Statistical analysis may be invaluable in proving liability in disparate impact employment discrimination cases arising under Title VII of the Civil Rights Act of 1964. This is the federal statute which prohibits employment discrimination against people based on their membership in certain classes. The discussion presented will deal with the application of statistical analysis to employment discrimination cases with special emphasis on wrongful discharge litigation. An example of the use of this technique based on a litigated case concludes the discussion.

This chapter is designed to give attorneys, who may not be versed in statistical analysis, an intuitive understanding of how some of the more commonly used statistical techniques can be applied to employment litigation and to give economists, who may not be versed in the requirements of the law, an intuitive understanding of what their models must show to be useful to the client. The discussion is not meant to be comprehensive. Rather, it is meant to serve as an introduction to the field for both legal practitioners and economists.

Statistical Analysis in the Abstract

Review of Basic Probability Theory

Statistics, as a mathematical topic, is based on probability theory. In order to understand what a particular statistic indicates and in order to judge the appropriateness of one statistical approach as compared to another, it is essential to understand the basics of probability theory. In general, the statistician compares a sample to the population at large, and then uses probability theory to determine whether any observed difference between the population and the sample can be attributed to chance or, if not to chance, to something else. For example, one might compare a sample, such as the set of employees hired in some time period by XYZ Corp., to a defined population, such as the set of all adults living within one hour's drive of XYZ's place of business. Perhaps one or two contrived examples will help to illustrate the underlying logic of statistical analysis.

Consider the case of a coin flip. Assume that an individual proposes a wager based upon a flip of a coin. Let us say that the coin is flipped ten times and comes up tails all ten times. The obvious question arises: Is this a fair coin, and the results attributable to mere chance, or is some other factor at work, such as an individual is cheating?. You might suspect that the odds of a coin coming up tails ten times in a row are slim. Let us assume that the only alternatives are that the coin is fair or the individual is cheating. While life rarely presents such neat, mutually exclusive alternative explanations for events, let us, for the sake of illustration, assume such a situation. At what point in the process of flipping coins do we become certain, within a reasonable degree of statistical certainty, that the coin is not fair or, in statistical terms, that this occurrence is not random?

To make a determination of whether the coin is fair or the individual is cheating, we need to compare the results of tossing this particular coin (i.e., the sample) with what we would expect from a fair coin flipping game (the population of all fair coins). In a game using a fair coin, the probability of the coin, when flipped, coming up tails is 0.5 and the probability of it coming up heads is 0.5. In other words, for ten coin flips our expectation about the outcome would be to see five heads and five tails. This does not imply, however, that every set of ten coin flips will result in five heads and five tails. It might happen, for example, that we get four heads and six tails. We have to ask ourselves: How unusual is this result compared to the five: five scenario? Is the four heads and six tails result so different that we would suspect the individual of cheating? In the absence of a clear statistical test, we would probably conclude that this result is not so unusual. Ten tails or heads in ten flips, however, may seem such an unusual a result that it cannot have happened by chance alone. This may imply that some kind of cheating must have been involved. Probability theory provides us with objective standards to allow us to compare the actual outcome with our expected outcome. This coin flipping process is an example of what is called a binomial process in probability theory. The probability of ten tails coming up in a row can be computed by examining tables created for this type of problem. These tables are called binomial probability distribution tables. They reveal that the probability of getting ten tails in a row in ten coin tosses is .001.

The above result tells us that the probability of getting ten tails in a row is one chance in a thousand! This means that if we played this game one thousand times, we would expect to come up with a ten tails in a row outcome only once. It is so unlikely that this result occurred by pure chance that we might be justified in concluding that there was cheating involved, *i.e.*, the coin has been unfairly altered in such a way as to make it more likely that a given flip will come up tails. Please note that cheating has not been "proven" in the sense that there is no other possibility. It is just that the other possibility is so remote that we do not mind concluding that there was cheating. To phrase it in the jargon of the statistician, we can say with a high level of confidence that this result is attributable to cheating. In statistics, the analyst will set a standard, called a confidence level, to describe how certain it is that a result did not occur by chance. A typical confidence level is 95%. That means that the analyst must be 95% certain that a particular result is not the product of chance before attributing it to something other than chance. In the present case, a statistician could say with 99.9% certainty that the ten tails in ten tosses result is not the result of chance alone. Alternatively, this is equivalent to rejecting the hypothesis that the coin is fair at the 0.1% level of significance, again using the jargon of the statistician. It is quite common in statistical work to make conclusions at the 5% level of significance. We will have occasion to return to this subject later.

The problem is less clear when considering the intermediate situations such as eight tails and two heads or nine tails and one head. When we apply the 5% level of significance to the coin toss game where nine heads came up in ten tosses, we find that the probability of this occurrence is .01 or one in a hundred (assuming the coin is fair). This probability (1%) is lower than our 5% threshold so we dismiss the occurrence as non-random. We, therefore, again conclude that the game is not fair.

What about seven tails in ten tosses? Tails came up seventy percent of the time; is this too often to conclude that the game is not fair? The binomial probability distribution tables tell us that the probability of this occurrence is 11.7%. This is greater than our significance level of 5% so we cannot conclude that the game is unfair. Did the statistics prove anything? We will return to this issue with another binomial example in a later section.

Using The Standard Deviation

In the coin flipping example, we defined the population to be all fair coins. Because we knew the characteristics of the process of flipping fair coins, we were able to figure out how often to expect the different possible outcomes to occur while flipping an individual coin, provided the coin in question was part of the population of fair coins. We also knew about the flipping characteristics of unfair coins; they usually come up tails. To some extent, the range of possibilities using fair coins overlaps the range of possibilities using unfair coins. Is there a statistical way to tell whether a particular coin came from the population of fair coins or from the population of unfair coins? This can be done by using a statistical measure called the standard deviation.

The standard deviation is measured from our expectations about the outcome of the process we are studying. Recall that the expected outcome of the process of flipping a fair coin was 50% heads and 50% tails. When we repeat this binomial process of coin flipping a large number of times, the binomial distribution approximates a normal distribution. This is a very useful property for any distribution to have. Statisticians have discovered, for instance, that in a process described by a normal distribution, 68% of the trials (flips in our case) will occur within one standard deviation of the expected outcome. In the case of a normal distribution, the expected outcome is the mean. Statisticians have found that 95% of the trials will occur within 1.96 (call it 2) standard deviations from the expected outcome. To put it another way, if the expected outcome from some population is x and we observe some outcome y which is more than two standard deviations from x, we can say with 95% confidence (in other words, at the 5% level of significance) that y came from a different population than x did. The greater the number of standard deviations the actual outcome is from the expected outcome, the lower is the probability of the occurrence being purely random.

Large differences between the expected outcome and what is observed, *i.e.*, greater than two standard deviations, are sometimes referred to as being statistically significant. Courts have recognized that the existence of a statistically significant difference between a group protected by Title VII and the population as a whole in terms of their employment outcomes is probative of employment discrimination. See <u>Hazelwood School District v. United</u>

States,[1] in which the Supreme Court ruled that deviations greater than two to three standard deviations were properly relied upon by the trial court to determine whether employees were hired without regard to race.

Chi-Square Goodness-of-Fit Tests

The chi-square goodness of fit test is a statistical test that was developed in the early 1900's by Karl Pearson. As the name implies, the test allows us to compare an observed set of data, such as the age composition of a firm's work force, with the expected data set, as reflected by the surrounding relevant population.

In a chi-square test, a test statistic, X^2, is computed based upon factors such as the number of alternatives that are possible in the data set. For example, two possibilities are for a dismissed employee to be over forty years of age or under forty. Statisticians have developed chi-square tables which can be used to indicate the probability that age played a role in the number of terminations that may have occurred at a firm.

In order to use this analysis we need to examine the number of individuals in the relevant population who are over forty years of age. For example, if 40% of the work force is over the age of forty, we would expect that 40% of

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[1] 433 U.S. 299, 311, N. 17 (1977).

the terminations would consist of employees over the age of forty. This assumes that advancing age does not bring with it one or more legitimate reasons for dismissal and that terminations were an "age neutral" process. If there were twenty employees terminated, we would expect that eight (40%) were over the age of forty. If there is a difference between the actual number of employees over the age of 40 that were terminated and the expected number, eight, we then have to determine if that difference is statistically significant. This analysis can, of course, also be applied to any different definition of older workers. For instance, another commonly used line of demarcation between younger and older workers is age fifty.

The chi-square test statistics can be used to determine the probability that factors other than age could explain the difference in the termination rate for older versus younger employees. If this probability is greater than our selected level of significance, we may have reason to conclude that age played a role in the terminations of employees.

To enhance the explanatory power of our result, we may want to separate the company's work-force into subgroups. One such sub-grouping would be salaried v. unsalaried workers. We can then do the chi-square analysis on the separate subgroups of the work force to determine if there is a statistically significant relationship between, say, terminations and age within a subgroup.

The chi-square test statistic is most useful in making a determination of a difference in the termination policies of a firm with respect to age. The analysis is not without limitations, though. One of the limitations of this analysis is that it does not explicitly take into account other relevant variables which might explain some of the differences in the termination rates. Statistical analysis that did not consider other possible explanatory variables have been successfully challenged in several cases.[2]

Regression Analysis

So far, the discussion has considered only statistical processes involving a single variable (age, or the outcome of a coin flip). Given that there is only a single variable, there is no question of one variable being statistically associated with another. Often, though, the question asked is whether the occurrence of event x is related to the occurrence of event y. To answer questions of this kind the statistician may employ regression analysis.

To understand the underlying logic of regression analysis without the added complication of legal issues, let us consider a hypothetical example. Let us say that we want

[2]Palmer v. Schultz, 815 F. 2d 84 (D.C. Circuit 1987), Sobel v. Yeshiva, 839 F. 2d 18 (2nd Circuit 1988), E.E.O.C. v. Sears, Roebuck & Co., 839 F. 2d. 302 (7th Circuit 1988).

to investigate the association between the outdoor temperature and beer consumption. The first step in this analysis is to specify a model. For this analysis, the model must either be linear or capable of being made linear. We might therefore specify:

$$C = \hat{\beta}_0 + \hat{\beta}_1 T + e$$

where: C = beer consumption per day

T = outdoor temperature in degrees

Estimates of the terms $\hat{\beta}_0$ and $\hat{\beta}_1$ are to be deduced from a series of daily observations on C and T using the regression technique. The last term, e, collects all the other forces which are associated with C. It is called the residual term. Once we have estimates of $\hat{\beta}_0$ and $\hat{\beta}_1$, and if they are significantly different from zero (*i.e.*, if the estimated coefficient $\hat{\beta}_1$ is at least double its standard deviation (also called the standard error), we can say that for every one degree increase in T, C will change by $\hat{\beta}_1$ units.

There are many caveats that should be mentioned in connection with this analysis, but one should be especially highlighted at this point. It is easy to be fooled by the language of regression analysis into thinking that the results mean more than they do. The left hand variable, C in our case, is generally referred to as the dependent variable. The right side variable or variables (T in our case, but it is permitted to have more than one variable on the right side) are called the independent variables or explanatory variables. There is a temptation to deduce from this language that the model "proves" that temperature increases cause increases in beer consumption. Such a deduction is not warranted. A simple regression analysis, such as in this example, does not prove causality, but rather, merely shows that the dependent variable and independent variable are associated. It may very well be that variations in beer consumption are causally related variations in temperature, and that this causal relationship is the reason for the statistical association between these variables. It may also be that there is no causal relationship between these variables, only a statistical association. More sophisticated analysis would have to be conducted to prove causality.[3]

In addition to using a variable that can take on a whole range of numerical values, such as temperature, the analyst can also include a variable called a dummy variable. This variable is restricted to being either 1 or 0. Suppose that we theorize that the beer consumption response to temperature changes differs as between men and women. We might therefore specify:

$$C = \hat{\beta}_0 + \hat{\beta}_1 T + \hat{\beta}_2 D + e$$

where: C = beer consumption per day

[3]Ernst R. Berndt, The Practice of Econometrics, (New York: Addison Wesley, 1991), 380-383.

T = outdoor temperature in degrees

D = 1 if the observed behavior is that of a woman, 0 otherwise

Because there is now more than one explanatory variable, the technique is called multiple regression. The point of this specification is that if the estimate of $\hat{\beta}_2$ is statistically significantly different from zero, we have shown that there is some difference in beer consumption behavior associated with gender. The relevance of this dummy variable approach to showing that there is a difference in the way men and women are treated by some employer with respect to compensation should be obvious. Suppose we specify:

$$C = \hat{\beta}_0 + \hat{\beta}_1 D + \hat{\beta}_2 Q + \hat{\beta}_3 N + e$$

where C = compensation

D = the gender dummy, as above

Q = qualifications for the job, such as a test score

N = number of years with the company

If the estimate of $\hat{\beta}_1$ is significantly different from zero, we have shown that there is some difference in compensation associated with gender. Is this proof that the employer discriminates on the basis of gender in matters of compensation? The court in Sobel v. Yeshiva[4] held that the

[4]839 F.2d 18 (2nd Cir.1988).

finder of fact could properly consider this evidence. We will return to this issue in when we consider the application of statistical analysis to Title VII cases.

Logit and Probit Analysis

A dummy variable need not be restricted to being on the right side of the regression equation. Both the logit and the probit techniques put a dummy variable on the left side of the equation. Until we reach our applied example, we will refer only to logit analysis. This is done for the sake of clarity. Probit analysis is a statistical procedure which is very similar to logit analysis, but uses a different mathematical formula. To employ a logit analysis we might, for example, specify:

$$D = \hat{\beta}_0 + \hat{\beta}_1 N + \hat{\beta}_2 O + \hat{\beta}_3 A + e$$

where D = employment status (e.g., terminated or not terminated)

N = tenure with the firm

O = other work related experience

A = age of employee

When the dependent variable is in the form of a binary variable, terminated or not terminated, this analysis is sometimes referred to as limited dependent variable analysis. The specific multiple regression techniques that are used in such cases are logit and probit analysis.

Logit and probit analyses are more sophisticated model specification approaches which allow the researcher to address some of the issues raised by the court in the above referenced cases. A model that is correctly specified (that is, one that includes all of the important explanatory variables), may better explain the pattern of terminations at a firm. It is worthy of note, though, that models which do not control for all important explanatory factors have been found to be probative of discrimination in employment in spite of this drawback.[5]

Types of significance tests similar to those which have been discussed in this chapter can be applied in the more sophisticated logit and probit specifications. A model or equation might be specified which includes the following variables:

TABLE 1

VARIABLES IN THE LOGIT AND PROBIT SPECIFICATIONS

Dependent Variable	Explanatory Variables
employment status	age
(whether terminated	gender
or not)	salary
	tenure
	education

[5]Bazemore v. Friday, 751 F. 2d. 662, 667 (4th Circuit 1984), 478 U.S. 385 (1986).

The analyst then must collect information on each of these variables (i.e., employment status, age, gender, salary, etc.) for each employee. This collection of information is called the data set. The regression coefficients are then estimated using this data set. Among the numbers generated by this mathematical solution of the regression equation will be t-statistics, which can then be used to test the statistical significance of each variable in this model. A t-statistic above an absolute value of 1.96 will allow us to conclude that the variable in question, such as age, has a statistically significant relationship with the employment status of workers at the corporation. A t-statistic above the 1.96 level, which is the same 5% standard threshold that was employed earlier in the chapter, for the age variable, may allow us to conclude that the company is using age as a factor in their decision to terminate an employee.

Relating Statistical Analysis to Title VII

All of the foregoing may seem unnecessarily complicated. Surely there was a time in the history of Title VII when all the plaintiff had to show was that the percentage of the protected class represented by the plaintiff in the defendant's labor force was smaller than the percentage the protected class made up of the pool of qualified candidates for the defendant's jobs. With this unsophisticated analysis, the plaintiff almost always prevailed. The later history of Title VII litigation, though, can be seen as a process of education of the federal courts on the powers and limitations of statistical methods of proof. In order to set all of this out, it will be necessary to introduce some elementary legal concepts, just as it was necessary to present some elementary statistical concepts at the beginning of the chapter.

Disparate Treatment v. Disparate Impact

Early in the history of Title VII litigation, the Supreme Court distinguished between disparate treatment cases, which require the plaintiff to prove intentional discrimination, and disparate impact cases, which require only that the plaintiff prove by a preponderance of the evidence that some facially neutral employment criterion, in practice, produces results less favorable to the protected class than some unprotected class. This distinction was announced in Griggs v. Duke Power Co.[6] The Supreme Court went so far as to set up a system of shifting evidentiary burdens designed to bring the factual issues[7] into sharp focus in McDonnell Douglas Corp. v. Green.

The Prima Facie Case

The term "prima facie" case refers to a set of specif-

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[6]401 U.S. 424 (1971).

[7]411 U.S. 792 (1973).

ic facts, or "elements" in the argot of the law, which, taken together, constitute conduct from which relief is available. It is the duty of the plaintiff, or "complainant" in terms of Title VII, to present to the finder of fact at least some admissible evidence (whatever its probative value) of each and every element of the offense with which the defendant (or "respondent" in terms of Title VII) is charged. If the complainant fails to do that, a motion for dismissal will be granted. The respondent may also challenge the admissibility of the complainant's evidence supporting the prima facie case. If the complainant puts in a prima facie case, the respondent may attack the credibility of the evidence entered in support of the complainant's prima facie case or present evidence or affirmative defenses, or both.

In Title VII cases, one of the elements of the complainant's prima facie case is that the adverse (to the complainant) employment outcome occurred "because of" the complainant's membership in a class of persons protected by Title VII. The evidence offered on this element of the complainant's prima facie case is very often statistical in nature. Indeed, absent intentional discrimination, it may be impossible to make a prima facie case without statistical evidence.

Both sides may find experts in economic theory and statistics useful. The nature of the statistical evidence depends on the complainant's theory of Title VII liability (disparate impact or disparate treatment) and the type of employment outcome complained of (e.g., refusal to hire, compensation or promotion differentials, wrongful discharge). In general, however, the testimony of experts may be used in the following ways:

1. by the complainant to present a statistical study to establish the disparate treatment or disparate impact
2. by the respondent to attack the admissibility of the complainant's study on the footing that it is not probative of any fact the complainant must prove because it is defective in its underlying economic theory or statistical method
3. by the respondent, once the prima facie case has been put in, to attack the credibility of the complainant's study by criticizing its economic theory, by criticizing its statistical method, by offering an alternative study that is in some way superior, or by all three
4. by the complainant to rebut the respondent's criticisms and to criticize the respondent's alternative study
5. by the respondent to support an affirmative defense
6. by the complainant to rebut an affirmative defense

On the Burden of Proof

The Civil Rights Act of 1991 , *inter alia*, reversed the holdings Watson v. Ft. Worth Bank & Trust[8] and Wards Cove Packing Co., Inc. v. Atonio,[9] insofar as they seemed to alter the system of shifting the burden of proof outlined in McDonnell Douglas Corp. v. Green.[10] The statute as amended therefore places both the burden of production of evidence and the burden of persuasion on the complainant as to the prima facie case. Both burdens then shift to the respondent as to any affirmative defenses. These defenses may consist of essentially a showing that the practice complained of is supported by legitimate, non-discriminatory business reasons. If the defense carries that burden and establishes such a defense, the complainant then has the opportunity to persuade the finder of fact that the legitimate reason articulated by the respondent for the employment outcome was a mere pretext for discrimination against a protected class of persons. At least one court has held that the statistical evidence required to prove such a pretext existed need not be as precise and conclusive as statistical evidence required to prove discrimination in the prima facie case.[11]

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[8]487 U.S. 977 (1988).

[9]490 U.S. 642 (1989).

[10]411 U.S. 792 (1973); 42 U.S.C.A. (2000e-2(k)(1)(A).

[11]Moynihan v. Massachusetts Mut. Life Ins. Co., 773 F Supp 502 (1991, DC Mass).

Cases Involving Refusal to Hire or to Promote

The most obvious statistical evidence of disparate impact in hiring is to compare the respondent's set of employees with some larger population. The cases reveal three main populations which have been used to make comparisons of this sort in support of the "because of" element in Title VII cases. Each of these comparisons may be open to question on statistical grounds.

In some cases the flow of applicants for employment or promotion over some time period is compared to the set of persons actually hired or promoted, as appropriate to the case. If the selection rate from that flow of applicants of members of the protected class is less than four fifths of the rate at which the group of persons with the highest selection rate are hired, the finder of fact may well infer that the complainant has satisfied the "because of" element.[12] The statistical issue is whether the difference in the rates is significantly different from zero, given the sample size. If there are ten applicants for three positions, five from the class of persons seeking protection and five from some other class, and the respondent hires one of the former and two of the latter, the rate at which the members of the protected class are hired is only one half of

[12]29 CFR 1607.3D; Nash v. Consolidated City of Jacksonville, 905 F.2d 355 (11th Cir.1990).

the rate at which the members of the other class are hired. Title VII claims based on such low numbers have been rejected, but on the footing that the sample size was too small.[13] The more proper way of putting the problem would have been to say that the rate at which the protected class was hired was not statistically significantly different from four-fifths of the rate at which the group of persons with the highest selection rate were hired. Some courts have recognized the statistical fact that some variation occurs by chance alone.[14] A variation on this approach is to compare the percentage of members of the protected class among those the respondent has hired (or promoted) with the percentage of the population at large (in hiring cases) or of the respondent's work force (in promotion cases) composed of members of the protected class.[15] The choice of the geographic area which defines the population at large for this comparison is crucial.[16] The failure to clearly distinguish

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[13]Oliver v. Pacific Bell Tel. Co., 106 Wash 2d 675, 724 P 2d 1003 (1986). The basis of the litigation was a state statute modelled on Title VII.

[14]Casteneda v. Partida, 430 U.S. 482 (1987); San Francisco v. Fair Employment & Housing Com., 191 Cal App 3d 976 (1987, 1st Dist).

[15]Hazelwood School District v. U.S. 433 U.S. 299 (1977).

[16]E.E.O.C v. Chicago Miniature Lamp Works, 947 F.2d 292 (7th Cir. 1991); E.E.O.C. v. Andrews Corp., 49 BNA FEP Cas 804 (ND Ill, 1989); Johnson v. Goodyear Tire & Rubber Co., 491 F.2d 130 (5th Cir.).

between these approaches led to great confusion in Wards Cove Packing Co., Inc. v. Atonio.[17] In that case, the respondent had a group of unskilled employees who were almost exclusively members of a protected class and another group of skilled employees among whom the protected class was much less heavily represented. The complainant's contention that this fact alone made a prima facie case was rejected by the Court on the footing that the proper comparison was of the percentage of the protected class among the skilled employees to the percentage of the protected class among the qualified (for the job) population at large. For a contrary result, see Green v. Kinney Shoe Corp.[18] The holding in Wards Cove did not, as so many believed at the time, render applicant flow data inadmissible. It merely required a careful comparison of selection rates from appropriately defined groups.[19] This part of the holding in Wards Cove was not reversed by the Civil Rights Act of 1991.

Both of the approaches discussed above compare the respondent's history with some population. There is a third approach which compares the percentage of the protected

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[17]490 U.S. 642 (1989).

[18]711 F. Supp 34 (DC Dist Col, 1989).

[19]Green v. USX Corp., 896 F.2d 801 (3rd Cir.1990).

class which could pass muster under some hiring rule or standard of the respondent with the percentage of the most frequently hired class which could pass muster under the same hiring rule or standard. If the disparity in the percentages is sufficiently large, the finder of fact may infer that a disparate impact exists.[20] It is not true, though, that Title VII requires the respondent's set of employees to be a mirror image of the U.S. population as a whole.[21]

Probability v. Causation

The question remains, though, whether these percentage comparisons prove the "because of" element of the prima facie case. In other words, was discrimination the cause of the complainant's adverse employment outcome? Let us imagine, for the purpose of exposition, that Title VII protects short people from discrimination based on height. Let us further imagine that among the population as a whole, half of all people can be classified as short and half of all people can be classified as tall. Lastly, let us imagine that only 10% of the players in a professional basketball league, drawn from that population, can be classified as being short. The basketball league has no written policy

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[20]Dothard v. Rawlinson., 433 U.S. 321 (1977).

[21]42 U.S.C.A. (2000e-2(j).

concerning the height of players. Can the league, in its capacity as an employer, be said to have discriminated against short people in its hiring? To put it another way, does the difference between the height composition of the population and the height composition of a sample drawn from that population (the group of employee/players), as measured by the percentages of short and tall, prove that the employer/league has discriminated? The short answer is no.

Assume that the league has no minimum or maximum height requirements and that its teams are, in fact, indifferent to the heights of the players. Any given team in the league is, in effect, a sample of 10 players drawn from the population. One might expect that the sample would be composed of 5 short players and 5 tall players. It is true that, given the selection process, we would expect the average of all possible samples from this population would be 5 short players and 5 tall players, but that does not mean that each and every sample would be composed of 5 short players and 5 tall players. It is possible to draw other samples of 10 from the population that turn out to be combinations of short and tall other than 5 short and 5 tall. The reader will recognize this statistical process as a binomial process, as discussed earlier in the chapter.

In drawing samples of ten individuals from the population, it is possible to draw eleven different combinations of short and tall players, as set out in Table 2.

TABLE 2

COMBINATIONS FOR THE BASKETBALL EXAMPLE

Letter	Combination
A	0 short, 10 tall
B	1 short, 9 tall
C	2 short, 8 tall
D	3 short, 7 tall
E	4 short, 6 tall
F	5 short, 5 tall
G	6 short, 4 tall
H	7 short, 3 tall
I	8 short, 2 tall
J	9 short, 1 tall
K	10 short, 0 tall

The binomial distribution gives the probability of drawing any particular combination A through K given the number of tries (*i.e.*, teams in the league). These calculations are set out in Table 3.

Table 3 is saying that combination A (and K) happens by chance 0.1% of the time, combination B (and J) happens by chance 1% of the time, etc. If any one of the league's teams all had 10 tall players and no short players, we could claim with 99.9% confidence that this result was not the product of chance alone and if, as posited above, any one of the league's teams had 9 tall players and 1 short player, we could claim with 99% confidence that this result was not the product of chance alone. That is, we could claim with 99% confidence that some factor (perhaps prejudice against short basketball players among coaches) other than pure chance caused this result. To make its prima facie case, the complainant must put in evidence which would allow the finder of fact to reasonably infer that this employment result occurred "because of" conduct proscribed by Title VII. The statistical conclusion that this employment result is not likely to be the result of chance is not the same as concluding that it is the result of proscribed conduct.

It should be carefully noted that Table 3 says nothing about how many factors or what factors other than chance may have caused this result. There may be a reason or reasons for choosing combination A that have nothing to do with

TABLE 3

PROBABILITY THAT EACH COMBINATION OCCURS BY CHANCE

Letter	Combination	Probability	Sum
A	0 short, 10 tall	.001	.001
B	1 short, 9 tall	.010	.011
C	2 short, 8 tall	.044	.055
D	3 short, 7 tall	.117	.172
E	4 short, 6 tall	.205	.377
F	5 short, 5 tall	.246	.623
G	6 short, 4 tall	.205	.828
H	7 short, 3 tall	.117	.945
I	8 short, 2 tall	.044	.989
J	9 short, 1 tall	.010	.999
K	10 short, 0 tall	.001	1.000

prejudice against short players. The respondent may assert such reasons as affirmative defenses. The question of affirmative defenses does not arise, though, until after the complainant has put in a prima facie case. The logically prior question is how certain we have to be that chance alone cannot explain a particular result to say that the result is "because of" some factor other than chance. To put the question another way, what confidence level should be adopted? Let us assume that the law is that the 95% level of confidence should be adopted. What would be the effect of this ruling in terms of our hypothetical combinations of short and tall players?

In our example, combination F (five short, 5 tall) is the expected result in the sense that it occurs most frequently (24.6% of the outcomes). Combination F accounts for 24.6% of the outcomes and all of the other combinations together account for 75.4% of the outcomes. Now let us add combinations on either side of combination F until we have accounted for at least 95% of the outcomes. Taking E, F, and G accounts for 65.6% of the outcomes, taking D, E, F, G, and H accounts for 89% of the outcomes, and taking combinations C, D, E, F, G, H, and I accounts for 97.8% of the outcomes. Therefore, we can say that combinations A, B, J, and K lie outside a 95% confidence interval centered on the expected outcome. Indeed, it would be even more accurate to say that combinations A, B, J, and K lie outside a 97.8%

confidence interval centered on the expected outcome, combination F. Alternatively, we could say that combinations A, B, J, and K, collectively account for 2.2% of the outcomes occurring by chance.

Compensation Disparities

The potential for discrimination against members of a protected class does not end with their being hired or promoted. There may also be later discrimination against members of a protected class in terms of compensation. The issues of economic theory and statistical method surrounding the question of disparities in compensation are more complicated than those of hiring and promotion and require more careful analysis.

In one sense, competitive labor markets are similar to other markets in the sense that there will be a demand for and supply of the services of labor which together determine the market price, or wage, or more precisely, compensation. Title VII does not hold the employer responsible for labor market conditions over which it has no control.[22] Therefore, the complainant alleging discrimination in compensation is, effectively making two allegations. In terms of economic theory, the complainant is alleging that the respondent has one demand curve for the services of labor of the protected

[22]Ibid.

class and another demand curve for the services of labor of others. The complainant then alleges further that the difference between the demand curves is not explained by any objective (*i.e.*, not stemming from mere invidious discrimination) difference in the marginal valuation of the labor services of the two classes. In terms of statistical analysis, the complainant generally must present a model which accounts, as fully as practicable, for the variation in compensation and attributes at least a significantly larger than zero portion of the variation to membership in the protected class. The respondent will often counter with a model which, it is claimed, better accounts for the variation in compensation and which attributes no significantly larger than zero portion of the variation to membership in the protected class.

The complainant may try to accomplish its task by using a regression model in which compensation is the dependent variable. To account for differences in the marginal valuation of the labor services of the two classes, measures of experience, education, etc. will be used as explanatory variables. To account for membership in the protected class, the analyst could either separate the data into two sets, one for members of the class and the other for everyone else, and run two regressions, or, alternatively, include among the explanatory variables a dummy variable which is equal to 1 for members of the protected class and equal to 0 for non-members. The specification in this latter case would be:

$$C = \hat{\beta}_0 + \hat{\beta}_1 EX + \hat{\beta}_2 ED + \hat{\beta}_3 D + e$$

where: C = compensation

EX = job experience

ED = education

D = protected class membership dummy variable

The idea is that if the coefficient for the dummy variable is negative and its estimated coefficient is significantly different from zero, any compensation disparity between the two classes is at least partly accounted for by membership in the protected class.

Although models of this type have been accepted by some courts,[23] the most that they can prove is that the disparity in compensation is statistically associated with membership in the protected class. This is because these models are based on a restrictive economic theory. The implicit assumption of such models is that the employer is confronted by a single supply curve for the services of the labor of both classes combined and that this supply curve is fixed. In that case, any disparity in compensation could only be caused by the respondent's having two demand curves for the services of labor. This is just what the complainant wants to prove. The existence of one demand curve for

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[23]Sobel v. Yeshiva Univ., 839 F.2d 18 (2nd Cir.1988).

the labor services of the non-protected class and another demand curve for the labor services of the protected class lying to the left of that for the labor services of the non-protected class means that the respondent values the labor services of the protected class less highly. The result would be a disparity in compensation based on membership in the protected class. This implicit assumption is too restrictive because there is an alternative way for a compensation disparity to occur which has nothing to do with the attitudes of the employer. If the members of the protected class faced lower opportunity costs for accepting employment than members of the non-protected class did, there would be two supply curves for labor. This would be the case, for instance, if the members of the protected class were discriminated against in hiring by employers other than the respondent or if the members of the protected class found the employment offered by employers other than the respondent particularly inconvenient of otherwise undesirable. The supply curve facing the respondent for the non-protected class would lie to the right of that for the protected class. Given a fixed demand curve, the result would be a disparity in compensation based on membership in the protected class. To put the problem another way, this single regression equation approach does not distinguish between a compensation disparity caused by the respondent's attitudes toward members of the protected class and a compensation disparity caused by the attitudes of other employers or by attitudes of the members of the protected class. This difficulty has been recognized by some courts.[24] A model which fails to make this distinction is not properly identified and its probative value is impaired.

While the methods of solving the identifying a model are too complex to be discussed here, some of the practical consequences of dealing with the problem should be noted. The steps needed to identify the model frequently introduce new problems. If the model is to distinguish between a compensation disparity stemming from the respondent's having different demand curves for the labor services of the two classes and one stemming from supply conditions, a model with separate equations describing supply and demand must be used. This generally involves adding more explanatory variables to the model, but adding variables has a cost.

Simply adding variables to the model may open avenues for the other side to attack its probative value, both in terms of its underlying economic theory and in terms of the explanatory weight of the individual variables. Adding variables which are economically relevant will increase the proportion of the variation in compensation that is ex-

[24] E.E.O.C. v. Sears, Roebuck & Co., 839 F.2d 302 (7th Cir.1988); International Union, United Auto., Aerospace and Ag. Implement Workers of America v. State of Michigan, 886 F.2d 766 (6th Cir.1989).

plained by the model as a whole (as measured by the coefficient of determination, R^2). This increases the probative weight of the model as a whole, but the addition of a variable that is correlated with the membership dummy will cause the t-statistic of the membership dummy to get smaller. Indeed, it is possible for the model, having been thus improved in its underlying economic theory and overall probative weight, to defeat its original evidentiary purpose of reporting a statistically significant coefficient for the membership dummy variable.

The upshot of all of this is that model building is an art which requires the analyst to strike a balance between the need to include all of the relevant variables and the statistical price that must be paid for their inclusion. As a result, the finder of fact must ultimately choose which side's model is the more convincing. Mere allegations that this or that variable has been improperly included or excluded will not defeat the other side's model.[25]

Failure to Hire or Promote & Wrongful Discharge

A logit or probit specification of a multiple regression model of a particular employer's practices may have special usefulness in persuading the finder of fact that Title VII has or has not been violated. This specification

[25] E.E.O.C. v. Sears, Roebuck & Co., 839 F.2d 302 (7th Cir.1988); Sobel v. Yeshiva Univ., 839 F.2d 18 (2nd Cir.1988).

reveals how the presence or absence of a given characteristic, such as membership in a protected class, affects the probability of one's being the subject of a certain employment outcome (hiring, promotion, or discharge, depending on which outcome the model is set up to measure). In other words, a well specified logit or probit model predicts the probability that applicant X, who is a member of a protected class and is otherwise similar to current employees, will be fired. If that probability is significantly less than the probability that an otherwise similar applicant who is not a member of the protected class will be fired, a prima facie case of disparate impact, at least by the reasoning of the plurality in Price Waterhouse, has been shown.

A Logit Analysis Example

This example is derived from an actual case in which Economatrix Research Associates, Inc. was retained to render an expert opinion on the statistical likelihood of age discrimination. The analysis is derived from one that was originally presented in a report co-authored by Patrick A. Gaughan and Salih Neftci.[26] The case involved a fifty-four year old female employee of a large advertising agency who was terminated. She alleged that the reason for her termina-

[26]Patrick Gaughan and Salih Neftci, unpublished report produced by Economatrix Research Associates, Inc., for litigation purposes.

tion was that she was an older female. The example presented below investigates the statistical basis for the allegation of age discrimination.

The specific tool of analysis used in this example is logit analysis. The results of the application of this procedure were used to see whether there is a statistically significant relationship between age and the number of terminations from the firm. Two probabilities are computed: one assumes that age is a factor and the other assumes that it is not. In addition, the probabilities of being terminated for employees over and under the age of forty are computed. A logit model is constructed using explanatory variables such as age, seniority, department, job classification and sex. These regressions are sometimes called logistic regressions. These data are compiled for both active and terminated employees. For the sake of clarity, we have presented only the results of logistic regressions using age as the explanatory variable.

Summary of Findings

Tables 4 and 5, which present the results of a logit and probit regression respectively, reveal similar results. They show that age is a statistically significant factor in explaining terminations at the six percent level. These regression results are further reinforced by a more basic presentations of percentages and average ages. These show that 28.5% of active employees were over the age of forty while 35.6% of the terminated employees were over forty. One may conclude from the analysis presented in Tables 4 through 7 that it is more likely that an employee at this firm would be terminated as aged.

The results presented in this example would be even more compelling if even more dramatic results were found. For example, if the t-test showed even higher values that one could conclude that the probability that mere chance could explain the results would be even lower. A value of less than five percent would be desirable. Stronger conclusions could be arrived at if the differences between terminated and non-terminated employees were even greater. This would imply that employees are terminated when they advance in age and are replaced by younger employees. The termination of the older employees and replacement by younger

TABLE 4

RESULTS OF THE LOGISTIC REGRESSION

Explanatory Variable	Coefficient	t-statistic
constant	-2.258	-3.317
age	0.032	1.960

TABLE 5

RESULTS OF THE PROBIT REGRESSION

Explanatory Variable	Coefficient	t-statistic
constant	-1.369	-3.37
age	0.019	1.90

TABLE 6

TERMINATED EMPLOYEES ARE OLDER ON AVERAGE

	Number of Employees	
Age Group	Active	Terminated
under forty	95	29
forty or over	38	16
percentage over forty	28.6	35.6

TABLE 7

AVERAGE AGE BY EMPLOYEE STATUS

Average Age of Terminated Employees	39.53
Average Ago of Non-Terminated Employees	36.64
Difference Between the Ages	2.89

employees would have the effect of increasing the gap between these two populations.

CONCLUSION

The above discussion showed how statistical analysis can be used to analyze the liability side of an employment discrimination law suit. It was shown that there are a variety of statistical techniques that can be employed to explore the issue of liability. These techniques range from a basic application of probability theory to a more complex techniques such as logit and probit analysis. The more complicated analytical techniques place greater demand on the presenter to explain the methods in a easy to understand manner that can be useful in a courtroom environment. It is clear that, while the courts have had some initial difficulty in correctly interpreting statistical analysis, the statistical approaches have been judged to be an acceptable part of the liability presentation of both the plaintiff and the defendant.

CHAPTER 2

LAND TENURE AND THE PRESENT VALUE OF RAIN FOREST PRODUCTS

Introduction

Balick and Mendelsohn's recent article, "Assessing the Economic Value of Traditional Medicines from Tropical Rain Forests"[1], represents an important contribution to the conservation literature. It is also an example of a growing body of literature which offers the prospect of sustainable commercial extraction of rain forest products (medicinal herbs in this case) which can bring into accord a market oriented desire for profit and the widely recognized need to conserve a precious resource which plays an important role in maintaining biological diversity and preventing global warming--the tropical rain forest.[2] The finding that sustainable extraction of medicinal herbs in Belize yields a land value for the rain forest that is superior to the value of alternative land uses conjures up the image of Adam Smith's "Invisible Hand" whereby the market mechanism harmo-

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[1]Michael Balick and Robert Mendelsohn, "Assessing the Economic Value of Traditional Medicines from Tropical Rain Forests," Conservation Biology 6, no. 1, (1992): 128-130.

[2]See, for instance, Charles M. Peters, Alwyn H. Gentry, and Robert O. Mendelsohn, "Valuation of an Amazonian Rain Forest," Nature 339 (29 June 1989): 655-56.

nizes the untrammelled pursuit of individual self-interest (consumer pleasure and producer profit) with the greater well being of mankind.

One purpose of this chapter is to make more explicit some of the limiting assumptions that are necessary for the commercial exploitation of rain forest medicinal herbs to yield the felicitous result that Balick and Mendelsohn suggest, and to raise methodological questions that Balick and Mendelsohn do not, in our view, adequately address. Economists argue that policy makers should distinguish conditions in which market solutions to problems are likely to succeed in efficiently achieving a resource allocation objective from those conditions in which markets are likely to fail to optimally provide for the public good. Sharma and Rowe have correctly asserted that the market is likely to fail to protect or conserve a resource such as the rain forest if there is "an absence of clearly defined property rights on forest resources, both within a particular time period and between the present and the future..."[3]

In their article "Assessing the Economic Value of Traditional Medicines from Tropical Rain Forests," (hereinafter, "TMTRF") Balick and Mendelsohn calculate the present value of a flow of net revenue from the sale of medicinal plants from each of two plots of land in Belize. While the

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[3]N. Sharma and R. Rowe, "Managing the World's Forests," Finance and Development, (June 1992): 32.

approach Balick and Mendelsohn take to data collection is perfectly sensible for the purpose of making present value calculations, there is a conceptual error embedded in the calculations they perform. Moreover, Balick and Mendelsohn make an implicit assumption about property rights which affects the starting point for their present value calculations. Another objective of the present chapter is to improve upon the calculations which appeared in TMTRF and to provide some background for non-economists on several of the economic issues which the article raises.

How Property Rights Affect the Market Price of Medicinal Plants

Any analysis of land uses relating to rain forests must give adequate attention to the institutional issue of property rights arrangements. In general, people will attempt to use land in the way which maximizes their economic welfare (at least, we will proceed from that assumption). Whether or not this is the same as maximizing the value of the land (with its plants) as an asset (as Balick and Mendelsohn assume) depends on who owns the land and on exactly what ownership means.

To illustrate the effect of the form ownership takes, let us consider three cases: ownership in fee simple absolute[4] (hereinafter, "ownership in fee"), conditional ownership by a person, and common ownership. Balick and Mendelsohn implicitly assume ownership in fee when they conceptualize somebody choosing between using a plot of land to gather medicinal plants and some other use. Only an owner in fee would have the right to make the choice and enforce it against all comers. Such an owner, Balick and Mendelsohn properly assume, would pursue that use of the land which would maximize the value of the land in the long run, even beyond the life of the present owner[5]. As we shall see, under different property rules, it is unlikely that the same choices concerning land use, investment, and method of harvest would be made.

Ownership in Fee

Different plots of land are different. On some plots, the harvesting of medicinal plants would be the use of the

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[4]This is a form of ownership of land in which the owner is entitled to the entire property, with unconditional power of disposition during life or by will or the operation of the law of descent and distribution after death.

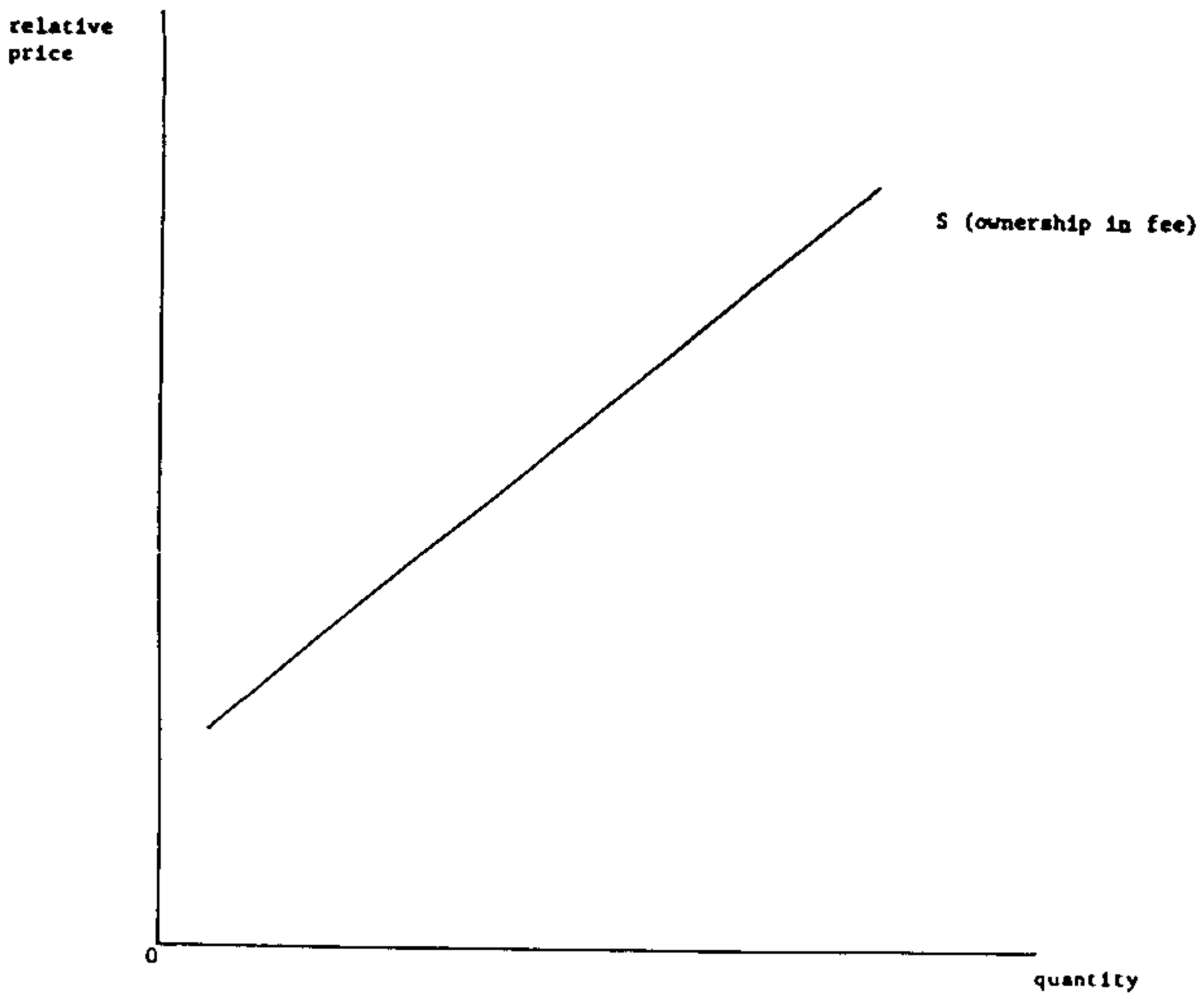
[5]Presumably, the present owner will want to either sell the land during life and get the best possible price for it by keeping it in its most highly valued use or to pass it to beneficiaries after death and bequeath the largest possible legacy by keeping the land in its most highly valued use. The owner might not try to maximize the value of the land if, for instance, it would escheat to the state upon death or if there were restrictions on the profit from the sale of land. We are using this term in the sense it had before zoning statutes came into general use.

land which maximizes its long run value even if a very low price is received for the plants. This would be the case on plots of land on which, perhaps because of their location or topography, alternative uses of the land are particularly difficult or otherwise costly. As the price received for medicinal plants rises relative to the price received for the product of alternative uses of the land, more and more plots would be devoted to the gathering of medicinal plants by owners in fee. Thus, there would be a positively sloped supply curve for medicinal plants, as depicted in Figure 1. We will use the "ownership in fee" supply curve as the standard to which we will compare the supply curves that would result from other property rights regimes.

Common Ownership

Common ownership is functionally equivalent to no ownership. Each individual has an incentive to take as much of the product of the common property as possible as quickly as possible. If an individual does not do so, someone else will. The only way to assert control over the product of the common property is to take it. So each common owner will try to gather the useable medicinal plant material as quickly as possible. None would be left to ripen or grow fully, much less produce seeds or reproduce naturally. Medicinal plants would be gathered even from some commonly owned plots which, had they been owned in fee, would have

Figure 1. Supply curve for ownership in fee



been devoted to uses other than gathering medicinal plants.

Moreover, no land will be improved. Who would improve, plow, or even clear land knowing that anybody else who came along would have just as good a right to it as the one who made the improvements? For both of these reasons, the supply curve for medicinal plants under a common ownership regime would lie to the right of the ownership in fee supply curve (see Figure 2) in the short run. For any given demand curve for medicinal plants, common ownership will produce a lower equilibrium price and a larger equilibrium quantity gathered and consumed, in the short run, than ownership in fee.

The low price will prevail so long as the plants persist. Unless the plants have extraordinary powers of reproduction, the likelihood is that they will be harvested so intensively that they will be driven close to extinction[6]. In the long run, the supply curve will move to the left. The resulting higher price in the long run, combined with the incentives inherent in common ownership, will prevent the species from rebounding unless demand for traditional medicines based on medicinal plants disappears.

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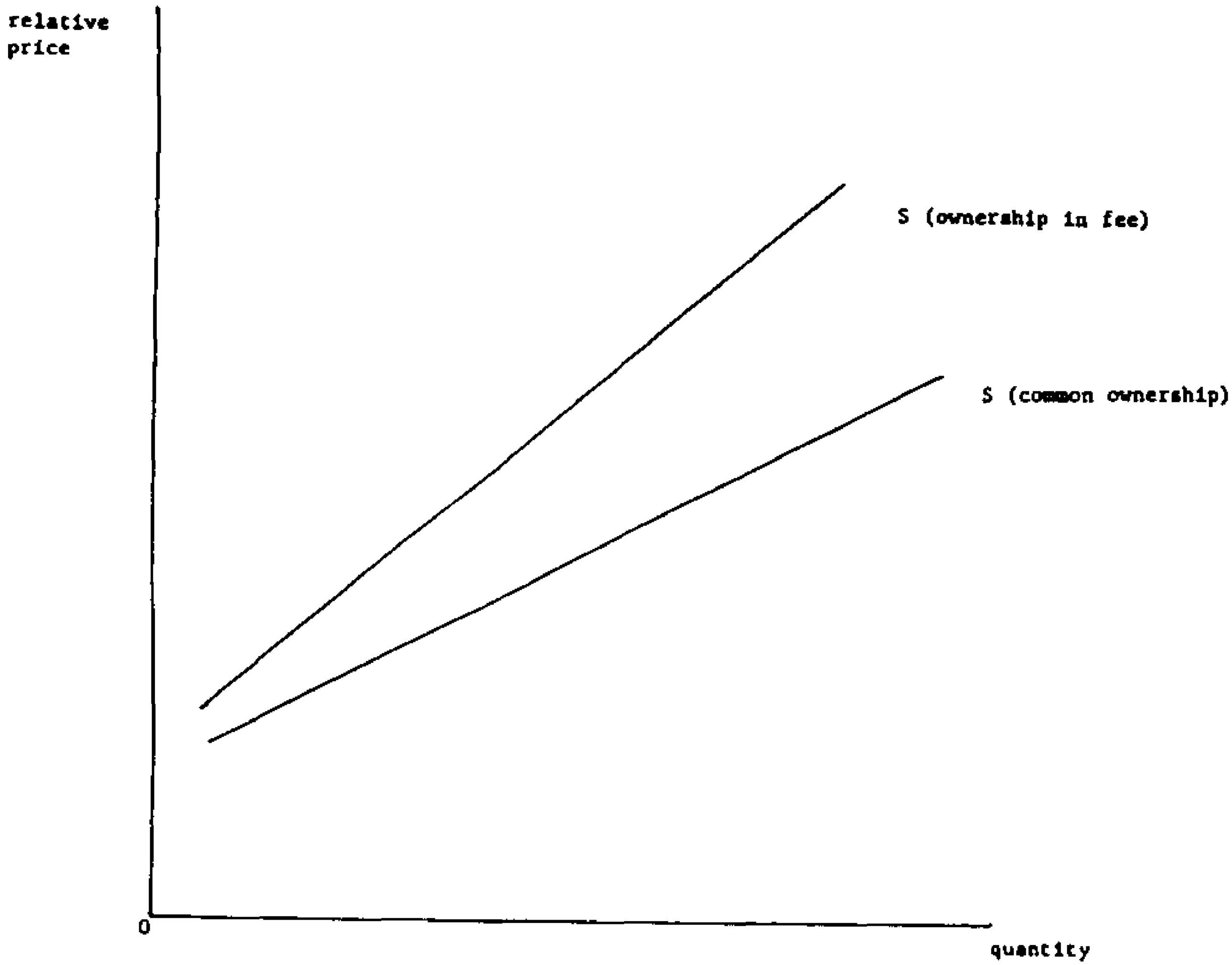
[6]This was the case with buffalo on the Great Plains and with whales in the 19th century, and with the elephants in most parts of Africa in this century. In Zimbabwe, where the government has conferred ownership in fee of specific elephant herds on specific villages, the elephant population is increasing. By some accounts, it has reached destructively high levels (i.e., overgrazing of "common" land) in that country.

Figure 2. Supply curve for common ownership



Therefore, under this property rights regime, there is little reason to expect a commercial incentive to preserve the use of the land as rain forest.

Conditional Ownership

Between the extremes of common ownership and ownership in fee lies a broad range of regimes by virtue of which the use of the land is restricted in some way. Consider, for instance, a grant of land to a person on condition that it be devoted to agriculture (as opposed to mere gathering) for 20 consecutive years[7]. Let us imagine that you could become the owner in fee of any particular plot of land by occupying it and farming it for 20 years. In such a case, some plots for which medicinal plant gathering would have been the most highly valued use will be cleared and used for farming instead. The supply curve for medicinal plants under a conditional ownership regime would lie to the left of the ownership in fee supply curve, and for any given demand curve for medicinal plants, the equilibrium price in the

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[7]We are thinking specifically of the Homestead Act in the United States. Other countries have adopted similar arrangements. In Belize, 70% of the land is essentially unoccupied wilderness, owned by the government. [March 2, 1993 telephone conversation with Yvonne S. Hyde, Economics Attache with the Embassy of Belize] People may buy land from the government if the government approves their proposed use of the land. If the land is not used in the approved manner, it reverts to the government.

short run[8] would be above the price that would prevail under a regime of ownership in fee. The equilibrium quantity of medicinal plants gathered and consumed would, of course, be less than what would be the case under ownership in fee (see Figure 3). Again, little economic incentive for rain forest preservation would exist under this conditional ownership scheme, unless the conditions of ownership stipulated that the land can only be used as rain forest and such stipulations can be effectively enforced.

There is considerable evidence that the lack of clearly defined in fee ownership rights is a major factor contributing to the degradation and destruction of the tropical rain forests.[9] Even if all of the other objections raised to the Balick and Mendelsohn article were put aside, until the property rights issue is addressed and remedied, market oriented solutions to problems of the rain forest preservation offer no basis for optimism.

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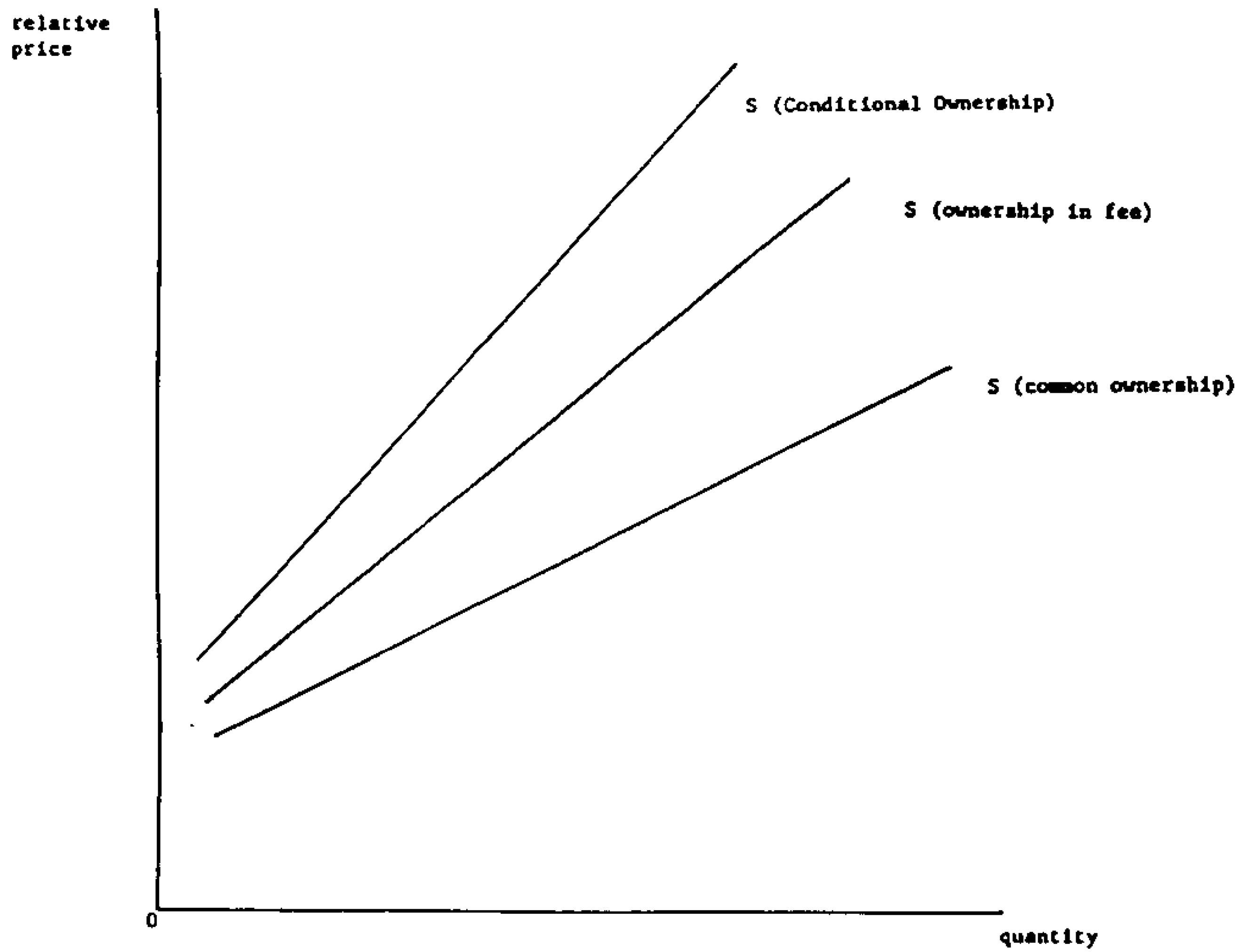
[8]The short run would last for as long as the conditions on ownership were enforced.

[9]See, for example, N. Sharma and R. Rowe, "Managing the World's Forests," Finance and Development, (June, 1992); A. Bauer and G. Illing, "Debt-for-Nature Swaps: Axing the Debt Instead of the Forests," Internomics, (January/February, 1992); T. Tietenberg, Environmental and Natural Resource Economics, 3d ed., (New York: Harper Collins Publishers, 1992), 286-293; R. Heinzman and C. Reining, "Sustained Rural Development: Extractive Forest Reserves in the Northern Peten of Guatemala," USAID/Guatemala Contract Number 520-0000-00-8532-00, 1988.

Figure 3. Supply curve for ownership on condition



How Market Prices Affect Present Value Calculations

As we have seen, the ownership arrangements affect the equilibrium market price and quantity of medicinal plants. This is very important because Balick and Mendelsohn use the net revenue realized from the sale of the plants they gathered as the starting point for their present value analysis. That analysis contains a conceptual error, as we will show in the next section, but the present point holds regardless of the details of the mathematics of present value analysis.

The idea behind all present value analysis is that there is an opportunity cost associated with the passage of time. Therefore, it is appropriate to discount (i.e., reduce) future streams of revenue to account for this opportunity cost. In this way, the value of future revenues receipts can be fairly compared with present revenue receipts. The relevance of the market price of medicinal plants in this analysis is that it affects the size of all the revenues, future and present.

To illustrate the point, let us consider plot 1 in TMTRF. Balick and Mendelsohn received a net payment (after expenses for labor, transportation, etc.) of $564 for the medicinal plants harvested from plot 1. They then calculate that the present value of a perpetual stream[10] of $564 payments every 30 years is $726, assuming a 5% real rate of

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[10]Here is an example of the implicit assumption of ownership in fee.

discount. Now let us assume that the price for the plants falls such that the harvest from plot 1 provides a net payment of, say, \$282 (half of \$564).[11] Repeating Balick and Mendelsohn's calculations but starting with a revenue stream of \$282 payments instead of \$564 payments gives a present value of the land in the gathering of medicinal plants use of:

$$V = (282 / (1-e^{-rt})) = \$363$$

Similarly, doubling the net payment to \$1,128 yields[12] a present value of the land in the gathering of medicinal plants use of:

$$V = (1128 / (1-e^{-rt})) = \$1452$$

Do we know what sort of ownership regime predominates in the region surrounding the market in which Balick and Mendelsohn sold the medicinal plants they harvested from plot 1? In planning a "sustainable yield" pattern of harvests, they conducted themselves as an owner in fee would. If ownership in fee arrangements predominate, as they im-

[11]Cutting the net payment in half may seem a rather extreme assumption, but it might not take much of a fall in price to cause such a fall in the net payment. Let us assume that initially, the gross revenue from selling the harvest of plot 1 is \$3,000 and that the expenses are \$2,436, giving a net of \$564. Now assume that the price received for the plants falls by 9.4%. Gross revenue would fall to \$2,718, but the expenses would, ceteris paribus, still be \$2,436, giving a net of \$282.

[12]This reflects a 19.8% increase in the price received for the plants, given the assumptions in the preceding note.

plicitly assume, then the starting point for their analysis was quite correct. If common ownership arrangements prevail, though, their analysis began with a net revenue stream that is too low in light of their ownership in fee assumption. In consequence, they under-estimated the present value of the land in the gathering of medicinal plants use to owners in fee. Likewise, if ownership on condition[13] predominates, the starting point of their present value analysis was too high, and, as a consequence, they over-estimated the present value of the land in the gathering of medicinal plants use to owners in fee.

It is important to compare apples to apples. Balick and Mendelsohn make their argument that their proposed gathering of medicinal plants use of the land makes financial sense by comparing the present value they calculate for the gathering use with the present value reported in the literature for other alternative uses of the land, such as logging or milpa. Balick and Mendelsohn assume implicitly (and perhaps wrongly) that the ownership regime that prevailed when and where the data for those studies was collected matches the ownership regime that prevailed when and where they collected their data.

While it might be tempting to assume that ownership in fee is the normal case, it is not necessarily the case even

[13]We are assuming that the condition is not that the land be used for the gathering of medicinal plants.

in countries associated with a strong tradition of personal property rights. Logging on government owned land in the U.S. is often conducted under a modified form of common ownership[14] and farming and railroading were both conducted (west of the Mississippi) under an ownership on condition arrangement. Have Balick and Mendelsohn compared apples to apples?

A Conceptual Problem in the Present Value Analysis

Let us assume away all of the problems with the data used in the present value analysis. They found a plot of rain forest land, found all of the medicinal plants thereon, harvested them, took them to a local market and sold them for R dollars (net of harvesting expenses for labor, etc.). They then reasoned that if it took t years for the plot of land to fully regenerate the plants that had been harvested, using the land in this way would yield to its owner a stream of payments of R dollars every t years in perpetuity. They then found the present value of this stream of payments. Comparing this to the present value of alternative uses of the land, they found that the "gathering of tropical pharmaceuticals" use has a higher present value than uses such as intensive agriculture (present value = $339), milpa (present value = $288), and pine plantation (present value =

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[14]We refer to a system of leases under which logging companies have, in the past at least, been permitted to treat the land as if somebody else owned it (*i.e.*, clear cutting).

$3,184).

The conceptual error in this method is to regard the flow of revenue from the plot of land as being continuous. It is, in fact, a discrete flow which occurs once every t years. Consider again the example of plot 1, the plot from which Balick and Mendelsohn realized $564 per hectare net revenue, R, and for which they estimate a rotation period, t, of 30 years. The present value of this revenue stream would be:

$$V = R/(1 - e^{-rt}),$$

where V is the present value and r is the real rate of interest, which Balick and Mendelsohn assume is 5%.[15] This calculation gives a present value of $726 per hectare of rain forest land in the "gathering of tropical pharmaceuticals" use.

The problem with this is that the day after the harvest and sale each 30 years, the present value of the plot falls to $162. To understand why this is so, imagine that

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[15]The assumption of a 5% real rate of interest for a country such as Belize may not be very realistic. It amounts to saying that the marginal product of capital in a country with little capital already and which presents a much higher level of many types of risk than, say, one of the G-7 countries is nevertheless about the same as it is in the G-7 countries. The choice of such a low rate does have the effect of not reducing the present value of remote receipts as quickly as a higher rate would. For instance, if a real rate of 10% is assumed instead of 5%, the present value of the perpetual stream of $564 receipts from Plot 1 falls from $726 to $593.55.

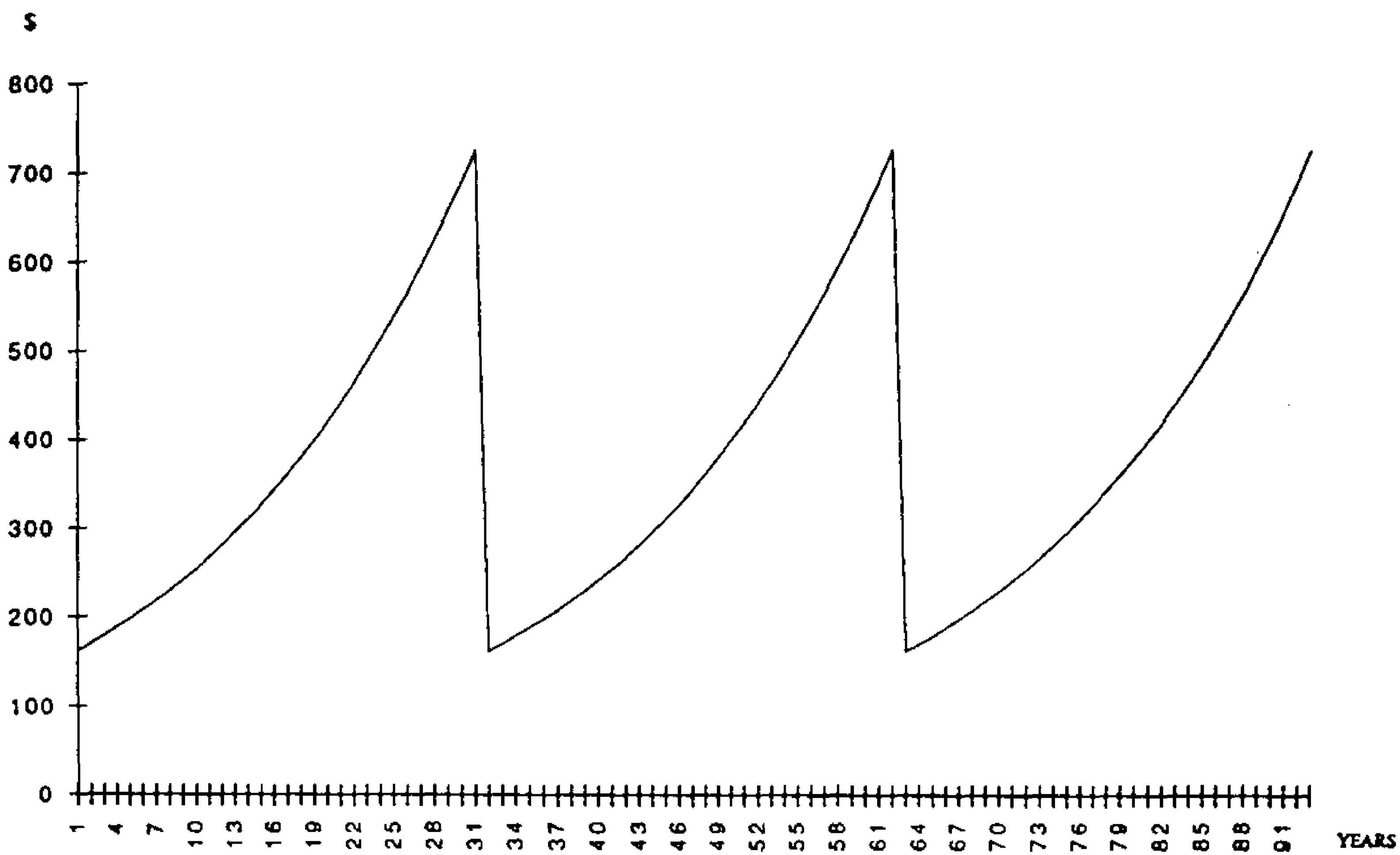
you are someone interested in buying this plot of land and that you are willing to pay its present value in its most advantageous use. If you buy the land on the day before it is to be harvested, assuming it is to be used for gathering of tropical pharmaceuticals, you are buying the right to receive \$564 today, plus \$564 thirty years from today, plus \$564 sixty years from today, plus \$564 ninety years from today, etc., in perpetuity. The present value of that stream of receipts is \$726. If, on the same assumptions, you buy the land tomorrow (after the harvest), you are buying the right to receive \$564 as of 29 years, 364 days from today, plus \$564 as of 59 years, 364 days from today, plus \$564 as of 89 years, 364 days from today, etc. The present value of that stream of receipts is \$162 (\$726 - 564). If t equals zero on the day after the harvest, the pattern of present values would appear as depicted in Figure 4. The present value, V, of the land in the gathering use at any time t would be:

$$V = 162e^{0.05t},$$

for any t from 0 to 30.

What would our prospective buyer be willing to pay for the land? That depends on the uses to which it may be put. For the purpose of illustration, let us assume that there are only two alternative uses of the land--the gathering use

Figure 4. Time pattern of present value of the land when used to gather medicinal herbs



and the milpa use.[16] In the first few years after the harvest of the pharmaceuticals, the present value of the land in the gathering use will be less than the $288 present value of the land in the milpa use.[17] Setting V equal to

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[16]A fall in the present value immediately after harvest would occur for milpa too, but it would be much less pronounced and would build back to $288 by the time of the next harvest (presumably in one year). Given the 5% real rate of interest assumption and recognizing that t=1, the yearly net revenue from the milpa operation, Rm, would be:

$R_m = V(1 - e^{-0.05})$, so $R_m = 288(0.049) = \$14.05$

Therefore, the present value of the milpa operation on the day after the harvest would be $273.95. For the sake of clarity of the figures, the $288 present value of the milpa operation has been treated as a constant.

[17]The higher the present value of the alternative use, the longer will be the period from t=0 during which the alternative will be taken up immediately instead of waiting for the next harvest of pharmaceuticals. The length of that time would be:

$$t = \frac{\ln\left(\frac{V_{alt}}{V_p}\right)}{r}$$

where V_{alt} is the present value of the alternative use and V_p is the present value of the pharmaceuticals use. So the period for milpa would be:

$$t = \frac{\ln\left(\frac{288}{162}\right)}{0.05} = 11.51 \text{ years}$$

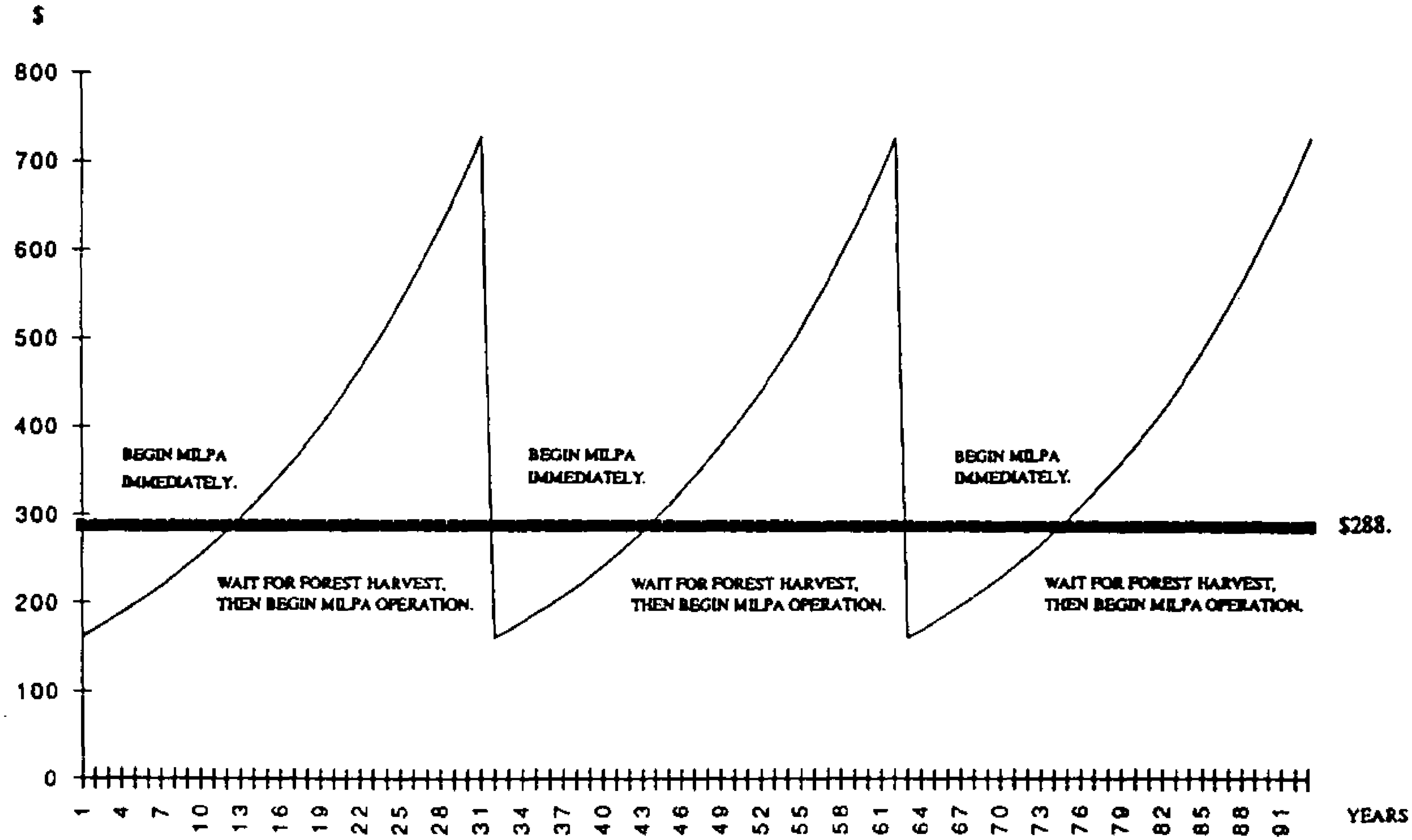
and for intensive agriculture,

$$t = \frac{\ln\left(\frac{339}{162}\right)}{0.05} = 14.77 \text{ years.}$$

$288 and solving for t gives 11.51 years. Therefore, the owner of the land at any time between harvest at t=0 and t=11.51 should convert the land to the milpa use. Anybody who acquires the land between t=11.51 and t=30 will wait until the next harvest of the pharmaceuticals and then introduce the milpa use. This is summarized in Figure 5.

Finally, it should be pointed out that this static analysis implies that at whatever time one acquires the land, the financial incentives point to a conversion to a milpa (or higher valued) operation within twenty years, given the 5% real rate of interest. The larger the real rate of interest becomes, the shorter the period for which the land will be used for gathering pharmaceuticals will be. A dynamic analysis would recognize that as more and more land is converted to the milpa use, the yearly revenue per hectare from the milpa operation would fall, *ceteris paribus*, and with it its present value. Likewise, as the pharmaceuticals become more difficult to find, their supply will decrease and the revenue stream from selling a given quantity would rise, and with it, its present value. These two effects would eventually remove the financial incentive to convert land from rain forest to milpa operations. This would occur only after some, perhaps considerable, rain forest destruction had occurred.

Figure 5. Timing of the switch to the milpa use of the land



Comparative Statics and a Dynamic World

Even if Balick and Mendelsohn had made no conceptual or data collection errors in TMTRF, there would still be a problem with concluding that free market arrangements, by themselves, would preserve the rain forests of Belize (or anywhere else). The problem has to do with the fact that supply curves and demand curves shift; they are not constant. In fact, many events can and do cause them to shift and they are shifting all of the time. Consequently, so are equilibrium prices. The desirable aspect of free market arrangements is that free markets will change the way resources are used in response to changes in relative costs and revenues. Those who do not want to see change in the way some resource (*i.e.*, rain forest land) is used should not favor free market arrangements.

There are other potential problems with the validity of Balick and Mendelsohn's comparison of economic values of land devoted to extraction of medicinal plants and alternative land uses. As Reining *et al.* (1992) point out, there are inherent botany-related problems (e.g., changes in plant population densities over time, differences in precipitation, harvesting practices, and soil type) of maintaining comparability in cross-regional and inter-temporal comparisons of the present value of various land uses. There are also economics related problems in making such comparisons. Richard Tremaine's comments on the possible weaknesses of

Balick and Mendelsohn's land use comparisons are correct.[18] That is, the comparisons should take into account cross-national differences in land use taxation, inflation, and cost of living. Other criticisms raised by Tremaine regarding useful information omitted by Balick and Mendelsohn also seem well founded. Moreover, it is also possible that differences in other forms of taxation, transportation, or other infrastructure characteristics could partly or fully explain differences in the present value of alternative land uses between nations or time periods.

With respect to the Balick and Mendelsohn's comparison to intensive agriculture in Brazil, they cite the Florschultitz (1983) study which utilized intensive methods on six plots of land. How did Balick and Mendelsohn arrive at one present value number for this comparison? Did they take a simple average, an average weighted by acreage or some other variable?

A further complication relates to how Balick and Mendelsohn converted Brazilian cruzeiros of 1981 to American dollars of 1991. There are several methods of doing this. Such a conversion must also address the problem of Brazil's practice in the 1970's and 1980's of setting its official exchange rate rather than relying on market forces to determine exchange rates (which would provide a better basis of

[18] Richard Tremaine, "Valuing Tropical Rain forests," Conservation Biology 7, no. 1, (1993): 7-8.

comparison of market land use alternatives).[18] Did Balick and Mendelsohn use the official, misleading exchange rate, a parallel market (black market) rate, or a separate estimate of the market rate (*i.e.*, shadow price)? Given the hyperinflation in Brazil in the 1980's, the decision as to when the currency conversion occurs is also critical. Unfortunately, there is no information in TMTRF as to how they navigated through these treacherous methodological waters.

Conclusion

The purpose of this chapter is to make more explicit the assumptions and conditions that would have to prevail for the success of market oriented strategies to protect the rain forest. The standard economic argument is that market solutions will fail to efficiently preserve a resource such as the rain forest if that resource generates external benefits (or costs) that accrue to third parties who are not directly involved in decisions affecting the use of that resource. In this case, the rain forest generates the external benefits of biodiversity and carbon dioxide absorp-

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[18]A black market exchange rate should be used with caution because it will include the transactions costs inherent in operating outside the official system. Even a free, floating exchange rate provides an imperfect instrument for such international comparisons because it is, unfortunately for these purposes, influenced by the expected rates of inflation between two countries (*i.e.*, the United States and Brazil) and the expected rate of return on dollar denominated assets relative to the expected rate of return on non-dollar denominated assets.

tion which give all of us a present and future stake in preserving the rain forest. In the presence of such externalities, economists argue that an allocation of resources based on the self-interest of the profit motive would result in a less than socially optimal outcome and must be tempered by the social interest of government (in this case, international agreements) designed to achieve an efficient degree of rain forest preservation. Our argument, has also stressed that no conservation strategy is likely to succeed without the recognition of properly defined property rights.

CHAPTER 3

SUSTAINABLE YIELDS, PUBLIC GOODS, AND RAIN FOREST PRESERVATION

Introduction

In the previous chapter, it was seen that Balick and Mendelsohn have argued that competitive market[1] arrangements would reveal that the highest present value use of rain forest land is in the gathering and sale of natural products of the forest on a sustainable yield basis. That chapter was devoted to exposing some of the economic and financial assumptions which were implicit in their work, many of which, it was argued, were faulty. That one argument leading to a particular conclusion may be faulty, though, does not imply that all arguments leading to that conclusion are faulty. The purpose of this chapter is to show that there are circumstances under which competitive market arrangements will preserve some quantity of rain forest land in its present condition. It will also show that there are circumstances, however unlikely they may be, under which competi-

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[1]The term "competitive market" is preferable to the term "private market" or "private enterprise" because the free (i.e., without extraordinary or special opportunity costs imposed by other people, including government) movement of resources into or out of a business or activity is not necessarily implied by having arrangements that are merely private.

tive market arrangements will fail to preserve any quantity of rain forest land in its present condition.

It will be useful, for the purposes of this discussion, treat rain forest land as an economic good. It is thus theoretically no different than some hypothetical "good x". The plan of the chapter is to develop the underlying theory in terms of good x and then apply it to the case of the rain forest, using what, it is hoped are some particularly illustrative examples along the way.

Before any useful discussion of whether competitive markets will provide good x at all or whether competitive markets will provide good x in a socially optimal amount can proceed, it is necessary to describe the circumstances of the production of and consumption of good x. This must be done because the answers to the questions depend on whether good x is a pure private good, a good whose production or consumption is characterized by externalities, or a pure public good. It is helpful to think of these classes of goods as lying on a continuum ranging from pure private goods to pure public goods. These terms must themselves be defined. To do so, the concept of externalities must be introduced. To properly explain externalities, we must think in terms of the two most fundamental concepts of economics, utility and opportunity cost.

Opportunity Cost, Utility, and Externalities

Utility is the capacity of things (goods and services) to satisfy our wants. A raincoat in the Pacific Northwest has utility because it satisfies our want to remain dry. The same raincoat would have little utility in Death Valley. Opportunity cost is best understood in terms of activities. The opportunity cost of some activity, Q, is the value of the highest valued activity foregone. In order to do the activity Q, some resources (even if only one's time) had to be used. If resources are used to do Q, they cannot at the same moment also be used to do some alternative activity, R. Therefore, if Q is to be done, R must be foregone. The value of doing R, what ever it would have been, must be sacrificed in order to do Q instead. Thus, we say that sacrificing the value of doing R is the cost of taking the opportunity to do Q. Of course, we cannot count the sum of all of the possible alternatives to activity Q as the opportunity cost of Q because we could only have done one of them; even choosing to do activity R is also choosing not to do Q and all of the other alternatives to R. Thus, we can only count as the opportunity cost of Q the single alternative to Q that we would have valued highest. Likewise, the opportunity cost of activity R would be the highest valued alternative to R (which may well have been activity Q!). It would be useful to note that opportunity cost is a very broad concept, much broader than the accounting concept of cost. The accounting concept of cost deals with money; out of pocket expenses, if you will. The concept of opportunity cost deals with resources. While society as a whole always bears the full opportunity cost of all activities, it is not always true that each individual or group of individuals always bears exactly the full opportunity cost of their own activities.

The production of any economic good involves some opportunity cost. In fact, having an opportunity cost in production greater than zero is an essential part of the definition of an economic good, because that which can be produced without opportunity cost is free and thus outside the range of economic inquiry. A business firm is a social organization for the purpose of producing economic goods (there is no useful distinction between goods and services in this context), but to do so, the firm must bear some opportunity cost. In the normal case, the opportunity cost to society as a whole of producing good x is the same as the opportunity cost to the firm of producing good x. To put it another way, the full opportunity cost of producing good x is reflected in the prices the firm paid for the resources necessary to undertake good x production. Under some circumstances, though, a firm may be able to avoid (often quite legally) bearing the full opportunity cost to society as a whole of its productive activities. Thus, some portion of the opportunity cost of the production of good x is "external" to the firm and left for other members of society to bear. This set of circumstances is described as a negative externality.

Perhaps the classic textbook example of a negative externality is excessive pollution of the atmosphere. Since no legal person owns the atmosphere, a steel mill, say, would be perfectly free to discharge some or all of the waste from its production process (which waste is part of the opportunity cost of steel production) into the atmosphere for zero cost in the accounting (*i.e.*, on the firm's books) sense. Thus, the firm would escape recognizing that portion of the full opportunity costs of its productive activity.

Please note that the firm was able to do this because nobody owns the atmosphere; because of a failure of property rights. The firm would not dump its wastes, say, in my driveway, because I would instantaneously sue them in trespass and win a judgement for damages. The highly developed state of the law of property in land prevents that form of pollution, just as the almost non-existent state of the law of property in the atmosphere invites atmospheric pollution. Please note further that it was not the firm's intention or objective to pollute the atmosphere. The opportunity cost to society in terms of pollution was incurred as part of the process of producing something society wanted, namely, the steel. The socially optimal level of atmospheric pollution is not zero because the socially optimal level of steel production is not zero. Society must balance the extra utility of the next unit of steel consumed against the extra cost (including the extra pollution that comes as a by-product) of that extra steel. Economists refer to the extra utility of the last unit of steel (good x) consumed as the marginal utility of steel (good x). The extra opportunity cost of the last unit of steel (good x) produced is called the marginal cost of steel (good x).

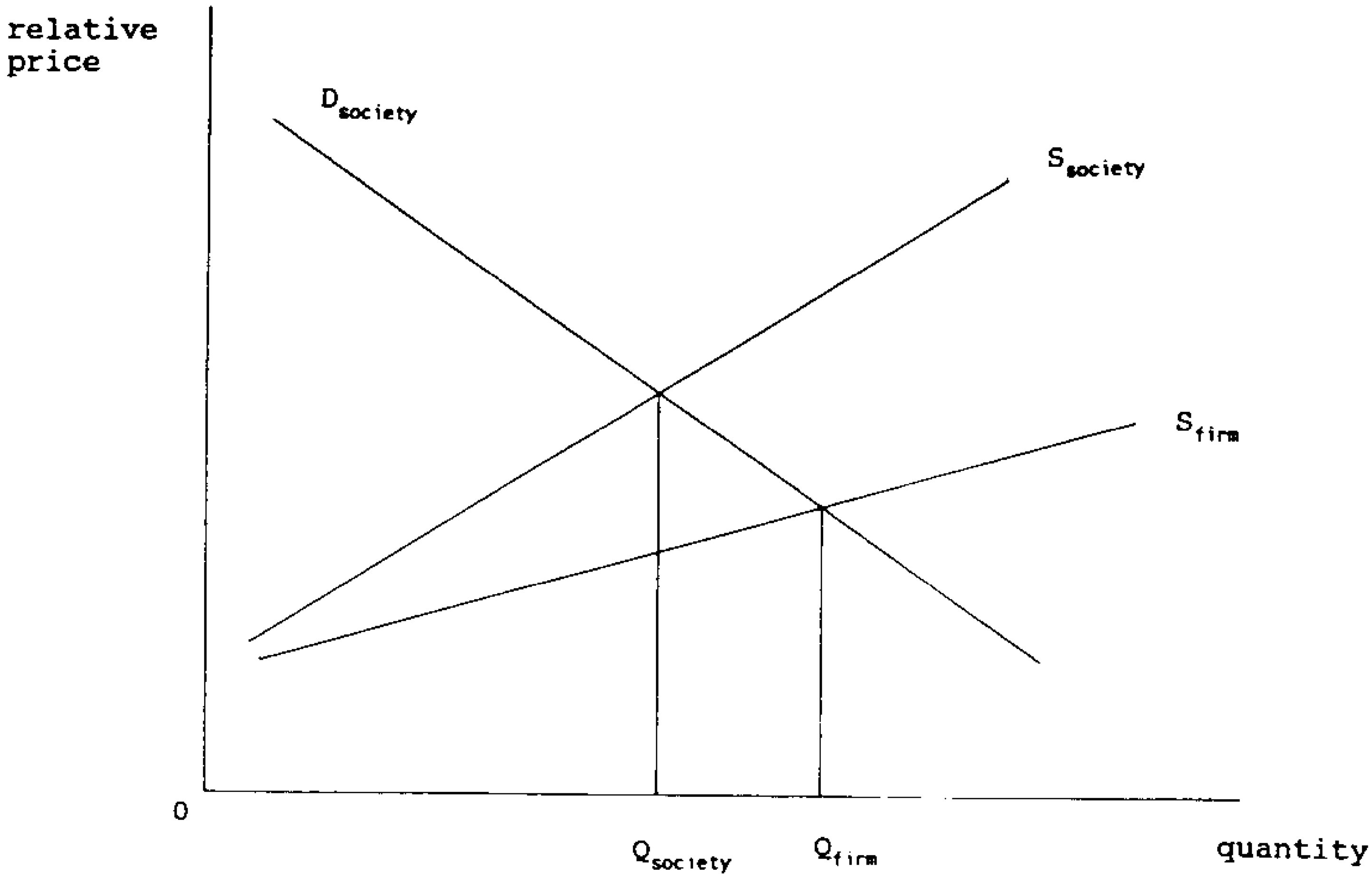
Except in very special cases, the marginal utility of any good diminishes as more and more units of the good are consumed. This is because the early units of consumption will be put to the most highly valued (*i.e.*, highest utility) uses. With the highest utility uses being already completed, later consumption units can only be put to relatively lower utility uses. Thus, the more you have of something already, the lower will be the marginal utility of another unit of it, whatever it is. A demand curve for good x is really just a plot of the marginal utility (or marginal valuation, which amounts to the same thing) of good x given the number already consumed. It is because of diminishing marginal utility that the demand curve for good x has a negative slope.

Similarly, the marginal cost of any good increases as more and more units of the good are produced. We live in a world in which we can think of more things we would like to have done than we have resources to do them, so, if we are to produce an additional unit of good x, we have to take resources away from the production of something else. To produce the early production units of good x, we can take resources from relatively low valued alternative activities. Thus, the opportunity cost of the early production units of good x is relatively low. To produce more and more units of good x, though, requires that we draw more and more resources into the x production process. That means taking resources away from more and more highly valued alternative activities, so the marginal cost of good x must rise as we produce more and more units of good x. A supply curve for good x is really just a plot of the marginal cost of good x given the number already produced. It is because of increasing marginal cost that the supply curve for good x has a positive slope.

The supply curve for good x and the demand curve for good x will intersect at some combination of price (on the vertical axis, measuring marginal utility and marginal cost) and quantity (on the horizontal axis). This price and quantity combination marked out by the intersection of the supply curve and the demand curve is called the equilibrium price and quantity. It is called that because whenever the actual market price and quantity combination differs from the equilibrium combination, competitive forces, operating through the profit motive, will push the market price and quantity toward the equilibrium. It can be shown that the socially optimal quantity of good x to produce is that quantity at which the marginal utility of the last unit is equal to the marginal cost of the last unit produced. Please note that the socially optimal quantity is exactly the equilibrium quantity. One of the senses in which competitive market arrangements are efficient is the tendency for such markets to move back toward the socially optimal quantity after a disturbance. This is called allocative efficiency. If a market ceases to be (or never was) competitive, there is no reason to think that the socially optimal quantity will be produced or that there are any systematic forces to move the market toward producing the socially optimal quantity.

In a competitive market characterized by a negative externality, though, it can shown that the quantity produced will be greater than the socially optimal quantity. Consider the supply curve, or, more properly, supply curves, in such a case. Let us imagine that there are two supply curves: one that is defined as before and reflects the full opportunity cost to society as a whole of good x production (labelled "$S_{society}$" in Figure 6), and another which reflects only that portion of the full opportunity cost to society of good x production that must be recognized by the firm (labelled "S_{firm}" in Figure 6). The profit maximizing firm will want to sell another unit of good x until the marginal utility they receive (in the form of the price of good x) is equal to the marginal cost <u>to the firm</u> of producing that

Figure 6. Negative externality



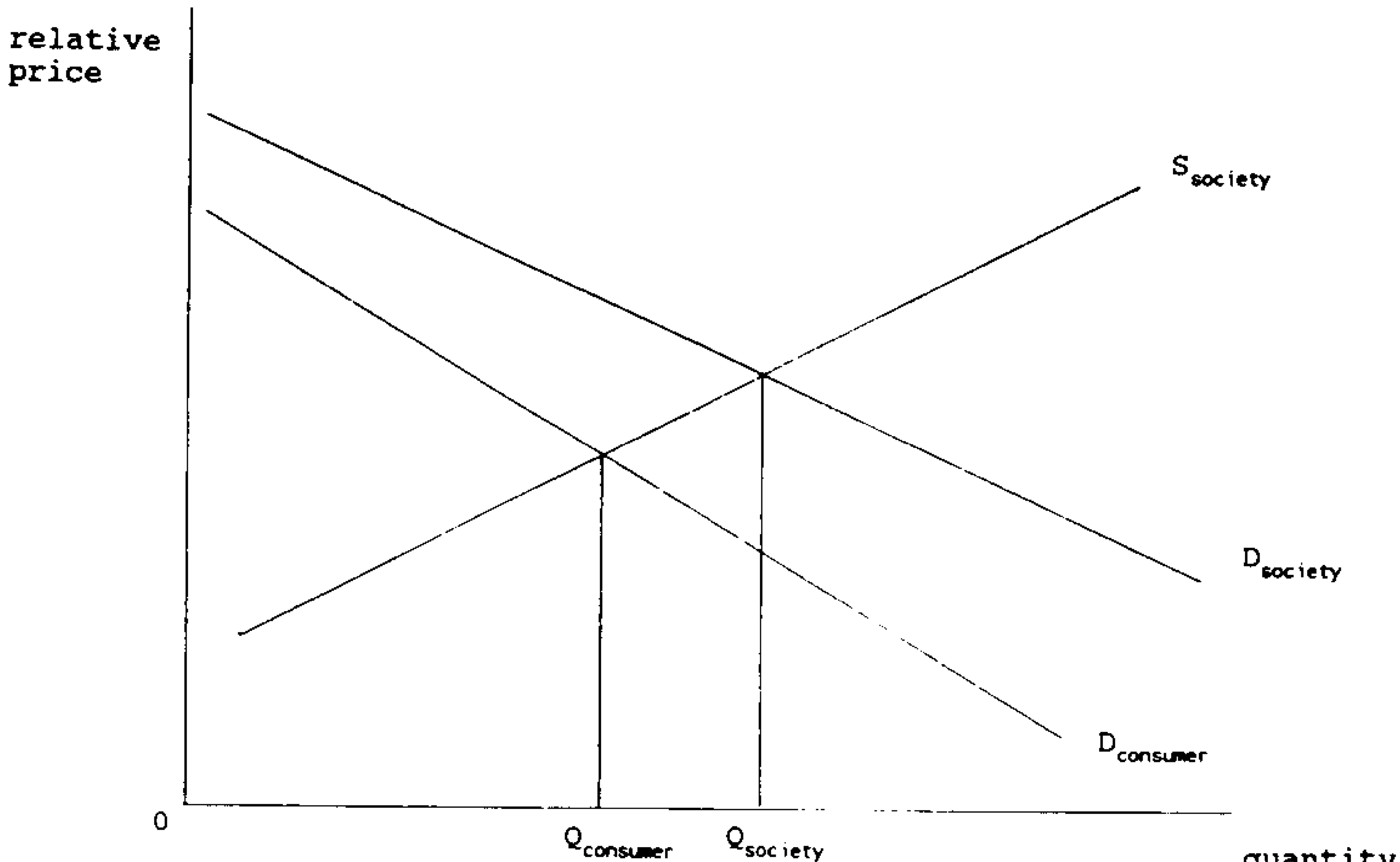
unit of good x. The resulting quantity, which is optimal from the point of view of the firm, occurs at the intersection of the demand curve for good x and the supply curve for good x labelled S_{firm}. The optimal quantity from the point of view of society as a whole occurs at the intersection of the demand curve for good x and the supply curve for good x labelled $S_{society}$. To return to the steel making example, the opportunity cost of the atmospheric pollution associated with making each unit of steel is represented by the vertical distance between the two supply curves. The "excess" pollution would be that associated with the production of $(Q_{firm} - Q_{society})$ units of output.

Just as a competitive market characterized by a negative externality would produce more than the socially optimal quantity of good x, a competitive market characterized by a positive externality would produce less than the socially optimal quantity of good x. Recall that a negative externality arose when some members of society other than the producer of good x had to bear part of the opportunity cost of producing good x. A positive externality arises when some members of society other than the owner of good x receive some utility from the consumption of good x. For instance, the gardener who purchases and successfully raises flowers creates a positive externality for his neighbors in that they may look upon the gardener's property for free and in that the value of their property is enhanced by its proximity to such floral beauty.

Please observe that, like negative externalities, positive externalities arise from a failure of property rights. Our gardener has no property right in the light reflected by his flowers' blooms. Consequently, any effort on the part of the gardener to get the neighbors to pay for the utility they have received as a consequence of the gardener's efforts is bound to suffer failure and derision.

To show that competitive markets would produce less than the socially optimal amount of a good characterized by a positive externality, begin by imagining that there are two demand curves for good x: one that is defined as before and which reflects the full utility received by society as a whole as a result of the consumption of good x (labelled "$D_{society}$" in Figure 7) and another which reflects only that portion of the total utility received by society from good x consumption that can be captured by the owner of good x (labelled "$D_{consumer}$" in Figure 7). The welfare maximizing consumer will want to purchase and consume another unit of good x until the marginal utility of good x <u>to the consumer</u> equals the marginal cost of good x. This occurs at the quantity at which the supply curve for good x and the demand curve labelled $D_{consumer}$ intersect (*i.e.*, at $Q_{consumer}$). The optimal quantity from the point of view of society as a whole occurs at the intersection of the supply curve for good x and the demand curve for good x labelled $D_{society}$, at

Figure 7. Positive externality



$Q_{society}$. Just as the existence of a negative externality resulted in a competitive market producing an inefficiently large quantity of good x, the existence of a positive externality results in a competitive market producing an inefficiently small quantity of good x. In terms of distortion of the quantity produced, the only limit on the effect of a negative externality is the number of units of good x produced. Since it is impossible to produce less than zero units of any economic good, there is a limit on how extreme the effect of a positive externality can be.

Public Goods and Joint Production

A positive externality so extreme that the result is that good x would not be produced at all by a competitive market is called a public good. Such goods have two special characteristics. The first is that the good is non-rival in consumption. This means that consumption of the good by one person does not reduce the amount available for consumption by anyone else and that everyone must consume the same amount of the good. The second characteristic non-excludability. This means that it would be impossible or extremely costly to prevent those who did not pay from consuming the good.

There are some special problems surrounding the production of public goods that stem from the fact that everyone must consume the same quantity of the good. Please recall that public goods are goods characterized by positive externalities so extreme that nobody would be willing to (or, very likely, able) to purchase any of the good on their own. This is so because the marginal utility that any one consumer could receive personally is far less than the marginal cost required to produce even one unit of the public good. The marginal utility (or marginal valuation, if you prefer) of society as a whole for the first unit of the public good, which is the sum of each individual's marginal utility for the first unit of the public good, may well far exceed society's marginal cost to produce the first unit of the public good. That means that the first unit, at least, of the public should be produced because it would increase the total economic welfare of society, but no individual will make the first move, even if they could personally bear such a large marginal cost. Instead, each individual will wait and try to be a free rider. The term free rider refers to the strategy of keeping secret one's willingness to contribute to the purchase of a public good in the hope that someone else will find that their own marginal valuation of the good is so high that they will provide it for themselves and, consequently, provide it for everyone else at the same time.

The consequence of each individual trying (quite rationally) to be a free rider is that the only way a pure public good[2] will be produced is through some form of collective action, such as government.[3] The individuals in society have to agree to tax themselves and make a collective purchase of the public good. Everyone will still want to try to be a free rider, though, so the taxes must be made compulsory. This fact makes it impossible to know what the marginal utility to society of any given unit of the public good may be. In markets for private goods, consumers reveal their marginal utility for another unit of the good by their willingness to pay or refusal to pay the price asked for the marginal unit. Could not the government simply poll the taxpayers by asking them how much they would be willing to pay (*i.e.*, how much would be their marginal utility) to consume one unit, two units, three units, etc. of the public

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[2]Some writers distinguish between pure public goods and impure public goods. Pure public goods are goods that fit the definition we have been using. Impure public goods are goods that would be provided by competitive markets because the positive externality element is not present or is insignificant, but which are nevertheless produced and distributed by government. Education is a commonly used example of an impure public good since it clearly does not meet the non-excludability part of the definition (colleges and universities have no difficulty in excluding those who do not pay the tuition). See, for instance, Heinz Kohler, Microeconomics, (Lexington, MA: D. C. Heath and Company, 1992), 539.

[3]This is not strictly so. There are cases of private provision of public goods through charitable donation, but it would seem that ignoring the hedonic value of giving in order to claim that the private marginal utility of provision of the good is less than the private marginal cost is taking too narrow a view of the matter. See, in this connection, Robert H. Frank, Microeconomics and Behavior, 2d ed.,(New York: McGraw-Hill, Inc., 1994), 706-7.

good in question? Undoubtedly, many governments have the technical capacity and resources necessary to do just that, but, it will be shown, it is very doubtful that anybody would answer honestly. Even if the amount of taxation levied on each payer were determined in a manner that is independent of the quantity of public goods government purchases, there is still the problem of allocating the taxes collected among competing goods.

The classic textbook example of a public good is national defense. National defense is non-rival because a given defense effort must, by definition, defend everyone simultaneously. Moreover, whatever quantity of national defense is purchased by society, it is the only quantity purchased by society. A wealthy resident of the country who thinks the amount of defense purchased is inadequate might choose to augment it using his own purchasing power, but even the wealthiest resident could not augment the defense he enjoys without also augmenting the amount of defense enjoyed by every other resident. It is also non-excludable because it is impossible to protect me without also protecting my neighbor, who happens to be a tax evader. A parallel example is the system of courts and police agencies. When the criminal justice system imprisons a criminal, I am that much safer from attack, but making me more safe does not make you less safe. Indeed, both of us enjoy the same increment to our safety, so consumption of this good is also non-rival. It is also non-excludable in the same way national defense is non-excludable.

By shooting fireworks into the air on the Fourth of July, my neighbor across the street has created a public good. My viewing of the fireworks does not diminish the amount by which my neighbor can enjoy viewing them. We both view the same amount of fireworks, so consumption of the fireworks is non-rival. Furthermore, it would be impossible, without an illegal breach of the peace, for my neighbor to prevent me from watching the fireworks from my own yard. If I believed that he would purchase and display fireworks in the same quantity in any case, I would refuse to help my neighbor pay for them, even if I were approached before the Fourth. I will instead be what is known as a free rider.

I was quite willing to view my neighbor's fireworks, even eager to do so. I was also unwilling to pay. Being unable to withhold the benefit of his fireworks from me, my utility producing neighbor had to share the benefit with freeloading me. My neighbor could have withheld the utility of the fireworks from me only by withholding the utility from himself by not producing the activity at all. If my neighbor thought that there was a chance that I would be the first to break down and buy fireworks, he might well try to be the free rider. In the end, neither of us puts on a fireworks display and both of us try to be free riders.

More often than not, this is exactly what happens. Please note that this free rider problem stems directly from the positive externality. Producers and consumers of goods not characterized by externalities do not face the free rider problem. Such goods are called pure private goods.

Before turning to the problem of determining the socially optimal level of production of public goods, let us pause to place the various types of goods we have discussed so far on a continuum. Goods characterized by negative externalities are at one end of the continuum. Without intervention of some kind (effluent taxes, creation of new or adjustment of existing property rights, or direct regulation), competitive markets will produce these goods in a larger quantity than would be socially optimal. In the middle of the continuum we find pure private goods. These are goods which are produced and consumed without significant externalities. Consequently, competitive markets have no difficulty in providing these goods in the socially optimal amount. At the opposite end of the continuum are goods characterized by extreme positive externalities. If these goods have the additional characteristics of providing non-rival and non-excludable benefits to all members of society, they are called public goods. Near the center of the continuum can be found goods with negative externalities so mild that the costs of administering a program to deal with them would exceed the efficiency losses they cause and goods with positive externalities that are not so significant as to preclude or even significantly diminish their private production. The vast majority of goods can be properly classified as pure private goods.

The determination of the socially optimal quantity of a public good for society to produce and consume is determined in the same way the socially optimal quantity is determined for any other good. In theory, the socially optimal quantity is that quantity at which the marginal utility (or valuation) to society as a whole of the last unit consumed is equal to the marginal cost to society as a whole of the last unit produced. As a practical matter, though, it is not generally possible to know when this quantity has been produced and consumed. The difficulty lies in the fact that, in general, there are no private transactions in these goods to reveal to us what the marginal social valuation of them must be for different quantities consumed; there are no individual demand curves for us to sum to find the market quantity demanded at each possible price.

Please recall that one of the things that characterizes a public good is the fact that everyone has to consume the same quantity it. So, rather than finding the market demand curve by adding up each individual's quantity demanded for several different levels of marginal valuation and connecting the resulting plotted points to find the market demand curve, we must add up each individual's marginal valuation of each possible quantity of the public good and plot the resulting points.

To put it another way, for a private good, each person adjusts their quantity consumed so that their personal marginal valuation equals marginal cost. Each person may consume a different quantity of the private good, but each person's marginal valuation of the last unit they consumed is the same. In the case of a public good, though, everyone has to consume the same quantity, so each person's individual marginal valuation of that quantity may be different. That is why we find the market demand curve for a private good by summing the individual quantities demanded for each possible price along the quantity axis and we find the "market" demand curve (or "willingness to be taxed") curve for a public good by summing the individual marginal valuations for each possible for each possible quantity along the price axis.

There are no prices for public goods because competitive markets will not produce public goods at all. The reason is that even if a public good were produced and offered for sale, nobody would buy it. Please recall that public goods are goods characterized by positive externalities so extreme that nobody would be willing to (or, very likely, able) to purchase any of the good on their own. This is so because the marginal utility that any one consumer could receive personally is far less than the marginal cost required to produce even one unit of the public good. The marginal utility of society as a whole for the first unit of the public good, which is the sum of each individual's marginal utility for the first unit of the public good, may well far exceed society's marginal cost to produce the first unit of the public good. That means that the first unit, at least, of the public should be produced because it would increase the total economic welfare of society, but no individual will make the first move (even if they could personally bear such a large marginal cost). Each individual will wait and try to be a free rider.

Funding Public Goods Purchases

While this approach is perfectly correct in theory, it assumes that each person reveals their true willingness to be taxed. Each person, though, has an incentive to not be truthful about how much they value the next unit of the public good. To see why this is so, let us imagine that everyone in the real sounding but non-existent country of Freedonia agrees to be taxed an equal pre-determined amount, t_i, to pay for erection of a statue commemorating the memory of Rufus T. Firefly, a famous local citizen. Then each person (each voter, really) is called upon to announce the marginal value they place on the next (which is also the first) unit of this public good, v_i. We can then find for each person their net marginal valuation of this quantity of the public good, n_i, as the difference between the value they place on this public good and their willingness to be taxed to pay for it. So $n_i = (v_i - t_i)$. If the sum of the net values exceeds the total cost of the public good, the total welfare of society would be advanced by collecting the taxes and erecting the statue. Now imagine that you are someone whose marginal valuation of the public good is only slightly more than your marginal tax cost, so your true n_i is a small positive number and you would like to see the statue built. You may as well claim that your v_i is a billion dollars, though, because that claim will have the effect of ensuring that the sum of the n_i numbers for the whole country exceeds the total cost of erecting the statue, but your tax payment will remain the same. Likewise, someone whose true n_i is only slightly negative may as well claim that their v_i is zero, or even that the statue would be an affront to some socially favored group and an eyesore, and that their v_i is therefore a large negative number because that would render the sum of the n_i numbers lower than the total cost of erecting the statue. It is safe to make these assertions because one's tax payment is not affected by reporting an untrue n_i.

This pattern of exaggeration of the absolute value of v_i would have no effect on the decision concerning whether or not to erect the statue if both sides are equally bold in their assertions, but we have no way of knowing whether that condition is met or not. The exaggerations only matter if they change the decision. One particularly talented prevaricator could do that. such a person is called a pivotal agent. If these pivotal agents can be given an incentive to be truthful in stating their v_i, then the true "willingness to be taxed", or, if you prefer, demand curve for the public good can be found. There is an approach to doing this which may be practicable. It is a form of taxation whose objective is not to collect any revenue, but only to create an incentive for the voters to reveal their true marginal valuations; their true v_i. It is generally referred to as the Groves-Clarke tax, or simply the Clarke tax.[4] It is not intended to replace the tax designed to raise the revenue necessary to finance the public good.

The Clarke tax is based on the idea that whenever a pivotal agent's n_i would change the outcome of the voting, other voters will have been made better off or worse off. The tax is based on the sum it would take to compensate those whose welfare position is changed by the n_i of the pivotal agent, but the tax is not paid to those persons. To continue the Freedonia example, let us say that without considering Trentino, the sum of the net values for building the statue would be positive, but that Trentino's n_i is so large in the negative direction that he changes the sum of

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[4]T. Nicolaus Tideman and Gordon Tullock, "A New and Superior Process for Making Social Choices," Journal of Political Economy 84 (December 1976): 1145-59.

the net values to an overall negative. Trentino is a pivotal agent and his voting imposed harm on the other voters because without him, they would have had the statue. The total harm, H_t, would be:

$$H_t = \Sigma n_i > 0 \qquad for\ i \neq t.$$

Likewise, if the voters without Trentino would have had a negative sum of the net values and Trentino's n_i was so large and positive that he caused the sum of the net values to go to the positive side, then:

$$H_t = -\Sigma n_i > 0 \qquad for\ i \neq t.$$

Whichever way Trentino is pivotal, the Clarke tax requires him to pay a tax equal to H_t.

To see how the Clarke tax promotes truth in stating n_i (or v_i, which is effectively the same thing), let us consider the case in which Trentino was pivotal in causing the statue to be erected when it otherwise would not have been. Would it have paid Trentino to understate his n_i? No, because that would lower the chance that the statue will be built and would not lower his "statue tax", t_i. Should Trentino have overstated his n_i? Again, the answer is no because that would not change the marginal value he receives from erection of the statue or his "statue tax" either.

If any Clarke taxes are collected, they must not be distributed among the voters directly, because that prospect may change their net values. If the number of voters is large, though, it is unlikely that any one of them would be pivotal unless that voter's desires are particularly intense and the other voters are roughly evenly divided on the issue. Therefore, it is unlikely that the tax will actually have to be collected.

Rain Forests as Public Goods and as Private Goods

Now we are in position to turn to the analysis of whether, to what extent, and by whom economic theory suggests tropical rain forest land would be maintained in its present use. It is beyond argument that this would be an economic good (as opposed to a desirable outcome), since the maintenance of this land as rain forest yields certain flows of utility to certain people. Such land, though is susceptible of many different kinds of uses and of producing several kinds of economic goods. The analysis is further complicated by the fact that some of these economic goods must be produced jointly, while in some other cases the production of one good precludes the production of the others.

Tropical rain forest, at a minimum, produces or could be used to produce:

1. forest products (felled trees, fruits and herbs, etc.) on a one-time basis, followed by development of the land
2. forest products on a sustainable yield basis (felled

trees, gathered fruits and herbs, resins, latex, etc.)[5]

3. recreation in the form of hunting, camping, fishing, and tours for viewing flora and fauna, all for fees
4. services in the form of habitat for the preservation of bio-diversity[6]
5. services in the form of a CO_2 sponge for the planet
6. services in the form of providing a sense of well being to some people by virtue of its mere existence

Within certain biological limits, the uses numbered two through six (hereinafter "sustainable uses") can take place on the same parcel of land simultaneously.[7] These goods are therefore jointly produced in fixed proportions. Use number one (hereinafter "development use"), on the other hand, can only be done as an alternative to the sustainable uses; they are mutually exclusive.

Since sustainable uses and development use are mutually exclusive, the opportunity cost of devoting another unit of land to sustainable uses is the value of the land in development use. Let us assume that we devote to sustain-

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[5]T.A.S., "Using Market Forces To Save Nature," Fortune 14 January 1991, 42-3.

[6]Julian L. Simon, "Disappearing Species, Deforestation and Data," in Rational Readings on Environmental Concerns, Jay Lehr, ed., (New York: Van Nostrand Rheinhold, 1992), 741-49.

[7]John G. Robinson, "The Limits to Caring: Sustainable Living and the Loss of Biodiversity," Conservation Biology 7 (March,1993): 20-27; Raymond Rasker, Michael V. Martin, and Rebecca L. Johnson, "Economics: Theory versus Practice in Wildlife Management," Conservation Biology 6 (September, 1992): 338-49.

able uses those units of land least suited to development use earliest and only later and only later devote to sustainable uses units of land that are more and more suitable for development. We depict this assumption by drawing the supply curve for land for sustainable uses as being upward sloping to the right.

The demand for land for sustainable use is a bit more difficult to depict. Because the goods derived from sustainable use are jointly produced in fixed proportion, the quantity of one produced must equal the quantity of all the others produced. The demand for any given quantity of land for sustainable use is the sum of the marginal valuations of the next unit of each of the goods derived from the land. In order to cut down on the clutter in the diagrams, let us refer to goods two and three collectively as "lumber" and to goods four through six collectively as "preservation".

Suppose that the demand for lumber (D_L) is as depicted in Figure 8, the demand for preservation (D_P) is as depicted in Figure 9, and the demand for land in sustainable (D_S) uses is the vertical sum of D_L and D_P. In Figure 10, the demand curve and the supply curve (S_S) for land in sustainable uses are combined. At any given quantity of land in sustainable uses, the marginal valuation of the next unit of lumber is given by the vertical distance between D_P and D_S. The resulting equilibrium marginal valuation and quantity of land for sustainable uses is given by MU_S and Q_S, respec-

Figure 8. Demand curve for lumber

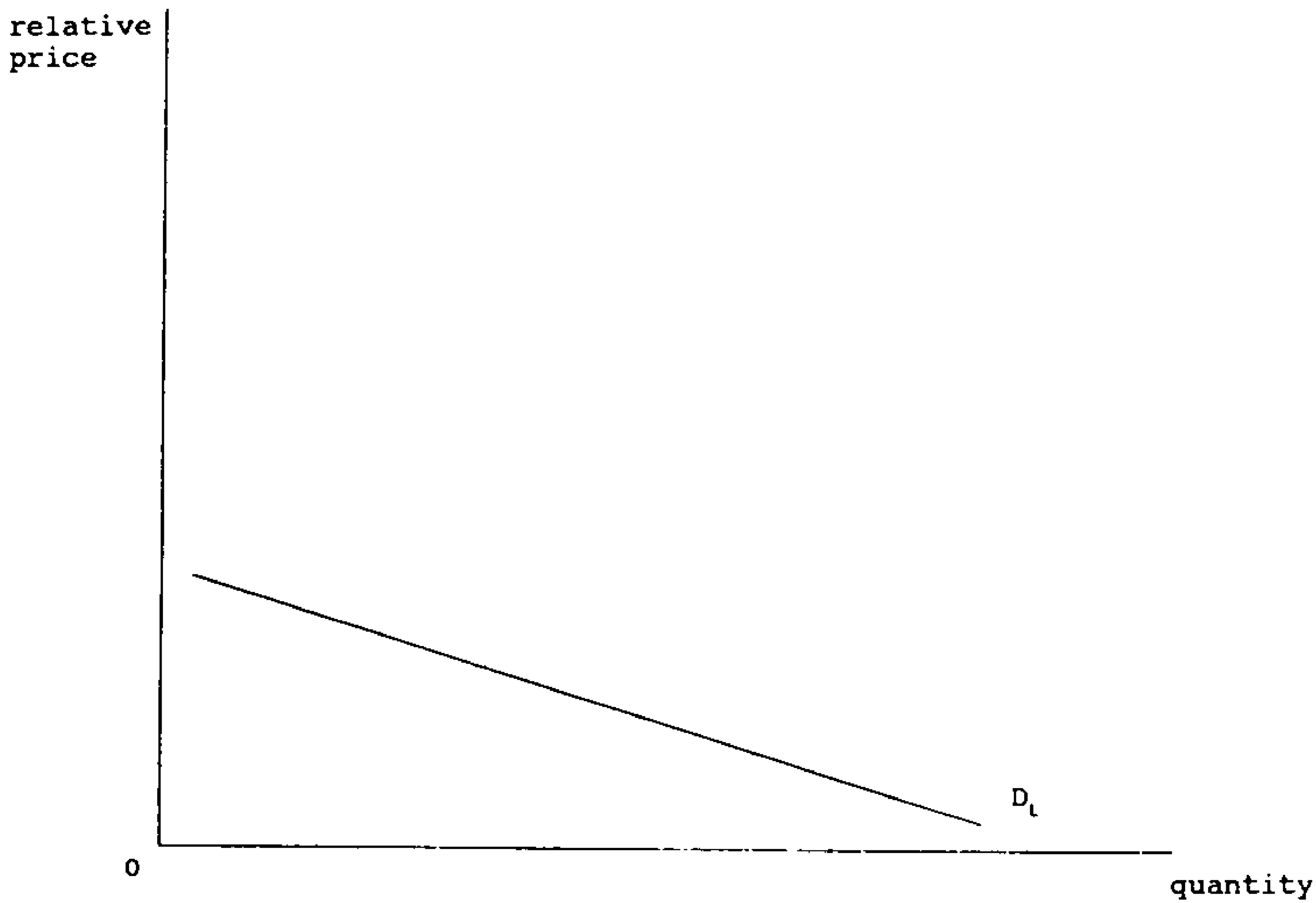


Figure 9. Demand curve for preservation

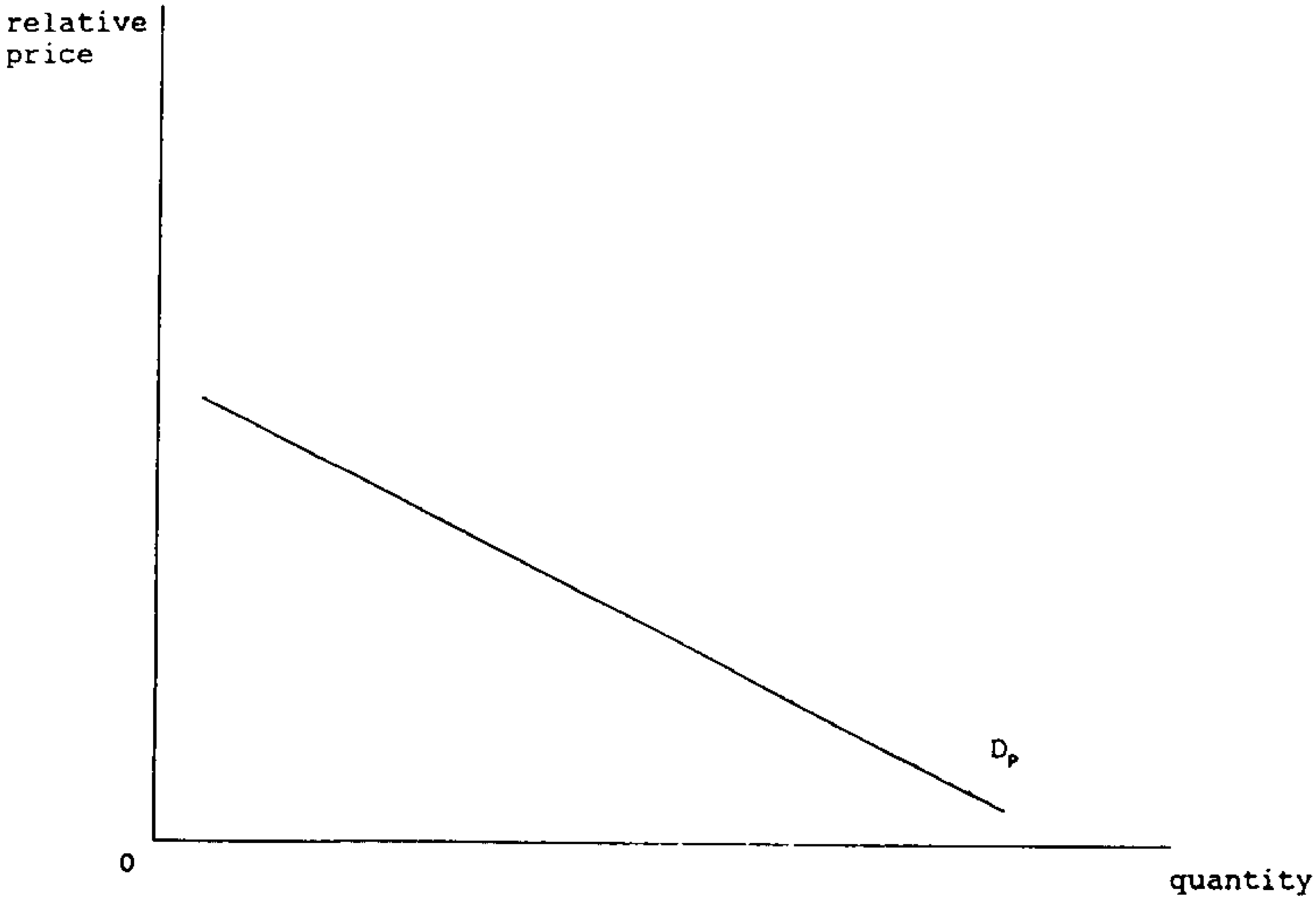
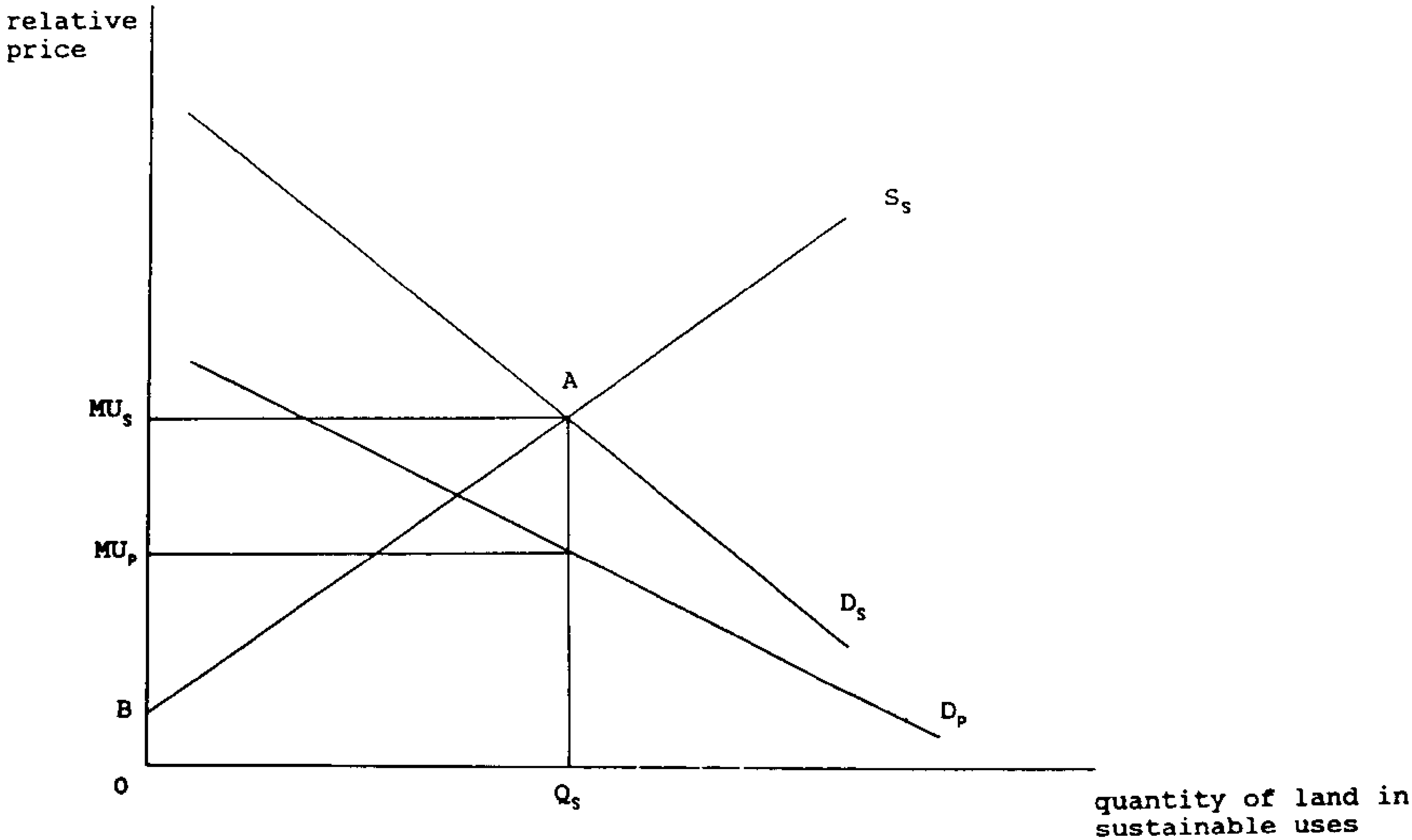


Figure 10. Joint production of lumber and preservation



tively. The marginal valuation of preservation is labeled MU_p. This could, presumably be established by means of a Clarke tax. The marginal valuation of lumber, MU_L, is represented by the vertical distance between MU_s and MU_p. Since the lumber is a private good with no suggestion of any externality, its marginal valuation is revealed by the prices people are willing to pay for it.

The socially optimal quantity of land in sustainable uses is given by Q_s. The purchase price that a prospective owner in fee simple absolute would be willing to pay for each unit of land in a competitive market would be the capitalized value of the periodic flows of the net benefits of ownership. Those net benefits are the revenues from sales of items the land yields plus non-monetary benefits of ownership less the sum of land taxes, maintenance expenses, and the like. In Figure 10, for instance, the net benefit of ownership of the land for the unit of time the diagram covers is represented by the area MU_sAB.

If land in sustainable uses were a pure public good for which the socially optimal quantity to produce were Q_s and the public good were to be provided in that quantity, this sum (the capitalized value of the net benefits) would have to be raised through some collective mechanism such as government. Since it is not a pure public good, part of this sum can be financed internally by using the capitalized value of each time period's operating income from the sale of the lumber. Thus, the tax cost of providing any given quantity of the public good is reduced by the sustainable lumber yield of the land.

A few points should be made at this juncture. First, please note that because lumber and preservation are jointly produced, some quantity of preservation will be produced so long as the price of lumber exceeds its marginal cost at some level of output. Although it is possible to imagine some set of relative prices for lumber and the products of developed land at which no lumber would be produced in a sustainable yield manner, it seems unlikely in the extreme that such a set of prices could ever occur. It would require such high relative prices for the products of developed land that all of the rain forest would be developed, even those areas that are unsuitable for building or farming given the current state of civil engineering and agronomy. Second, please note that any factor that changes the marginal valuation of the lumber also changes the quantity of land that will be devoted to sustainable use, *ceteris paribus*. The greater is the demand for lumber, the greater will be the number of units of land that are forested at any given moment. If, on the other hand, the quantity of lumber demanded at each possible price should fall to zero, then only collectively raised funds will be available to support preservation.

Tropical Hardwood Prices and Rain Forest Preservation

This conclusion runs counter to a recommendation commonly made by people who genuinely desire to see rain forests preserved. The suggestion is that social responsibility lies in abstaining from the consumption of lumber derived from tropical hardwood species. If the demand for the products produced using such lumber disappears, the reasoning goes, so will the motivation to clear rain forest land.

To see why this suggestion is misguided, let us look at the matter from the point of view of the fee simple absolute owner of a unit of rain forest land on which tropical hardwood species are growing or could be grown. Let us assume that wealth maximization is the objective of the owner and ask us how long it will be before the owner cuts the trees down and sells them to a lumber company. Let us assume further, for simplicity, that there are only two forms in which wealth can be held, trees and money in an interest bearing account. In order to maximize wealth, the owner must at all times keep his wealth in whichever form has the higher rate of growth. When the trees are cut down and sold, part of the land owner's wealth has changed form. It has been converted from being in the form of growing trees to the form of money proceeds from the sale.

For the trees, the rate of growth of the owner's wealth is equal to the rate of growth of the lumber value of the trees. That, in turn, is a function of the rate of physical growth of the trees and the price for which the lumber can be sold.[8] It is equal to the sum of the rate of growth of the trees and the rate of growth of the price of lumber. The rate of growth of wealth in the form of money is the after tax nominal rate of return on the interest bearing account.[9] As long as the rate of growth of the lumber value of the trees exceeds the nominal rate of interest, the owner will not harvest the trees. As soon as the nominal rate of interest is above the rate of growth of the lumber value of the trees and is expected to stay above it, the owner will harvest the trees. The harvested trees may well be replaced with seedlings, depending on why the rate of growth of the value of the lumber of the trees has fallen below the nominal interest rate.

The rate of growth of the lumber value of the trees depends on two sets of factors over which the owner has no control in competitive markets. One set of factors has to do with plant biology; the age of the trees, soil and weather conditions, etc. The other set of factors has to do with the market demand for and supply of the lumber. The rate of growth of the lumber value of the trees falls as the trees

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[8]Of course, this would be net of expenses, land taxes, capital gains taxes on the trees, and the like.

[9]Expected inflation would increase the nominal rate of interest, of course, but it would also presumably cause the nominal price of the lumber to rise as well.

age because the growth of the trees themselves slows as the trees age. If a tree is harvested because of its advanced age, it will likely be replaced with a young tree. If the tree is harvested because of low or negative growth of the price of lumber, it very likely will not be replaced because some development use of the land will now offer the prospect of higher returns. Indeed, in the case of low or negative growth of the price of lumber, the trees might even be harvested before maturity or deliberately destroyed in favor of some other use of the land.

Now let us return to our analysis of the effect of the suggestion of some rain forest preservationists that consumers abstain from buying products in which tropical hardwood species are an input. Let us assume that this suggestion falls on uniformly receptive ears. In that case, the demand curve for lumber would shift so far to the left that it would become identical to the price axis. The price of lumber and the value of the growing trees would fall to zero. Indeed, what used to be valuable trees would now be, effectively, weeds with a negative value because the owner of the land would have to bear some opportunity cost to remove them in order to put the land to some alternative use.

The opposite case is that in which the use of tropical hardwood becomes fashionable. Now the demand curve for the lumber would shift to the right and, *ceteris paribus*, the price of the lumber would rise. This will create an incentive to allow existing trees to grow for a longer period and, depending on how high the price gets and whether it is expected to remain at relatively high levels, to remove land from other uses so that it can be planted with tropical hardwood species.

So what would be a more sensible suggestion for those who desire rain forest preservation to make? The fact that the rain forest jointly produces both private and public goods means that there are four sources of preservation:

1. the value of the private goods derived from sustainable uses of the land
2. removal of subsidies[10] for development use of the land
3. private charitable purchase of the public good
4. governmental purchase of the public good

If society as a whole determines, perhaps through the U.N. voting by countries in a Clarke tax format, that the level of private preservation of the rain forest in inadequate, that amount can be augmented by subsidizing the consumption of the private goods derived from sustainable uses of the land, by direct purchase by governments of rain forest land, or by subsidizing private charitable purchase of rain forest land directly or via tax deductions, credits, and the like. What society as a whole cannot do is compel

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[10]Eugene Robinson, "Brazil Angrily Unveils Plan for the Amazon," Washington Post, 7 April 1989, sec. A, p. 1.

the country in which the rain forest land is situated to remove subsidies or other governmental action favoring development use of rain forest land.[11]

Even the measures listed above may not, as a practical matter, be up to the task. The purchase options rely on the government of the country in which the rain forest land is situated to recognize and enforce some land tenure system akin to ownership in fee. Can that government be relied upon to always enforce the property rights of an international quasi-governmental or foreign non-profit owner as against their own citizens? Pressure on the government of such a country to favor its own citizens will be even stronger to the extent that its citizens are seen as poor and oppressed and the foreigners are seen as rich. Moreover, adoption of ownership in fee arrangements does not guarantee that the country in which the rain forest land is situated will not use threats of environmental catastrophe to collect an economic rent from the rest of the world.

Conclusion

As so often proves to be the case, the question of whether some action ought to be taken or not taken by society can be usefully analyzed in terms of economic theory. In the case of the question of whether and how to preserve tropical rain forests, a careful analysis shows that neither

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[11] Ibid.

the arguments of those who would rely exclusively on market forces to preserve the rain forest nor the arguments of those who would impose rules prohibiting the use of rain forest land fare very well. Both arguments fail because there are sets of relative prices at which the measures they imply either fail to preserve the rain forests or do so at a cost in terms of economic welfare that society is unlikely to bear. At the same time, it is extremely unlikely that rain forests would disappear altogether under a regime of competitive markets and ownership in fee.

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