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Oil and gas leasing in Montana : an in-depth look at the process

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OIL AND GAS LEASING

IN MONTANA:

AN IN-DEPTH LOOK AT

THE PROCESS

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The State of Montana holds quarterly auctions for the rights to drill for oil and gas on state land. During the decade that this study encompasses the revenue from these auctions has risen from just over sixty thousand dollars in first quarter 1971 to a high of over fifteen million dollars in second quarter 1980. If the stream of revenues is to be maximized over time, it becomes important to forecast the future revenue from these auctions, given assumptions about certain economic and physical trends.

Using a market approach to distribute leases has three functional characteristics; the generation of revenues, the allocation of a scarce resource, and the provision of information for future decision making. This last function makes it unnecessary for the state to do extensive geological evaluation to determine the value of tracts, provided a *fair* auction process is used, awarding no leases in auctions with less than four bidders.

Several methods of regression analysis are used to analyze the data on successful lease bids. The announcement of large OPEC price hikes triggered increases in lease prices before the price hike actually occured. The effect of these influential observations is reduced using a linear regression technique that is not as responsive to outliers as ordinary least squares.

The equation developed include varibles for the price of oil, interest rates, state and national oil production and current oil field activity. This equation, given certain assumptions about the future, is then used to forecast revenue, and thus aid in long term planning.

One of the striking results of this analysis is that the government need not engage in gathering information about specific tracts. The only information that the government needs is of an economic nature, which is then used to plan the location and timing of future sales in a fashion designed to maximize the present value of the stream of revenues.

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Chapter 1

Introduction

The rapid increases in the price of oil over the last decade has lead to significant changes in the world economy. The structure of the oil industry has also been changing radically over that time, as well as the patterns of national and international trade and political power. These changes have been felt by consumers as well as producers of oil and related goods and services. The owner of the rights to petroleum or coal deposits has seen them grow in value three or four times. The implications of this to a state such as Montana are varied. The State of Montana owns a large number of tracts of land scattered across the state. Thousands of those acres are over potential oil producing deposits. Montana has seen the value of some oil leases increase greatly since the price of oil started to rise in 1972 and since the state leases out the rights to drill and extract oil on State lands, there needs to be some discussion both of the mechanism and the results of the process which allocates those leases.

Once every quarter the Montana Department of State Lands holds an auction to sell leases which confer both the right to explore for oil and gas, and extract it from land that belongs to the state. In general, the lessee is given the exclusive right to explore for, to drill for, to develop, to produce, and to remove and market his share of the production from a lease tract. In rare cases, exploratory leases are let, which restrict the lessee to just exploration. The attraction of these leases is that they tend to be considerably less expensive than full exploration and development leases. However, there is a risk that when the lessee goes to re-negotiate for development and production rights, the lessor will demand an ex-orbitant fee.

The State Lands auctions involve oral bids in which the bidding variable is a cash payment, or "bonus", which must be paid to the government before the lessee's rights may be exercised, i.e. before any exploration or development may begin. These leases extend for a period of ten years or as long as the tract is producing either oil or natural gas. Payments to the State include the original bid price or "bonus payment", a royalty of 13 percent on the value of the crude oil pumped per year, 12 1/2% on all gas produced, and an annual rental of $1.50 per acre. These leases often sell for the minimum bid, which in many cases is $1.50 per acre.

The Department of State Lands is charged with administering the lands under its control in order to maximize "...the advantage to the state". For the purposes of this paper it will be assumed that this mandate includes the maximization of revenue from lands leased for oil and gas exploration and development. To max-imize revenue can be taken as meaning the maximization of revenue across time, that is, the maximization of the present value of current and future sales from state lands. At a macro level, the more oil produced now, the less can be produced in the future. If the price of the particular resource is expected to remain constant or decline over time, the producer will prefer to sell the maximum amount in the earliest time period and thus be able to invest the proceeds elsewhere. If the real price is expected to go up at the same rate as the interest rate, the producer will be indifferent to production now as compared to production in later time periods.

The decision to drill in a particular area is, in reality, a two part process. The first step is deciding to gather information on a particular tract or area, and the second is then deciding to drill in a particular location and applying to The Department to make that tract available for leasing. For the sake of simplicity, both of these steps can be considered as one. The individual tracts are made available for lease by applying to the Department of State Lands. The Department then publishes a list of tracts to be sold at the next auction in The Montana Oil Journal. In this process, the state does not have any real control over the timing of oil and gas development on state lands.

As figure 1-1 shows, there has been considerable variation in the amount of land sold in each quarter over the study period 1971-1981.[1] The quantity of land that is available for lease seems to be very responsive to the desire to drill. If this is true, then a change in the quantity of land demanded for leasing will result in a supply quantity response that will offset to a great degree, the price response that would normally occur. The implication is that supply may be a demand response. If this is the case, then any attempt to maximize long run returns (or net present benefit) is bound to fail; because no amount of planning can influence the actual timing of the leases.

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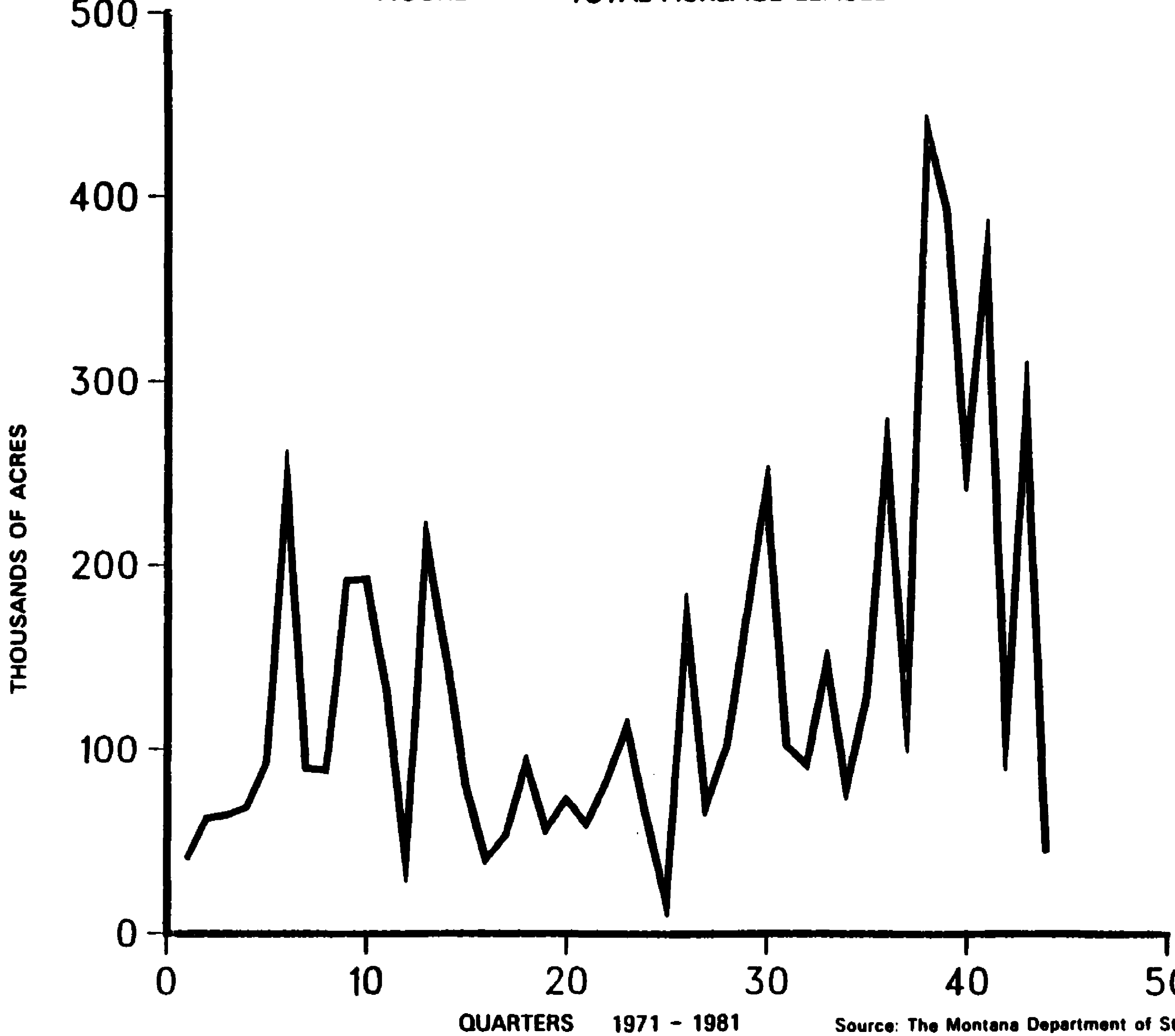
[1]This data is from The Montana Department of State lands which was kind enough to supply the Montana lease data for this study.

FIGURE 1-1: TOTAL ACREAGE LEASED



Source: The Montana Department of State lands

There are three primary objectives to this paper: a brief exploration of the literature, an econometric analysis of current behavior, and a discussion of the policy implications and alternatives. In discussing the current behavior, I will not be attempting to model the process a bidder goes through when deciding to bid on a tract or how much to bid, but rather to identify major influences and use them to project the revenue to the state from the sale of leases. The major issue to be considered is how the state allocates the scarce resource of oil and gas leases. A closely related issue is the criteria to be used in making the choices of how resources are allocated.

Chapter 2

The Petroleum Market

The demand for oil and gas leases is a derived demand, derived from the demand for crude oil, which in turn is derived from the demand for petroleum products. The major demands for petroleum are transportation; to produce gasoline, diesel, or aviation fuels, or as a feedstock for the petrochemical industry; used to produce fertilizers, pesticides, and plastics. Oil leases are purchased by both integrated oil companies as well as companies interested in marketing either crude oil, or producing wells. "Many companies have found it to be much cheaper to buy producing properties than to try to explore for and develop their own" [20,P. 9].

It is important to examine the influence the market for crude oil has on the market for oil and gas leases within Montana. For this reason, the analysis of oil and gas leasing is concerned in part with the price of crude oil. The wellhead price of crude is an important determinant of the lease price, which is evidenced by a strong correlation between oil prices and lease prices.[2] The wellhead price is affected by a number of factors: quality, costs of transportation and refining, and demand and supply conditions to name a few. There are two aspects of crude oil

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[2]A correlation of 0.708 was calculated using the data from The Montana Department of State Lands and the U.S. price for new oil over the study period 1971-1981.

quality which influence its price: the distillate content and the sulphur content. Light crude oils command higher prices than heavier crudes, both because of their higher distillate content and they invariably have a low sulphur content. The sulphur content is important for several reasons; the main ones are lower refining costs, due to the need for less desulfurization, as well as environmental constraints, which may restrict or even prohibit the use of high sulphur fuels. The wellhead price of crude also varies with the location of the well or collection terminal reflecting transportation costs to major markets.

An other influence on the price of oil and gas leases is the cost of bringing the oil to market. If we assume that exploration, development, and marketing of crude oil (within the United States) is a competitive industry,[3] then it is safe to say that producers (within the United States) can not influence the price of crude that they sell to refineries. In 1976, the eight major oil companies had only an estimated 40 percent of the total U.S. domestic oil production, while the number of oil and gas operators in the petroleum industry numbered over 16,000 [20,P. 267]. Competition in the market for an exhaustible resource is characterized by a great number of producers. Each producer can independently decide how much of the resource he will "produce" during each time period. Because the average producer can have no impact on the price, they want to minimize the cost of producing and transporting it to market.

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[3]Ramsey (1980) notes, "The conclusion from th(e) evidence was that the oil industry is at least as competitive as United States manufacturing is on average" [35,P. 153] and "On the demand side (of the lease market), one may usefully assume a competitive market." and this, he goes on to say "...leads to the formulation of a stochastic demand curve...where the expected value of market demand is the familiar quantity demanded/price relationship" [35,P. 153] (Emphasis added).

There are a number of forces which act on the cost of drilling an oil well, which is a factor in defining the oil lease market. The first is a change in the prices of goods and services purchased by the drilling company or operator. This affects all wells in proportion to the amount of those goods and services that are used in drilling them. The depth of a well influence its cost both directly and in- directly. Directly, in that, more powerful drilling rigs, and stronger drilling pipe are required for deep wells; the deeper the well, the longer the time it takes to replace the drill bit and so forth. Indirectly, because there is no reason to suppose that changes in prices will affect different depth wells proportionally. Thus the effects of price increases may not be, and probably are not, depth neutral. In addition, the effects of technological change will act to reduce the per well cost, but again the effects may not be clear. The reduction in cost may not be proportional from one well to another. The cost of an exploratory well is a function of the drilling depth, the success ratio, the average size of discovery per successful wildcat, and the number of wildcats drilled. Because there is no real apriori knowledge of location, depth, or size when drilling an exploratory well, the firm uses geological data to try and approximate that information.

One of the greatest influences on per unit cost, once the well has been drilled, is its productivity. The large onshore wells in the Middle East are some of the most productive in the world. They may flow at a rate of 10,000 barrels per day or more, and produce oil at a cost of about 10 cents per barrel. More moderate wells in areas such as Nigeria may produce 2,000 barrels per day at a cost of around 50 cents per barrel. Small wells, such as those in most parts of the United States have production quantities in the area of 20 to 100 barrels per day and may have to be pumped. The cost from these wells may be $1.00 per barrel. Production from more exotic wells, such as those on the North Slope or from typical offshore oil wells may also cost around $1.00 per barrel, and production from such unfavorable areas as the North Sea may cost $5.00 per barrel or more [23,P. 50].

In that the oil and gas under state lands is a non-renewable resource, the sale of leases to drill for oil and gas is also a non-renewable resource. If the bidder either defaults on the bonus payment, or fails to drill within the required amount of time, the lease may be sold again. However, once the purchaser (or his agent) has drilled, either successfully or unsuccessfully, that particular tract is no longer available to the State for resale. If the State was better able to make projections about future revenues, it would then be able to allocate the sale of tracts across time, additionally it might set a minimum price that better reflected the "cost" of selling a tract in the present as compared to selling it sometime in the future. Another option is to in someway alter the bidding process so that Montana captures a larger portion of the profits associated with oil production on state lands.

Chapter 3

The Theory of Auctions

There are three main roles for a market approach, i.e. the use of an auction process, in the distribution of oil and gas leases. They are the generation of revenues for the seller, the allocation of a scarce resource, and the provision of information for future decisionmaking. In most cases, this last role is considered the most important. The oil and gas industry is inherently an uncertain one. The auction process, when correctly functioning, generates relative prices for different areas, which reduce to some extent the uncertainty about their relative values. The government learns which areas should be given priority in future leasing and bidders learn from their success or failure how they should bid in the future. It is a process that reduces uncertainty over time by generating a stream of prices that are available to everyone.

It should be noted that oil and gas lease tracts are an example of either single items or multiple offerings of heterogeneous items. This is because, with some exceptions, tracts are neither homogeneous in size nor quality. In this context, the word quality generally refers to the likelihood of discovering oil or gas of a quantity and at a depth that would make the development of that tract profitable.

3.1. Bidding

When examining the auction process, it is useful to consider the differences between the two major bidding methods used. In much of the literature, the distinction among bidding procedures is between oral and sealed bids. This is a distinction by method, but not by effects, and as such is not very useful theoretically. A more valuable way to examine bidding procedures is to categorize them as either "competitive" ("standard", or "non-discriminatory"), or "discriminatory".

With competitive bidding, the highest bid wins "...but pays an amount equal to the second highest bid" [35,p. 66] and with discriminatory bidding the highest bidder also wins, but the winner pays the amount of his winning bid. Usually, sealed bidding is done is a discriminatory manner; and oral bidding, in the United States and Great Britain, is done in a competitive manner. However, it is possible for sealed bids to be carried out is a competitive manner and for oral auctions to be discriminatory.

It is important to consider the effects that the different bidding methods can have on the outcome of an auction. Vernon Smith (1967) has shown, for the simple models he examined, assuming each bidder maximizes the expected utility of the outcome of his actions, "...the effective demand curve under the discriminatory auction bidding procedure lay everywhere below the market demand curve..." [35,p. 67]. W. Vickery (1961), assuming profit maximizing behavior and a certain distribution of the value to each bidder of the item being auctioned, concluded that the expected price to the seller was the same under both methods.

From these and other studies, it has become clear that as the number of bidders increases the maximum bid price also increases. However, with a sequence of auctions, this result changes somewhat as the bidders learn from previous auctions. Winning bidders learn that in a discriminatory auction they can continue to win with lower bids and losers learn to raise their bids. However, "...changes in the amount supplied from period to period, or changes in the quality or nature of the object of bidding slow the learning process" [35,p. 68]. Smith (1967) found in repeated experiments where market demand and supply conditions were unknown to the bidders, bidding converged quickly to the experimentally determined market price, even though each bidder knew only his own circumstances and the current bid/offer amount. Wilson (1977) has shown that the maximum bid converges almost surely to the value of the item being auctioned. However, bidders were still assumed to be risk neutral and the bidding process discriminatory.

3.2. Rent

Low cost oil producing areas extract "rent" as the price of oil increases. "Economic rent is defined as the amount by which the price of a good or service could be reduced without motivating its owner to alter the use and employment of the resource" [5,p. 560]. This use of the word "rent" should not be confused with that normally associated with the price of using an apartment or car owned by someone else. Changes in the economy which in some manner either increase the demand for oil, or interrupt supply may lead to price increases that generate "rent" to the owners of the leases (wells). Rent can be thought of as the difference between the value received by producers (reflecting the consumers willingness to pay) and the transfer price,[4] alternatively, "economic rent can be defined as the difference between market price and opportunity cost" [5,p. 563]. Opportunity cost is the value of the resource in its next most profitable use. Payments above the opportunity cost (transfer price) are unnecessary for allocating the resource to a particular use.

Rent in the economic sense must also be distinguished from "quasi-rent". "The payment to any input in temporarily short supply is called a quasi-rent" [26,p. 370]. In the short-run it may seem that a company is making excess profit (or rent) on the production from a particularly rich field, but the company in all probability has drilled a number of "dry holes" in its search for oil. Normal profit must be large enough to cover the expenses of these dry holes as well as induce the company (or industry) to continue exploration. These short run surplus' which appears to be excessive profit or "rent" may be only normal profit or "quasi-rent" when viewed in the long-run. Real rent therefore is those same excess profits, when they continue into the long-run. For example, in fields which were drilled when the price of a barrel of oil was around two dollars per barrel, in the absence of regulation, there is enormous rent accruing to the owners of those wells now that oil sells for around thirty dollars per barrel.

Economic rent is an attractive target for taxation because the tax burden, "cannot be shifted onto others and consequently produces no distortions or excess

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[4]The transfer price is considered the price at which a producer is indifferent to allocating resources to one use or the next best alternative.

burden" [5,p. 563]. The oil severance tax and windfall profits taxes on oil producers are several ways society has for capturing some portion of the rent associated with the sudden upswing in the price of oil in the last decade.

3.3. Risk

The quality of a lease tract can be considered as a combination of the likelihood that there is any oil at all to be found in a particular tract, the quantity of oil to be found, the quality of that oil (BTU and sulfur content), and the depth of the oil. All these factors influence the risk of drilling a productive well. The higher the risk, the lower the potential future profits from a particular lease tract, and the lower the winning bid is apt to be. Ramsey has concluded that "an increase in risk for a given assumed value of the lease will lower the optimal bid price under both discriminatory and competitive bidding methods" [35,p. 81].

One of the levels of distinction which is often made in the theory, which is now practically irrelevant in real world analysis, is between risk, where the probablities of random occurences are assumed to be known, and uncertainty, where those probabilities are assumed to be unknown. In reality, the probabilities of random occurences are very seldom known, except for games, such as poker or roulette. The decision maker, usually, has some idea of the probability function and uses that uncertain information, along with any other data, to estimate the parameters of the probability distribution and thus derive estimates of the probabilities. This differs from the classical risk situation in that the decision maker can learn and thus acquire additional information about the problem or process. No decision making is carried out in pure uncertainty, since the only recommendation that could be made is that all unknown events are equally likely. Not a very useful form of analysis. A further complication is that the underlying probability functions often change from one situation to another, and sometimes from one time period to the next, thus making the learning process more difficult.

Each random process is composed of two components, the stochastic component (or variation) and the deterministic component. The stochastic component may be thought of as the effect produced by factors outside the bidder's control, and the deterministic competent as the direct result of the bidder's actions and decisions. In oil well drilling, the variation in the stochastic component is much larger relative to the deterministic component.

Compare the oil exploration process to the manufacture of high quality watches, where the stochastic variation is (presumably) quite small when compared to the deterministic component. It is this deterministic component that manufacturers are trying to contain with product inspections and quality control. There is no effective way for the entrepreneur to control for the stochastic variation that makes oil and gas drilling such a risky business.

There are two main sources of risk facing potential bidders for oil and gas leases, inherent causes and ignorance. Inherent causes of risk are derived from the physical or economic environment the economic agent (bidder) is operating in. Prices change due to unexplainable shifts in demand, machines that break down randomly and men who fail to show up at work are all examples of inherent risk. Both social and physical activities can be thought of as inherently random processes.

The second main source of risk is ignorance. Ignorance in this context means lack of knowledge on the part of the decision maker. For example, the future price of oil can play an important part in deciding on the price to pay for oil leases. One can be uncertain of the future price of oil, because prices are stochastic, but one can be equally uncertain even if prices are not stochastic. If the OPEC oil ministers are meeting to set the marker price of crude, the bidder is then uncertain about the future price, because he does not know what they will decide. If the uncertainly is due to ignorance, the bidder may be able to eliminate or at least reduce the the risk by obtaining new or better information. The uncertainty of future demand will affect the price of leases as oil firms attempt to maintain an inventory of exploration prospects. Demand in the future may be larger or smaller than it is presently and it has a variance that increases as the time horizon does. However, uncertainty will not directly affect the price of a lease. Pindyck notes that "...demand uncertainty has no effects on the expected behavior of price" [33,p. 124].

In most real world situations, both of these types of risk occur to some extent. Most commonly the "...situation is one in which an economic agent must make a decision where the outcome depends on the value of a random variable and the parameters of that variable's distribution are not known" [19,p. 12].

A decision maker can make investments in three broad risk categories: (1) investments with very little risk about the expected return; (2) investments with a moderate degree of risk, but with neither the expectation of a large loss or a large gain; and (3) those investments with a great deal of risk and the possibility of large losses or large gains. Generally, decision makers can be grouped into either the first category or the third. "[P]eople must in general be paid a premium to induce them to undertake moderate risks instead of subjecting themselves to either small or large risks" [18,p. 284]. We can consider the first group to be risk averse decision makers, and the second to be risk-takers. "The majority of firms in the [oil] industry exhibit significant aversion to risk, but the degree of risk aversion decreases among larger firms". [39,p. 267]

In the discussion of risk, it must be remembered that the level of response to risk are not the same as the level of risk itself. This becomes clearer when you consider that a risk adverse person has a much stronger negative response to the same level of risk, than someone who is either risk neutral or a risk taker.

For risk adverse decision makers, the presence of risk in a project imposes a certain cost. Risk can be viewed as a cost in that the decision maker could achieve a higher level of utility if there was no risk in the situation. Thus, the decision maker faces a choice among several alternatives: bearing the full risk himself, engaging in market transactions to exchange the risk for some commodity, or engaging in various activities to try to reduce the risk. The sale of stocks is a well documented form of risk transfer within the marketplace. The greater the amount of equity stock owned outside the firm, the greater the amount of risk the firm has distributed. Examples of the market transfer of risk are joint ventures, hedging, futures trading and of course insurance. There are two fundamental approaches for dealing with risk: benefit maximization, that is maximizing the benefits if everything goes right, or loss minimization, minimizing the losses if everything goes wrong.

If on average investors are risk averse, "properly functioning markets should confer higher profits on higher-risk firms and industries." [2,p. 304] This may explain the number of bids from small firms which are traditionally considered more risk averse, than larger firms. "[T]he premium required to induce a firms to accept such risks is inversely related to the size of the firm." [39,p. 252] One of the ways for firms to reduce the risk of investments is with a diversified portfolio, either by bidding on a number of small projects, or by the use of joint bidding, which spreads the potential losses over a consortium of firms.

If the risk is inherent in the physical situation, the decision maker may be able to alter the situation in such a fashion as to decrease the risk. The use of mine supports to prevent cave-ins and the use of quality control in manufacturing to reduce defects and the consequent product returns are both examples of reducing risk by changing the physical source of the risk. Insurance companies recognize this and often insist on changes in plant design or operation as a condition for coverage. If the source of the uncertainty is ignorance, then the acquisition of information can reduce that risk, as in the use of geological data to determine locations for wildcat drilling.

It is this last response to risk which explains the use of an auction instead of setting the price of a drilling lease on a particular tract. The question of why the owner of a resource will sell it at auction and not by setting a price, is answered in one word, ignorance. In this situation, the owner does not know the market price of the "item" up for sale and the cost of acquiring that information may be quite large. The use of the auction is a method by which the seller reduces his risk. There are essentially three alternatives to the seller who does not know the relevant demand curve he faces: he can acquire costly information about demand, he can set a price and bear the "waiting cost" until the good is sold, he can set a quantity and bear the cost of an uncertain price. There are substantial costs in determining the market value of an oil/gas tract, and while it is also true that there are costs of carrying out an auction, these costs probably will in no way approach those of acquiring the necessary market information to sell an oil and gas lease.

The distinction between an auction and just setting a price is that in the former the seller sets the quantity to be sold and is uncertain about the price at which the market will clear, and in the latter the seller sets the price and is uncertain about the quantity at which the market will clear. If there were was no uncertainty about the demand function, then the seller could choose to either quote a price and sell the desired quantity, or offer a quantity and accept those price offers at known demand prices. In either case, the result would be the same.

It is for these reasons that the auction process is superior to setting fixed prices. when the market price of a commodity is unknown, and an auction is a less costly way of reducing risk due to ignorance than acquiring information or waiting time costs, economic theory suggests that it should be used.

3.4. The Auction Market

While these lease auctions often involve a "large" number of people, from which some might infer a competitive process, oral bidding tends to understate the maximum value that bidders are willing to pay. Many similar auctions now take the form of sealed bid auctions. In this situation, there is no (or certainly much less) possibility of interaction among the bidders. "[T]heory predicts that collusive conduct is more likely to occur when... the number of firms in an industry is small". [17,p. 21]. This is because as the industry becomes larger it is both harder to coordinate the actions of the firms and because cost and demand conditions will vary among the firms which tends to reduce the incentive for collusion. A sealed bid auction would reduce the possiblity of collusion since the ability to explicitly collude beforehand would be significantly reduced by the sheer numbers involved. If a bidder wants to drill on a particular tract, there is no effective way for him to find out what the other potential participants are willing to pay for that tract. In this case, the only effective strategy is to bid the maximum amount the lease is worth, taking into account the risk of a dry hole, the anticipated costs of the project, and the potential for changes in the price of oil over the lifetime of the project.

The number of bidders also plays an important part in the results of the auction using either the discriminatory or competitive bidding scheme. Given the assumptions that each bidder has market information about the conditions that he faces, but no information about specific competitors, and that the bidder does not know how many competitors he has, Ramsey concludes "...the maximum expected...bid increases with...the number of bidders, despite the fact that each individual bidder lowers his optimal bid" [35,p. 94]. He also assumes that there is a single seller of a single good, (e.g. the State of Montana selling oil leases), that each bidder has the same access to information and that bidder react to the aggregate behavior of their competitors, not to individual ones.

Probably the most important question to be asked in this section is which of the two bidding procedures, discriminatory or competitive, yields the largest expected return to the producer. The answer is not a simple one since the results are affected by the number of bidders, their risk aversion, and their wealth. In general, one can say that discriminatory bidding will yield the greater return for small numbers of low risk averse, large-wealth bidders, and the competitive bidding procedure will yield the greater return for large numbers of low wealth, highly risk averse bidders. When we speak of "small numbers" of bidders, ten is generally considered the cutoff point [35,p. 96]. This is a number that is generally exceeded is Montana auctions. As to the question of whether the bidders are risk adverse or not and whether they are wealthly requires additional research.

3.5. The Long Term

There are three elements of the marginal, or incremental cost of oil left in the ground. They are the expected revenue, the discount rate, and the period of discount. The discount rate and the period of discount are tied together, because at any given discount rate there is a time period, beyond which any reasonable sum is discounted to a very small number or for the sake of analysis effectively to zero. The lower the discount rate, the more activity is moved into the future. If one assumes an interest rate and price structure of future increases such that a barrel of crude oil ten years from now is worth (in discounted dollars) the same as a barrel of current production (ceteris paribus), the decision to produce now or ten years hence is not a question that economics is capable of answering. It goes from being a question of efficiency to one of allocation. It does not seem legitimate to consider the opportunity cost of capital as the social discount rate (or social time preference), when "licensing" the production of an exhaustible resource. They are the same only under conditions of perfect capital markets, and a common perception of the future. That is, should that oil be used now, or should it be "allocated" to the future. A question that is beyond the scope of this paper.

Given the long-term nature of oil and gas development, the bidder has an enormous incentive to forecast the price of energy as accurately as possible. If future energy prices are overestimated, the firm will invest too much and realize a lower rate of return than if it had invested elsewhere. If, on the other hand, future energy prices are underestimated the firm will invest too little and end up foregoing profits. It is equally true that the state has the same incentive. The more accurate the state's forecast, the greater the likelihood that the leases can be properly allocated across time, and thus maximize present net value.

According to the theory, the price of oil leases is a function of a large number of economic variables, and therefore does not vary perfectly with the price of crude oil. Interest rates for investment capital, the amount of low cost crude being imported, the number of rotary rigs available for drilling, changes in U.S. oil production, and probably most important the location of the lease, all affect its selling price. If the price of crude rises and the new price is expected to persist, what happens? The number of wildcats drilled will be higher than if the old price had been maintained, and areas that were considered attractive under the old price will be come even more attractive, and areas that were only marginally attractive under the old price will now be considered worth drilling. These areas are marginal because of the perception that they are poorer prospects. If this perception is approximately correct, it follows in aggregate, that either the success rate will be lower, the drilling depth deeper, or the average find smaller. All of these are elements of total cost, and any one of these will serve to raise the average cost per barrel found, thus behaving in an offsetting manner. While the price is up, there is a strong incentive to drill poorer prospects, but the higher per barrel cost of these prospects acts in the opposite direction. It is also true that if the price of oil falls instead of rises, the reverse will occur as marginal tracts are cut from the list of drilling prospects.

3.6. Bidding Alternatives

In the leasing of state lands, the goal of government can be defined as the maximization of net present benefit from the bonus payments, and the royalty payments. This requires that the planning horizon be long enough for all present oil reserves to be utilized. It is, however, impossible to make realistic long-run projections of supply and demand conditions. Additionally, the consequences of an extended time period and the discount rate diminishes the effect of these distant changes to insignificance. The present value of net oil revenue from the sale of oil and gas during the relevant time period is given by:

$$PNV=\sum_{t=1}^{T} 1/(1+r)^{t}*(P_t-C_t)D_t$$

where T is the planning horizon, P_t-C_t is the net revenue per barrel in year t, and r is the discount rate and D_t is the production in year t. The interest rate is an important factor in the calculation of present new value. The higher the interest rate (or discount rate) the lower present net value is. The use of a simple discount approach to calculate net present value, or the internal rate of return can be used as a policy tool to determine the best timing of the sale of leases on State lands, given a particular view of the future.

From a broader, i.e. national, perspective, things do not have quite the same appearance. In 1980, imports of petroleum constituted over 40 percent of U.S. supply, and at then current price levels, it meant that we were spending over $90 billion annually for oil [35,p. xvi]. The amount of dollars that were being exported every week had a profound effect on the American economy. There are a number of possible remedies; encourage conservation, develop alternative energy sources and/or increase domestic production of oil and gas. This last policy option may conflict with the desires of the various states to draw out the production of oil and gas over time, in order to better utilize the resource.

Once the timing of the oil and gas development on state lands is determined, there are a number of bidding variables that can be used to allocate the oil and gas leases. They can be used as alternatives to one another or in combination.

TABLE 3-1:

COMPETITVE LEASE BIDDING MODELS AND OBJECT OF BIDDING

Oil and Gas leases, Federal and Active State Governments

	Bidding Method		Object of Bidding		
	Oral Auction	Sealed Bid	Bonus	Royalty	Rent
FEDERAL GOVERNMENT					
BLM		X	X		
STATE GOVERNMENT					
Alabama		X	X	X	X
Arkana	X		X		
California		X	X	X	
Colorado	X(1)	X(1)	X		
Florida			X	X	
Illinois			X	X	X
Kansas		X	X	X	X
Louisana		X	X	X	
Montana	X		X		
Nebraska	X		X		
New Mexico	X	X	X		
North Dakota	X		X		
Oklahoma		X	X		
Pennsylvania					
Exploratory lease		X	X		
Development lease		X		X	
Texas					
University Lands	X		X		
General land office		X	X		
Utah		X	X		

NOTES:
(1)Colorado accepts sealed bid offers of ten dollars per acres bonus or more If less than this amount is received by sealed bids, or none at all, the tract is offered in oral auction.

The problem of introducing more than one into the negotiations and/or auction is that the State has then to decide at what rate to trade one item for another. For example, if one bid is the highest for the bonus payment but not for royalties, and another is the highest for royalties but not for the bonus payment, who wins the bid? The State would have to develop a scheme to weigh the various items in a bid in order to determine the winning bid. However, if the weights are revealed the winner is the one with the comparative advantage in those areas most heavily weighted, if the weights are not revealed, the uncertainty of winning the bid, already implicit within the auction, will be increased, and such an increase may lower the amounts bid in the auction. The most common bidding variables are bonus payments, rent, royalty payments, exploration expenditures, "service" leases, and percentage rate of net return. Table 3-1 shows the bidding alternatives used by various governmental bodies in the U.S.

A bonus payment is a sum of money paid by the bidder to purchase the lease. With bonus payments the purchaser bears all the risk of the activity and the seller none.

In a royalty bid auction, the buyer bids on the amount to be paid on production. The units bid in may be payments per physical unit produced or it may be an *ad valorem* arrangement, i.e. a percentage of the value of production. As the price of oil has risen, the tendency is toward the *ad valorem* approach. For example, the traditional royalty in the Middle East before World War II was 4 shillings per ton. In 1971, the royalty was calculated at 15 percent of the posted price per barrel [40,p. 51]. There may also be a sliding scale used to calculate the amount of the royalty. In this instance, the percentage varies with output. This was the type of system that Montana had until March of 1983. Royalty percentages were not a bidding variable, but rather were fixed at 12 1/2 percent for the first 3,000 barrels produced per year, 17 1/2 percent for the next 3,000 barrels per year, and 25 percent for any production over 6,000 barrels per year. If the *ad valorem* approach is used, the seller of the lease bears some risk due to the potential for changes in future oil prices.

A combination of bonus and royalties enables the seller to bear a portion of the upside risk that the buyer would be bearing in a bonus bid only situation. The seller has no risk of receiving less than the bonus payment, but is trading a higher bonus payment for the prospect of sharing in the returns of a successful discovery.

Percentage profit bids are bids on the percentage of net annual return to be paid to the seller. While, this procedure lowers the cost on entry and encourages high risk leases, it generally involves higher "upside" risk for the seller than other methods. This procedure is different from the royalty procedure in that it is based on net return, i.e. after costs are subtracted from gross return. In fact, one of the drawbacks of this methods is defining costs, in particular, whether market return on equity capital should be treated as a cost. There has been some discussion in the literature that a major drawback of this method is that there is less incentive for the firms to minimize its costs of operation [25,p. 789]. Ramsey, however, has proven that this is not the case in a competitive environment. "The incentive to minimize cost and improve efficiency will be neither greater than nor less than for any other firm earing a competitive rate of return" [25,p. 127]. It should be noted that using percentage profit as a bidding variable is rare.

Another item that may be bid on is rent, the rate to be paid for holding the lease per unit of time. Rent has come to mean an advance payment for the privilege of postponing the drilling of wells on the leased tracts, and should not be confused with payments covering the use of the surface area of the land or with the concept of economic rent that was discussed earlier. The rental payments act as an incentive to the lessee to either start drilling as soon as possible or surrender the lease. Some of the risk is transferred to the seller in that there is a real possibility that the lease will remain undrilled and be subsequently returned to the seller. If a tract has been returned, bidders will most likely view it as more risky, since the perception is that any lease that has been surrendered is unlikely to be profitable.

Another procedure, one that is popular with the governments of Great Britain and Norway is the shared interest system. If the firm finds a commercially profitable amount of oil/gas, then the government is assigned a share in the venture both in costs and profits. In this scheme the seller bears some of the "upside" risk, with regard to the quality, quantity, and future price of oil found, but bears no "downside" risk if none is found. This is clearly an arrangement that only a national government could negotiate.

The effects of different bidding variables on present net worth are highly dependent on the timing of payments. In general, it can be said that the later the payment to the state, the less will be the influence on the bidders present net value. Conversely, the earlier the payment, the better it is from the State's point of view. The following observations can be made about the effects of differing payments on the present value calculations.

1. An initial bonus payment is a highly negative weight on the present net value of the bidder. If this payment must be made immediately, then it is accounted for at full value, because there is no discounting in the current time period. The later the bonus can be paid, the better off is the bidder and worse off is the State.

2. Annual rent payments have less of an impact that the bonus payment does, and its impact diminishes over time, due to the discounting process.

3. Royalties differ from both bonus payments and fixed rent payments in that bonuses and rents have to be paid from the time the lease is granted, but royalties are not paid until production starts. On the other hand, production in a lot of areas is much higher in the first few years and more royalties must then be paid. If the royalty is calculated on a sliding scale, then there is virtually no influence on small scale production but there may a substantial influence on large scale production, the degree of which will depend on the negotiated arrangement.

The possible methods for maximizing the state's percentage of the "rent" (in the economic sense) are bonus payments, surface rent, royalties, and taxes. Each has differing effects as mentioned above.

The average influence of the bonus on the present net value to the bidder has already be mentioned. The effect of this to reduce the amount of marginal land that will be drilled. The imposition of large bonus payments is not an efficient method for maximizing public revenue.

Similarly, high surface rents cut into marginal fields, while profitable fields do not contribute proportionally to public revenue. This is also viewed as an inefficient method for maximizing public revenue.

Another possiblity is the corporate income tax. Its effects depend on the use of the depletion allowance. The depletion allowance is in effect "a subsidy, administered through the corporate income tax, for the benefit of petroleum producers" [40,p. 123]. The inclusion of the depletion allowance makes the corporate income tax a less than perfect method for maximizing public revenue, because a large part of the rent is "returned" in the form of the depletion allowance. The corporate tax *without* the depletion allowance is "...a good medium for generating government proceeds as long as the tax rate is not excessively high" [40,p. 123]. If the tax rate is too high, the amount of reserves that can be economically recovered, will fall rapidly.

The fixed rate royalty, i.e. the royalty expressed as a fixed percentage of the unit price of oil, will have less impact on the economically recoverable reserves than any of the before mentioned options. However, it will still have some impact on the amount of economically recoverable reserves, and the higher the royalty percentage, the greater the impact will be. Sliding scale royalties can be used to mitigate a large portion of that impact. Highly productive fields would pay greater royalty percentages, and less productive fields would pay lower or no royalties at all. The state would still not be receiving the maximum public revenue, but the sliding scale would achieve this better than the fixed rate royalty.

It can be seen from this discussion that to maximize public revenue from state lands, the greatest weight should be placed on the use of the corporate income tax (without the depletion allowance) and sliding scale royalties. This is not to say that surface rents and bonus payments should be done away with. They reduce the risk of zero income, and provide an incentive to the purchasers to drill as soon as possible. This becomes increasingly important if the state is to time the development of land that it owns.

The timing of the release of tracts of land for auction and subsequent exploration and development is of great importance to the state. As it now stands, if there is an increase in the price of oil likely within the next few years, the state does not have the ability to defer the leasing of tracts, until the time when they will bring a higher price, and thus more revenue to the state. In fact, the whole concept of discounting and present net value computations for determining the optimum release of tracts over time is worthless if bidders can apply for and bid on tracts of their choice. One of the most important changes the State should undertake is to develop a long term plan to control the release of land for oil and gas development.

3.7. Lease Tract Information

The process of bidding at auction is a device to reduce the amount of information the lessor has to have about the property to be leased. In fact, in simple cases, the only information the lessor needs to know is that the market demand (bidding) is competitive, and that the tracts are in fact available for leasing.

From the buyer's point of view, there is fairly common agreement about what information is relevant for the bidding process. There is an active market in such information, and in addition to this geological and geophysical information there is other information that each firm wishes to acquire about potential lease tracts.

This information is specific to the firm, and includes not only data that the firm consider relevant and, consequentially, specializes in, but also the interpretation of that data reflecting the firms wealth (net worth), geographic concentration, and risk aversion. There are many firms which specialize in the gathering and processing of geophysical information, but are not the business of developing leases themselves.

It was noted earlier that a reduction in the risk of a project will increase the expected bonus payment received by the seller. So it can be concluded that "...under *competitive* conditions, the seller, not the buyers, gains from an increase in information...provided it is available to all parties" [35,p. 141]. Thus, from the lessors' point of view the value of additional information which is available to all potential participants in the auction is the amount of the increase in the expected value of the bonus payments received.

On the other hand, the information produced by or in the hands of a individual firm is of value only if it is not in the hands of other firms that are competing for a particular tract. The value of that information is the difference between the bonus payment that would have been made had everyone had the same information, and the payment the firm actually makes. This scenario is complicated when bidder A has information not available to others, but they know that A has the information, and further know that A knows that they know. This kind of theoretical asymmetrical information problem is often analyzed using game theory, simulations or other techniques.

These situations are interesting to consider, but often the assumptions are so restrictive or the analysis is not carried far enough to provide real world answers to questions that arise during a discussion of bidding strategies and the effects of different auction processes.

Some lessors (or their agents) worry about the lack of information they have on the value of the leases (or tracts) to be auctioned. In reality, it is more important that the lessors know that the bidders are not acting collusively, and to know the optimal pattern of leasing, both geographically and over time. Other lessors worry about the effect of large bids for lease tracts. Saying in effect, that if firms must pay enormous amounts for leases, they will not be able to afford the costs of exploration and development, or that large bids will force out the smaller firms and thus reduce competition in the industry. While at first this may appear to be sound, in fact bonus bids are large because the firms expect to earn large returns from the lease accounting for the costs of exploration and development. If the bids do become large, small firms can participate in joint ventures with other firms large or small.

Despite the previous discussion, one might consider that the owner of a scarce non-renewable resource, like a series of oil bearing lands, needs some information in order to answer the two key questions that face any non-renewable resource owner; what is the optimal rate of offering, and what is the optimal geographical distribution of the offering to be?

The details of this decision-making process will not be taken up here, but that information which is necessary for those decisions should be mentioned briefly. As has been discussed earlier, detailed geological and geophysical data is of great use to the firms, but even if such information were available at no cost to the lessor, the "...benefit to him would be quite small" [35,p. 148]. The bidder is the one that needs that detailed information. All the lease owner needs to know is what subjective evaluation those bidders are placing on the lease area, and this information is most efficiently learned through the bidding process. The information which the owner needs then is economic in nature, that information which will enable him to forecast the expected price for leases.

If the average number of bidders per bidding tract is "too small", then the number of tracts being let is probably too large. If the number of bidders per offered tract is very "large", then the number of tracts being let is probably too small. Ramsey defines "too small" as fewer than three or four bidders on a lease tract. "If the number is in excess of fifteen to twenty per lease, the rate (of offering) is probably too slow" [35,p. 150]. He says the "...rational for the[se]...numbers is that the lower bound indicates a "minimum" number of bids for the seller to be able to ensure a competitive return" [35,p. 150]. Earlier, it was noted that the expected return increases with the number of bidders, it should be mentioned here that this increase diminishes very fast, and three or four bidders should be considered as a minimum. Below that number no bids should be accepted on a particular tract. The upper limit, that is when the number of bidders is large, is suggested "as a first approximation at indicating a situation in which the rate of lease offerings is slower than the long-run demand..." [35,p. 150].

As was mentioned earlier, the demand for leases is a derived demand and grows of a desire by producers to maintain an portfolio of lease areas for future production. This demand depends on the expected rate of future exploration, and if the market is not in equilibrium, on the surplus or deficit inventories of exploration tracts held by firms. These inventories of lease tracts vary with oil prices, interest rates, lease prices, present and expected future input prices, which affect production rates and upon various technological and economic factors, which determine the rate at which lease areas can be brought into production. The optimum rate of leasing depends on the demand function that the lessor faces. Ramsey maintains that changes in the Federal governments lease offerings over the intermediate to long run would have "...little effect on demand price; that is, the lease market is competitive on the supply side" [35,p. 147]. If this is true at the Federal level, we can safely conclude that it is also true for Montana. Thus, a reduction in lease offerings will not substantially affect the expected market price for leases, and the complaint that fewer lease offerings will drive up the cost of exploration is clearly not valid and can be dismissed from further consideration (economic consideration at any rate) when planning the timing of the release of tracts for leasing.

3.8. An Optimal Lease Procedure

Throughout this discussion, I have mentioned the effects of different variables on the leasing process; as well as the informational requirements of both the lessor and the lessees. Without repeating that discussion, there are several recommendations for an "optimal" leasing policy.

The bidding firms have an interest in obtaining information about specific tracts to be leased, while informational needs of the seller are minimal. It is in the lessor's best interest to see that the firms can acquire the information they consider necessary. It is also in the sellers interest to see that this information is symmetrically available, that is, each bidder has equal access to the information that they feel they need. Note that this does not require that firms have the same amount or type of information only that there is non-discrimination in the access to information. This implies that tracts to be leased need to be announced with enough lead time to allow all (or most) firms the time to survey tracts before submitting a bid, and that the tracts should be offered at regular intervals so firms can make efficient inventory decisions.

The geographic dispersion of the tracts should be determined by the demand for them. However, the seller should try to make a lease offering as homogeneous as possible. This is to equate the "marginal exploration cost", i.e. the cost of acquiring information about a particular lease, for all tracts being offered at one auction. This helps maintain the probability of any one tract receiving a bid the same as the probability of any other tract receiving a bid. By preventing bidders from allocating all their resources to tracts, which are clearly in prime areas; they are encouraged to gather information about, and bid on the unknown speculative areas. The quality of tracts can be varied from sale to sale as desired. The long term timing of the lease sales should be based on expected demand for lease tracts in the future and their expected price per acre. This can be modeled using the approach to be discussed in the statistical chapter.

If Ramsey's rule of not accepting bids on tracts with less than four bidders is followed, then the seller need not establish a minimum or reservation price. Those ares receiving less than four bids are merely offered again at sometime in the future. Just because a tract received less than the minimum number of bidders does not suggest that it is less valuable than others that received more, perhaps only two bidders had what they considered adequate information to bid. A study done in 1969, has shown that re-issued tracts have same probability of receiving a given number of bids as first time tracts, and "...the amounts will be the same on average as ...equivalent tracts" [35,p. 155].

The bidding should be on a bonus amount with a given fixed royalty, but the royalty levels should be a negotiable item between the seller and all the bidders, before the bidding begins. This allows the bidders to determine their optimal trade-off between risk assumption and expected return. With the royalty payment fixed the lessor accepts a portion of the risk. A net-worth maximizing seller could set a royalty which maximizes the total discounted, expect return.

Chapter 4

Statistical Analysis

4.1. Modeling Theory

Many models are chosen with regard to the underlying mechanisms of the system. However, when the system is too complex, the analyst lacks understanding of it, or the necessary data is unavailable, an "empirical" or statistical model is developed to approximate the data, rather than describe the underlying relationships. Statistical models are used to approximate systems that are so complex that relevant information about the system can only be statistical in nature and typically the model is a distinct simplification of the system it is modelling. The task is complicated by the fact that the analysis is not aimed at constructing a complete theory of the system, and thus there can be a number of plausible models for any given economic phenomenon.

A statistical model is a model that expresses outputs in terms of probabilities. "Thus, a statistical model is used in those cases where the output cannot be expressed as a fixed function of the input variables [38,pg. 4]. Tests are usually performed to assess whether the output from the model yields reasonable inferences.

Models of broad economic systems generally include a whole network of relationships, which approximate the interrelationships in the economic structure.

The single equation model is appropriate when there is no interdependence among the the variables included in the model. "Because there are usually two more endogenous variables in each relation, it is impossible to specify which endogenous variable is the dependent one" [22,pg. 22]. In this study, the oil market in Montana is assumed to be determined by the national and international markets, and all of the variables are external (exogenous) to the model, which allows us to use the single equation type of model.

Another major consideration in formulating a model is its complexity. It can be argued that economic systems are themselves very complex and so the models used to describe them should also be very complex. In general, however, the goal of the model is to generate reasonable, accurate predictions without large amounts of data collection or computation time. Often this can be accomplished with a less complex (or more parsimonious) model.

A model of individual bids would include many variables, such as interest rates, oil prices, the bidder's wealth, tract location (and other geophysical information), exploration costs (which are site specific), availability of markets, number of bidders, etc. However, when modeling the market, a number of those variables are too specific, and others are unnecessary.

4.2. Analysis

Typically, the goal of a study such as this would be to develop a model predicting the future price per acre of lease tracts. However, since the bidders can change the acreage for sale by requesting that lands be put up for bidding, this creates a series specification problem and it is difficult to isolate the effects of changes in economic conditions on price alone, i.e. if the quantity supplied is determined by the buyers it is difficult to accurately estimate the demand response to changes in market conditions, and using some measure of average price would tend to underestimate the influence of the important economic variables.

In terms of the problem being examined in the paper, it is also unnecessary, because the implications to the state of changes in the petroleum market revolve around changes in total revenue from lease sales and not average per acre price. Figures 4-1 and 4-2 show two examples of extremes in market response to changes in demand. In figure 4-1 any increase in demand is taken up by an increase in quantity supplied. In this case there is no change in the price level. In figure 4-2, there is no change in the quantity supplied and any change must occur entirely in price. Contrast these with a more typical situation, in figure 4-3, in which there is both a price and a quantity response to changes in demand.

Given that both price and quantity change simultaneously, a composite variable, TOTREV, the total revenue received by the state from the sale was analysed. Since this is the number that would be used in analysising the impact of alternative leasing schemes, it is a reasonable choice. Figure 4-4 and table 4-1 show the movement in leasing revenue over the period of study, 1971-1981.

By making this change in the predicted (dependent) variable, the accuracy of the model, i.e. the R^2, was improved significantly. This seems to occur for two reasons. First, since both the price and quantity of land for lease can be varied in response to changing economic conditions in the oil and gas industry, it would be

FIGURE 4-1:
ELASTIC SUPPLY

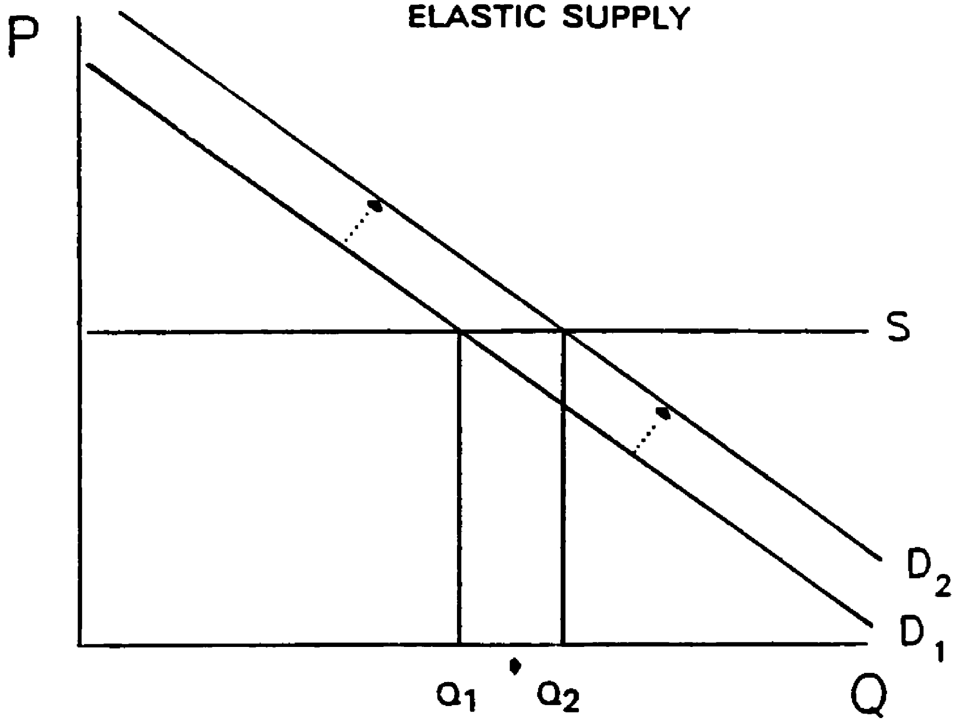
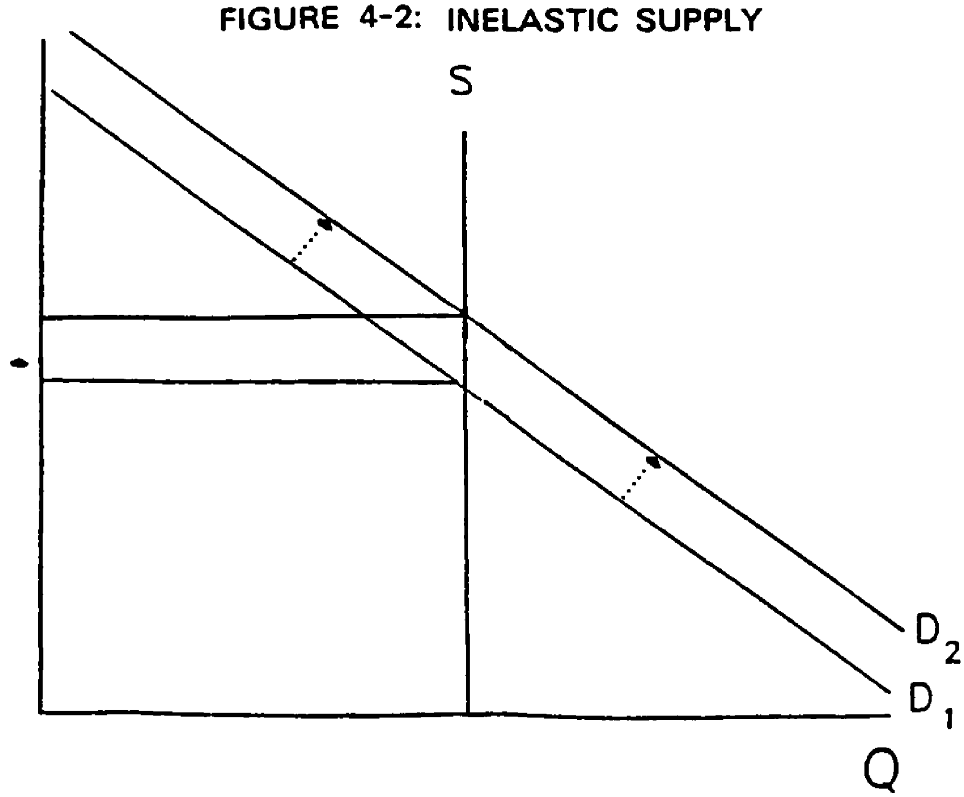
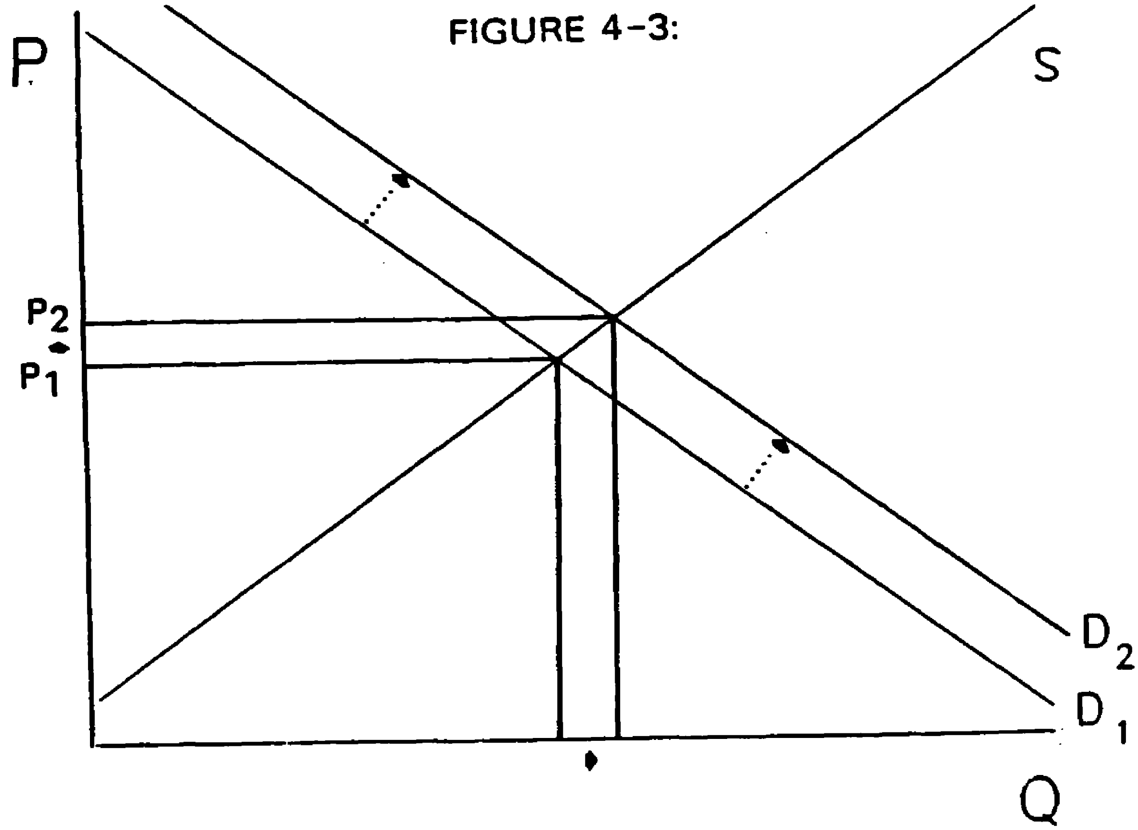


FIGURE 4-2: INELASTIC SUPPLY



MODERATELY ELASTIC SUPPLY

FIGURE 4-3:



a good strategy for a bidder to spend the same amount of money for a larger tract of land, which serves to reduce the variability in price as mentioned above. Secondly, the minimum bid of $1.50 per acre acts as a floor on the price of many of the tracts. This also acts to reduce the variability in the lease price.

4.3. Methodology and Statistical Model

An attempt was made to use lagged variables to produce a model that could be used for prediction using current data. However, when using even a two quarter lag many of the variables that the theory suggests should be important were in fact insignificant and the fit of the model was so poor that this approach was abandoned. The best approach seems to be a model that uses concurrent in-

FIGURE 4-4: TOTAL REVENUE

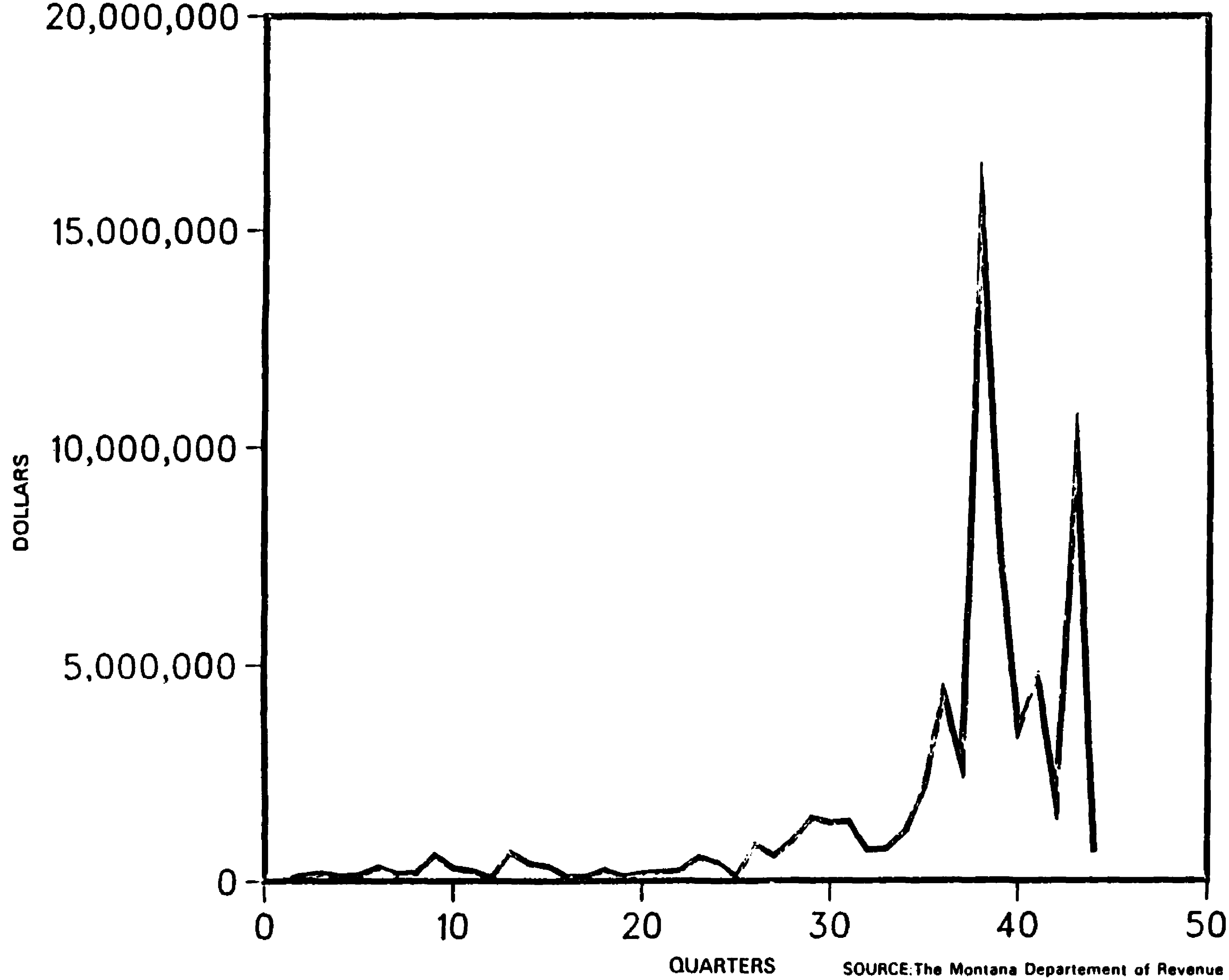


TABLE 4-1:

AVERAGE PRICE PER ACRE OF A LEASE TRACT AND TOTAL REVENUE FROM SALE BY QUARTER

YEAR	QUARTER	AVERAGE PRICE	TOTAL REVENUE
1971	1	1.50	60459.8
1971	2	2.13	132272.9
1971	3	2.96	189232.8
1971	4	1.58	107361.6
1972	1	1.58	144868.5
1972	2	1.35	330337.9
1972	3	1.80	159914.0
1972	4	2.16	189844.6
1973	1	3.21	614498.5
1973	2	1.57	301139.6
1973	3	1.74	230372.4
1973	4	2.06	84057.6
1974	1	3.17	674527.9
1974	2	2.75	415876.6
1974	3	4.32	345238.2
1974	4	2.59	103456.0
1975	1	2.08	110434.6
1975	2	2.88	264897.6
1975	3	1.85	104200.0
1975	4	2.64	190544.3
1976	1	3.63	214257.1
1976	2	2.93	240646.4
1976	3	4.97	556279.7
1976	4	6.63	417151.9
1977	1	5.92	101024.3
1977	2	4.97	847796.8
1977	3	8.54	591244.3
1977	4	9.33	946409.3
1978	1	8.47	1462940.0
1978	2	5.55	1349452.0
1978	3	13.58	1373948.0
1978	4	7.82	714239.0
1979	1	5.13	751542.3
1979	2	14.53	1148718.0
1979	3	16.80	2158898.0
1979	4	16.48	4354938.0
1980	1	22.58	2714208.0
1980	2	35.70	15538688.0
1980	3	19.14	7519995.0
1980	4	13.88	3528867.0
1981	1	12.64	4676348.0
1981	2	16.93	1888446.0
1981	3	34.28	9857650.0
1981	4	15.45	682572.3

formation. That is, in order to predict TOTREV, the total revenue from a sale of oil and leases, at some point in the future, the user must pick likely values for the variables in the model. While this leaves the burden of choosing those values on the users of the model, it also makes for a much more internally accurate model, that more precisely pins down the relationships between total revenue and the other variables. There are a number of large econometric models that can be used to forecast economic variables such as interest rates, or oil prices and certainly no lack of predictions. These are all complex modeling problems and beyond the scope of this project. The final model which is discussed below, will allow the user to take certain projected economic variables or make some assumptions about the future level of those variables and see what the likely effects will be on the total revenue from the sale of lease tracts. It is this aspect of the model that will be the most useful from a planning point of view. The planner or policymaker can then project a likely path of total revenue over a given period of time with an eye toward maximizing the revenue to the state, i.e. the discounted value of the stream of revenues through time.

Two different analysis approaches were used to determine the best model. Ordinary least squares regression was used to derive a number of equations under different conditions and least absolute deviations regression was also used.

A technique call "bootstrapping" was used to account for the possibility non-random error terms in the regression and to check the coefficients for bias. The bootstrap measure is a nonparametric estimate of the accuracy of the statistic being estimated. The statistic b (any statistic) is calculated a large number of times, and the width of the interval that contains 68% of the distribution centered at the mean is the bootstrap measure of accuracy. Simply put, the bootstrap is done by copying the data a large number of times, randomizing it and then samples of the same size as the original data set are repeatedly draw from the new data set. This is equivalent to drawing N observations from a sample of N, *with replacement,* and amounts to resampling the data space. These samples are called bootstrap samples. In this case, a regression is then run on these samples and the results are compared using a frequency distribution and a bootstrap statistic. Next the bootstrap form of the statistic in question is calculated, which is the mean of the statistics calculated from the each of the bootstrap sample sets. This allows us to estimate the bias of the numbers generated in the original regression. The fluctuations in the estimated parameters from the regression of the bootstrap data sets show the variability of the statistical estimators for this set of data.

There are other means of estimating the the bias and variance of a statistic, among them are the jackknife and cross-validation. Efron [11], [12], [13], and [14] has shown that the bootstrap out performs both of these methods. The bootstrap is a very robust statistic, and it is not apt to be highly influenced by a few influential observations.

4.4. Data

The data on oil lease sales is collected quarterly by The Department of State Lands, and it includes information on the location of the tract sold, the county it is in, its size, the price per acre of the winning bid and the name of the buyer.[5] The data was collected by county with the intention that they would act as a geographic variable to help explain the quality of a tract, i.e. the likelihood that oil would be found there. While there are some counties that appear more likely to have oil than others, there was no relationship that could be statistically determined. Furthermore, no relationship seemed to exist between the amount of oil that was currently being pumped in a particular county and the total revenue accounted for by that county in the lease auction. There may be two possible reasons for this; first, and probably most important, in the high production counties it is likely that most of the state land available for lease has already been leased and explored. Secondly, the known oil pools are not delineated by county lines. Thus, a pool could lie in a portion of the county and produce a large amount of oil, but tracts in another part of the county which are still available for lease are perceived has having a higher risk associated with them and thus would not be bid as high as others. This is a consequence of aggregating the leases into counties. If the tracts could be identified with a known pool or reservoir, perhaps this type of geographic variable could act as a proxy for the quality of the tract.

The variables included in the model are the price of oil, the interest rate, and a measure of U.S. oil production.

The marginal price of oil represents the average price for newly found oil in the continental United States, and does not represent the actual contract price that

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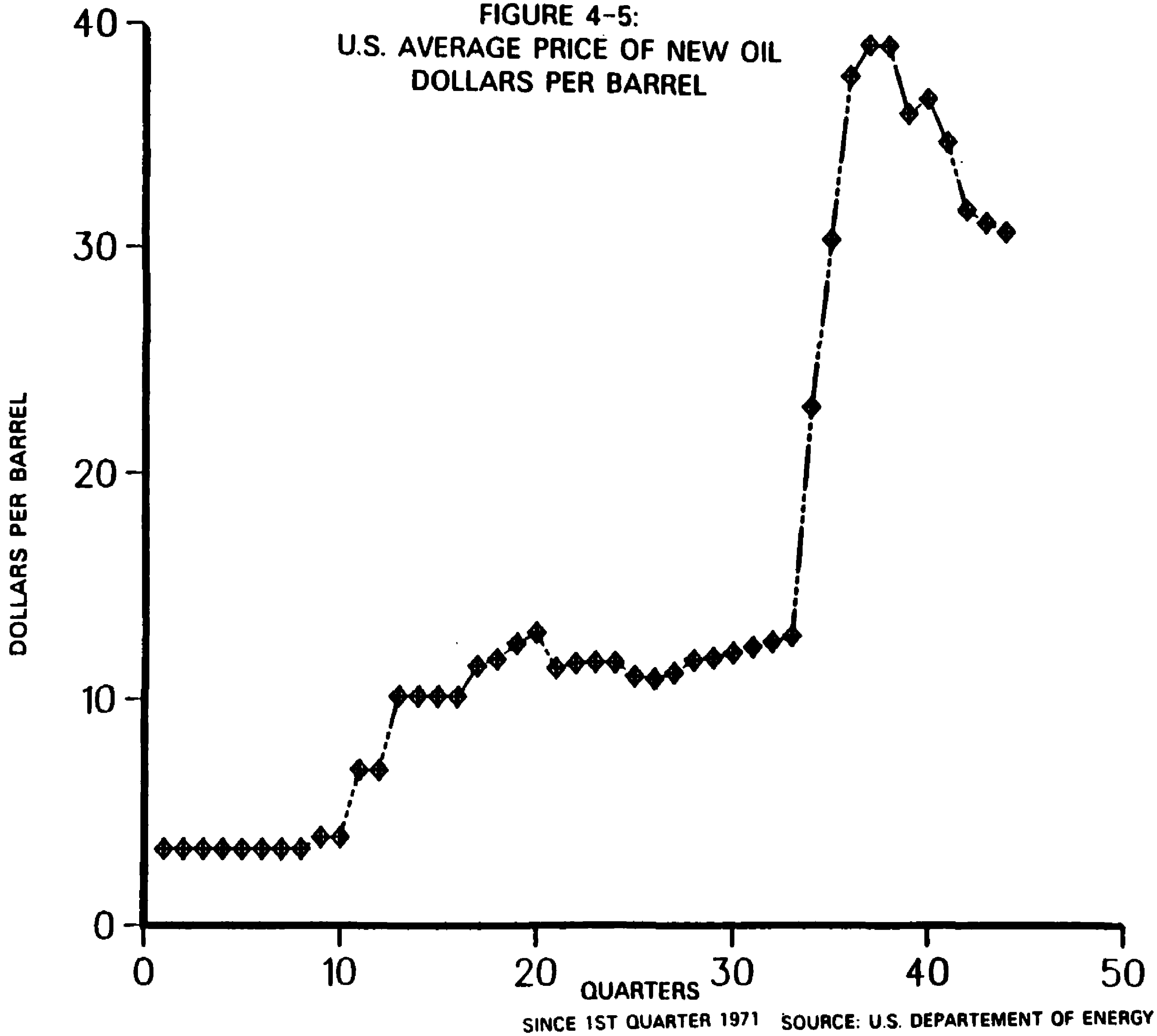
[5]Appendix A shows the changes in oil leasing patterns across the state during the study period.

FIGURE 4-5:
U.S. AVERAGE PRICE OF NEW OIL
DOLLARS PER BARREL



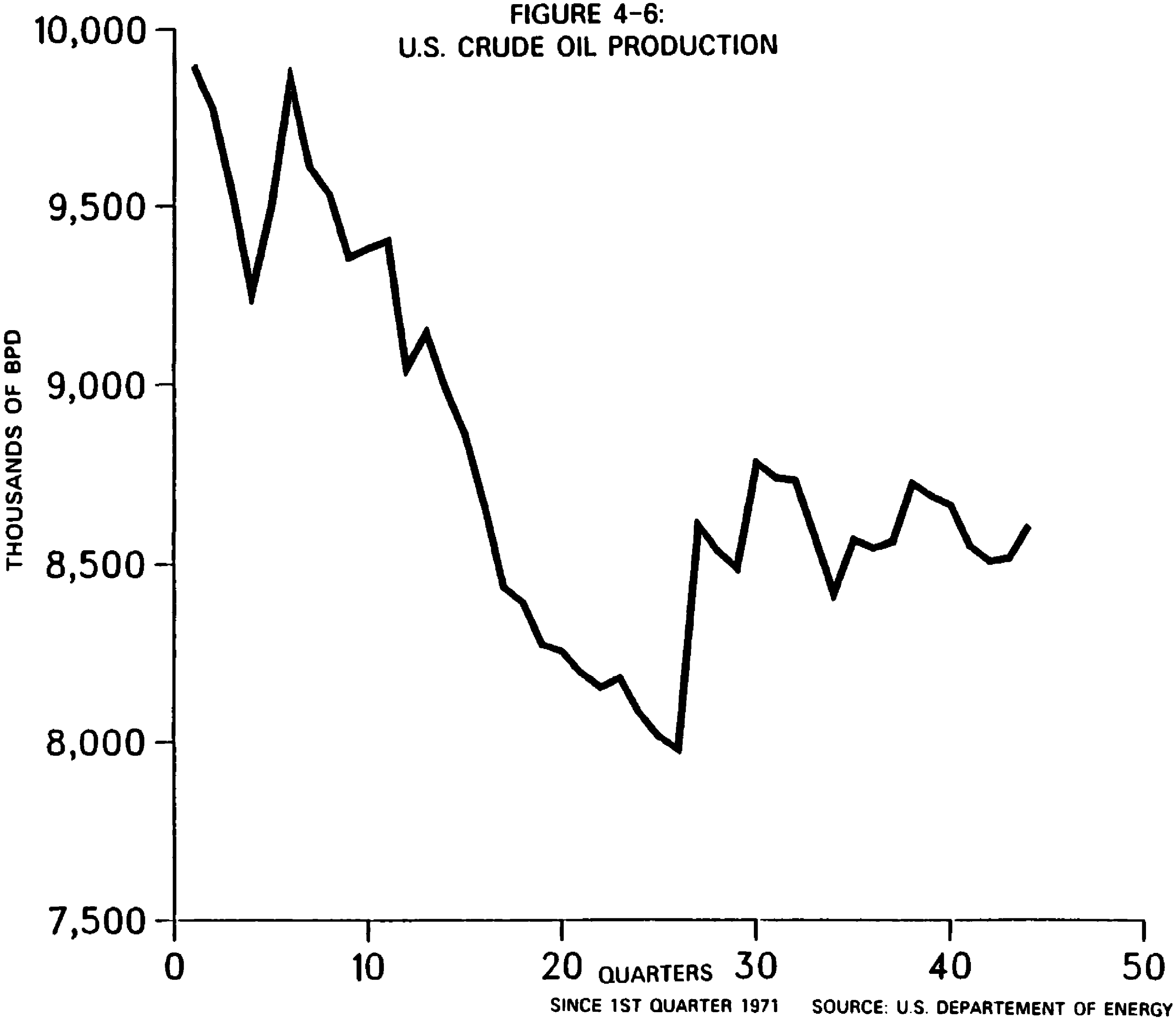
drillers would receive when they brought that oil to market. Generally, this is not the most desirable way to proceed, however contract oil prices are often not available or in the case of a vertically integrated oil company would only represent a transfer (or accounting) price as the crude is transferred from the production division or subsidiary to the refining one. Here the best variable would be the expected price of oil over the lifetime of the project, but for a number of reasons there is no adequate way to include that kind of information, so actual wellhead prices are used. This data is from the U.S. Department of Energy and it predecessors. Figure 4-5 shows the path of oil prices over time.

The next variable in the model is the interest rate, which by necessity is imprecise. The interest rate used in the model, one year U.S. Treasury bonds, only approximates the interest rate that is available to drillers, but changes in that interest rate are assumed to be approximated by changes in One Year Bonds. Additionally, the interest rates available for oil field exploration are confidential, while the One Year Bond rate is readily available from the Federal Reserve.

Given the ease of transporting petroleum and its derived products, theory suggest that the Montana oil market would be influenced by changes in the U.S. oil market. The variable used in this study to model that influence, changes in U.S. oil production, is a proxy for market conditions across the country, and represents the increase or decrease in thousands of barrels of domestic oil production between time periods. Figure 4-6 shows the changes in U.S. oil production over the eleven year study period. The data is taken from The Oil and Gas Journal.

There are three highly influential observations in this data series. They occur

FIGURE 4-6:
U.S. CRUDE OIL PRODUCTION



at times The Organization Of Petroleum Exporting Countries (OPEC) announced large price hikes or production cut backs. This is appears to be due to the "announcement effect", i.e. decision makers responding to the changes before they actually occur. The impacts of these announcements were modeled using a dummy variable that was set to one when an a price hike or production cutback was announced and zero all other times.

4.5. Statistical Procedures

The presence of the extreme (or outlier) observations creates a problem when estimating the relationships between the independent variables mentioned above and the dependent variable, total revenue. Two somewhat different statistical techniques were used to examine the influence of those three observations and derive a usable model; ordinary least squares regression and lease absolute deviations regression. Both of these methods were used on the full data set of 43 observations and on a data set of 40 observations with the outliers deleted. Ordinary least squares regression was also run on the data set of 43 observations with the dummy variable for OPEC interventions. In addition, both techniques were used with principal components to examine the effect of the multicollinearity that exists in the data set.

Ordinary Least Squares regression (OLS) was used to estimate the initial equation. The OLS criteria is designed to find a line that minimizes the sum of the squared distances between the actual observations and the regression line. However, OLS is greatly influenced by outliers. The effect of an outlier is proportional to the square of its distance from the regression line. If these outliers are due to rare events, it is often difficult to accurately estimate their effect in the regression. There are several methods for dealing with this type of situation. Deleting those observations the researcher thinks are causing the problems is one approach, but this means that some potentially valuable information will be lost. "As a general rule, outliers should be rejected out of hand only if they can be traced to causes such as errors in recording..." [9,p. 153]. Another method is to use a technique that is less sensitive to outliers, such as Least ABSolute deviations regression (LABS). Where ordinary least squares seeks to minimize the sum of the squared distance between the predicted and the actual observation, least absolute deviations, as its name suggests, seeks to minimize the sum of the absolute distance between the predicted and the actual points. This is considered the loss function to be minimized, in the case of OLS, the sum of the squared deviations is minimized, and in LABS, the sum of the absolute deviations is minimized. Thus, in least absolute deviations, a point that is four units from the regression line is only exerting four times the influence of a point one unit from the regression line, while in ordinary least squares such a point would exert sixteen times the influence. In some "circumstances least squares may give undue weight to extreme observations" [16,p. 361]. The problem is one of selecting the loss function, L, to be minimized when estimating the vector of B's, where L depends on the M dimensional multivariate distribution and the estimated parameter vector B. "Since the estimator B is random, as it depends on the random vector Y, the loss incurred in not knowing the parameter vector will also be random" [24,p. 21]. Since the vector B is not known, the estimation of B is entirely dependent on the choice of decision rules, i.e. the choice of loss functions to be minimized. Table 4-2 shows how an estimated coefficient, B, changes as the loss function is varied. The choice of OLS or LABS is determined by the researchers view of the loss function. If a quadratic loss function seems appropriate, then OLS is the desired technique. On the other hand, if a linear loss function seems more appropriate then LABS should be used.

Change in Coefficient Due to a Change in Technique

	OLS W/40	OLS W/43	OLS W/43&D	LABS W/40	LABS W/43
Value	0.5597	0.7668	0.6653	0.6630	0.8197

Table 4-2: Coefficients Under Various Loss Functions

Principal components is a technique that is used if there is insufficient data to adequately develop a model, or if there is some degree of multicollinearity in the independent variables. The principal components are derived such that they are linear combinations of the variables, and contain all the variation of the original variables, They are also derived so they are orthogonal which removes the collinearity problem in multiple regression. "The principal component, z_1, is seen to be a means of capturing the essence of both x_1 and x_2, without totally discarding either" [42,p. 425]. There is some concern with regard to the use of principal components in regression, because it is difficult to define them. They are artificial variables that are linear combinations of other variables, and thus not directly identifiable in economic terms. However, this does not prevent them from being used in predictive models. It just makes them hard to interpret.

4.6. Results

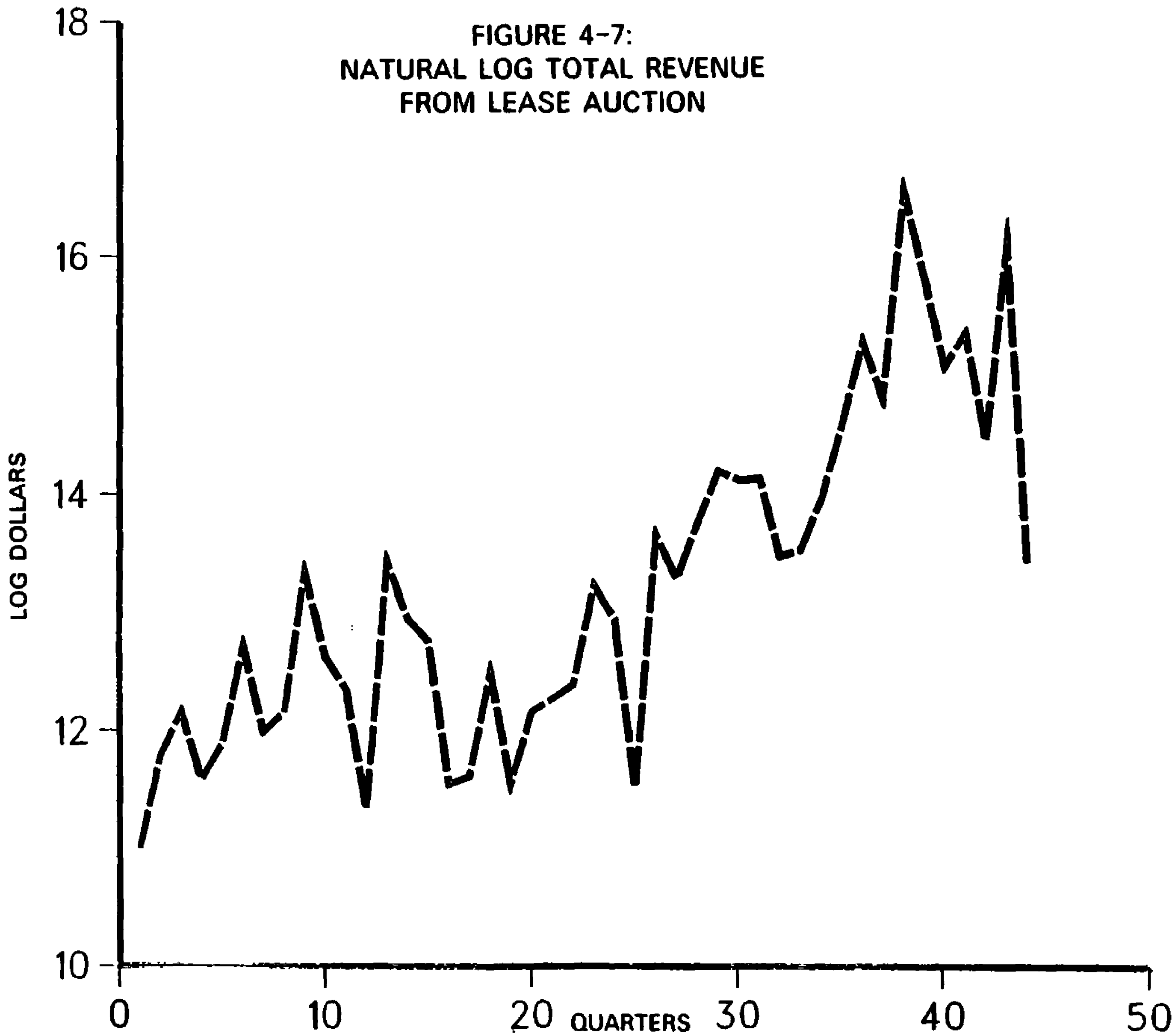
The coefficients from the final analysis of each technique appear in table 4-3. lnRev is the log transformation of the variable TOTREV (plotted in figure 4-7), lnPRC is the log transformation of the price of oil in the U.S., lnYRB1 is the log of the interest rates on one year Treasury bonds, difPR is the change in the amount of oil produced in the U.S., and OPEC is a binomial variable (0,1) that is used to model the OPEC oil shocks in 1972 and 1979. These transformations are used to improve the fit of the data.

BASIC VARIABLE COEFFICIENTS

COEFFICIENTS TECHNIQUE	OPEC	LNPRC	LNYRB1	DIFPR	CONSTANT
OLS W/40	-	0.5597	1.8079	0.00161	8.2300
OLS W/43	-	0.7668	1.5282	0.00170	8.3962
OLS W/43&D	1.6002	0.6653	1.5973	0.00171	8.3968
LABS W/40	-	0.6630	1.2620	0.00102	9.1820
LABS W/43	-	0.8197	0.9903	0.00097	9.3816

Table 4-3: Actual coefficients

FIGURE 4-7:
NATURAL LOG TOTAL REVENUE
FROM LEASE AUCTION



SOURCE: MONTANA DEPARTMENT OF STATE LANDS

4.6.1. OLS Regression

The final OLS equation with diagnostic statistics appears in table 4-4. The coefficients in the regression equation measure the change in lnREV associated with a unit change in the particular variable. For example, a one unit change in the logged price of oil results in a 0.6623 change in the logged total revenue, *holding all others variables constant*. Beneath the equation are the beta coefficients. They are obtained by normalizing the original data for each variable by subtracting its mean and dividing by its estimated standard deviation, and then regressing this transformed data. The beta coefficients are useful when making comparisons of the relative importance of the different independent variables in the regression model, which is not possible with the b coefficients, because the variables are measured in different units and have different variances [34,pg. 90]. The beta coefficient adjusts the unstandardized coefficients by the ratio of the standard deviation of the independent variable to the standard deviation of the dependent. Examining the beta coefficients, we note that the variable for the price of oil, lnPRC, and the variable for the cost of money, lnYRB1, have the greatest impact, and the variable for OPEC impacts has less impact and the variable for domestic production of crude, difPR has the least.

Table 4-5 and figures 4-8 and 4-9 show the total of the deviations of the predicted from the actual observation for both squared deviations and absolute deviations criteria, using as a measure, all 43 observations or only the 40 non-outlier observations. This total is one way to examine the accuracy of a particular model. The greater sum of the distances (either squared or absolute), the less ac-

TABLE 4-4:

The final OLS equation (with OPEC variable) is:

lnREV = 8.388 + .6623lnPRC + 1.6058lnYRB1 + .00171difPR + 1.598OPEC

R SQUARE	.75918		
ADJUSTED R SQUARE	.73383	DURBIN-WATSON	1.835
STANDARD ERROR	.70394	F - STATISTIC	29.984

VARIABLE	B	SE B	95% CONFDNCE	INTRVL B	BETA	SE BETA	T	SIG T
LNPRC	.66233	.22755	.20167	1.12299	.38264	.13145	2.911	.0060
OPEC	1.59752	.42644	.73424	2.46079	.30180	.08056	3.746	.0006
LNYRB1	1.60577	.53912	.51439	2.69716	.38506	.12928	2.979	.0050
DIFPR	1.712107E-03	6.26075E-04	4.446845E-04	2.979529E-03	.22169	.08107	2.735	.0094
(CONSTANT)	8.38800	.73162	6.90691	9.86909			11.465	.0000

TABLE 4-5:

DEVIATIONS FROM ACTUAL OBSERVATIONS USING VARIOUS ESTIMATION TECHNIQUES

	USING VARIABLES					USING PRINCIPAL COMPONENTS			
	OLS W/40	OLS W/43	OLS W/43&D	LABS W/40	LABS W/43	OLS W/40	OLS W/43	LABS /40	LABS W/43
ALL 43 OBS									
SQUARED DEV.	26.96	25.89	18.91	27.75	27.66	14.76	14.10	15.32	15.00
ABSOLUTE DEV.	27.28	27.23	23.76	26.77	26.56	19.73	19.70	19.26	19.21
WITH 40 OBS									
SQUARED DEV.	18.25	19.10	18.36	20.10	20.98	10.65	11.18	11.30	11.38
ABSOLUTE DEV.	22.41	22.86	22.54	22.23	22.25	16.37	16.89	15.89	16.03

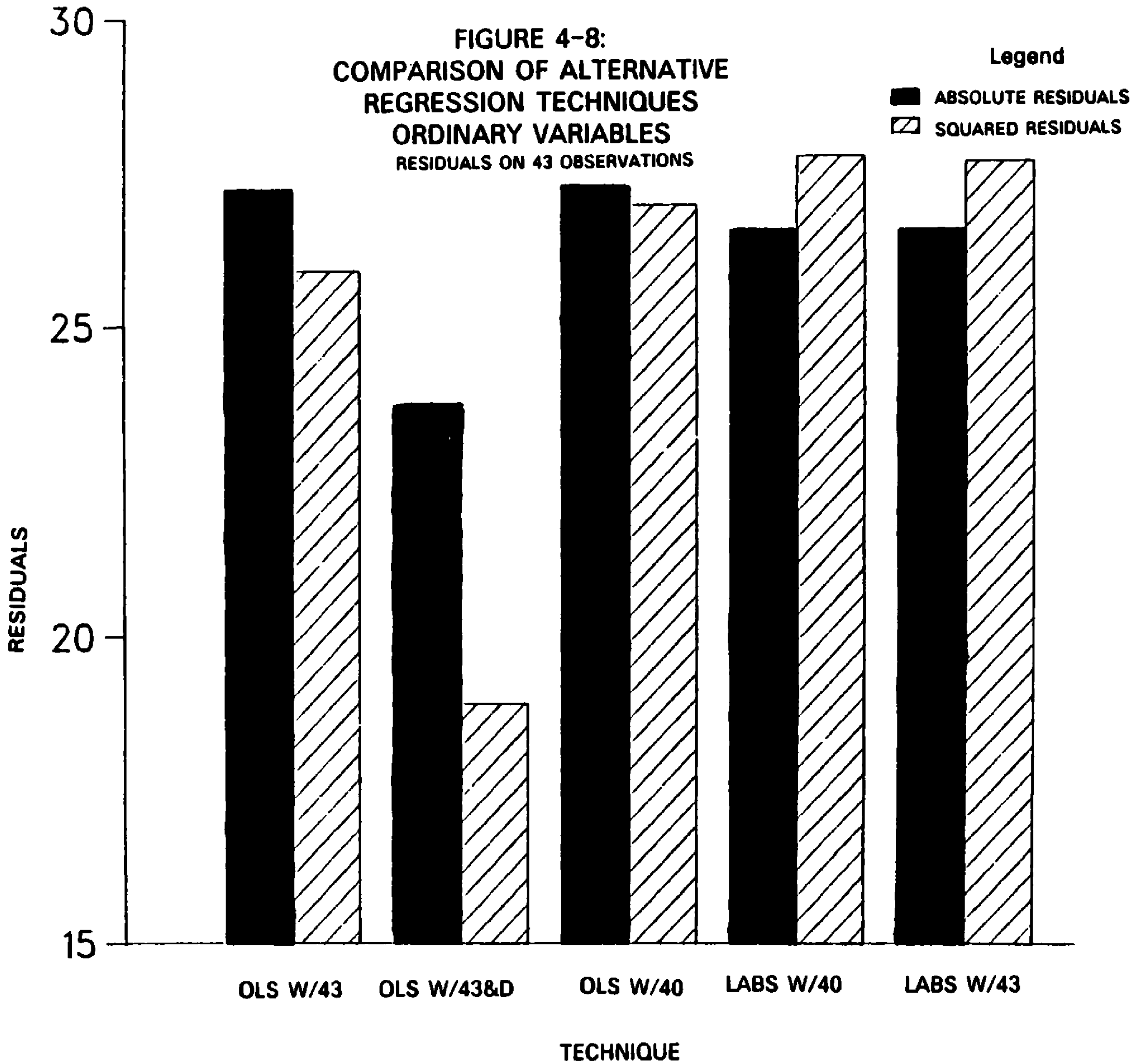


FIGURE 4-8:
COMPARISON OF ALTERNATIVE
REGRESSION TECHNIQUES
ORDINARY VARIABLES
RESIDUALS ON 43 OBSERVATIONS

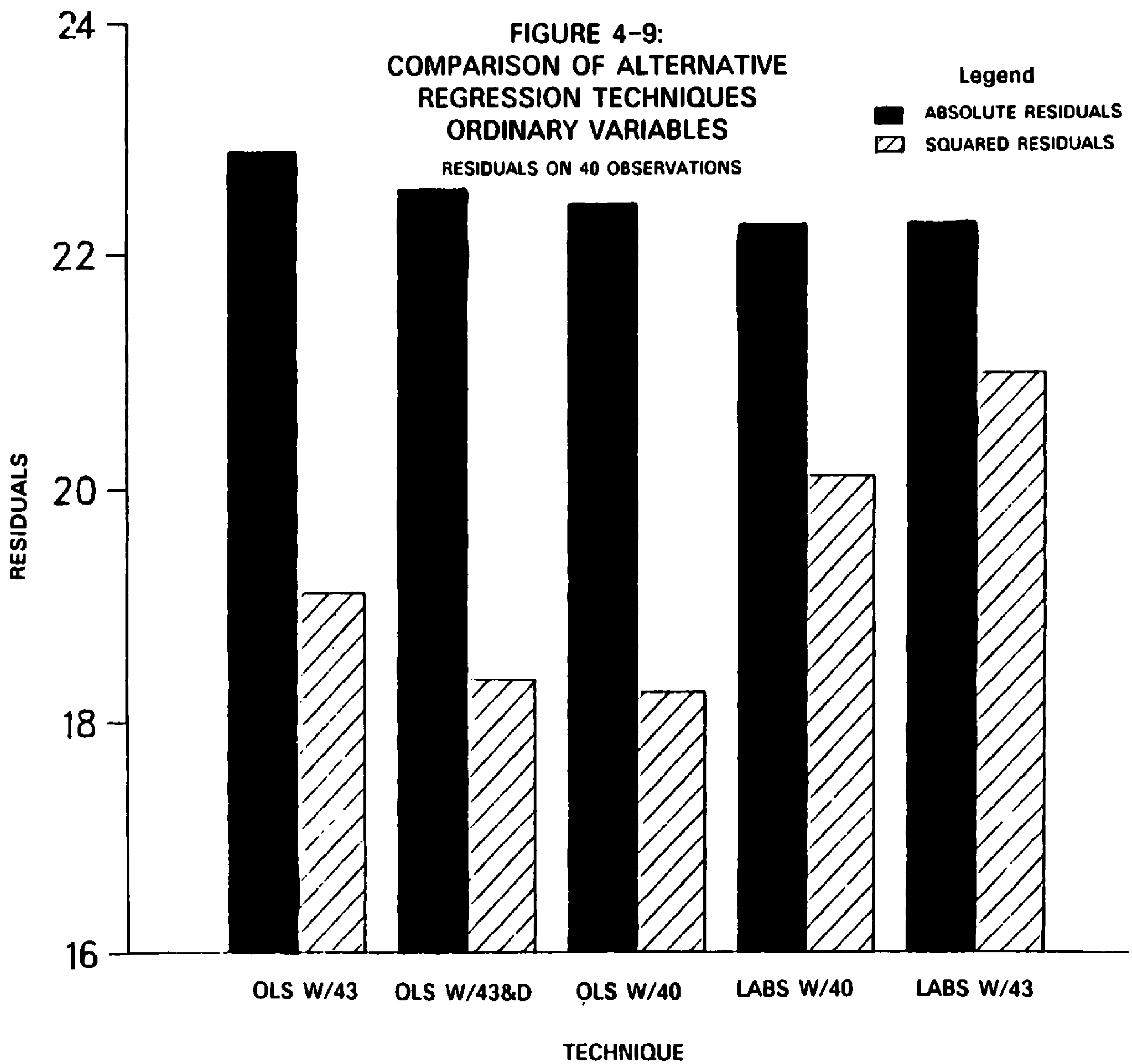


FIGURE 4-9:
COMPARISON OF ALTERNATIVE REGRESSION TECHNIQUES
ORDINARY VARIABLES
RESIDUALS ON 40 OBSERVATIONS

curate the model is. For example, the OLS variable model built on 43 observations with the dummy variable (OLS W/43&D) is more accurate than any of the other OLS or LABS models using all 43 observations as a criteria, but the LABS model built on 40 observations is more accurate using as a criteria of accuracy the total distance (absolute deviations) from the 40 non-outlier observations to the predicted observations.

4.6.2. OLS Diagnostics

The diagnostic statistics for the OLS equation are beneath it. They include measures of accuracy of the model, the proportion of total variation explained, accuracy of the individual parameters, and others.

The R squared (R^2) is the proportion of the total variation of the dependent variable explained by the regression, and is another way of identifying the accuracy of a model. It varies between 0.00 and 1.00 with an R^2 of 0.00 occuring when the regression equation explains none of the variation in the dependent variable and an R^2 of 1.00 indicating that the equation perfectly estimates the dependent variable. The R^2 value is sensitive to the number of parameters to be estimated because it does not account for the number of degrees of freedom in the analysis. With enough explanatory variables, it would be possible to fit every point in the data with the regression equation and thus obtain an R^2 of 1.00. We can account for this reduction in degrees of freedom by using the adjusted R^2. The OLS R^2 was 0.7592 and the adjusted R^2 is 0.7338. It is this last figure which more accurately states the percentage of variation that is explained by the above equation. Approximately 73 percent of the variation in the log transformed variable TOTREV is explained by this regression.

The T-statistics are used to test the significance of each coefficient. Those significance levels are next to the T values. The highest significance is less than .01, which means that we can reject the null hypothesis (with 99% confidence) that the parameter being estimated is equal to zero. This indicates that the relationship between the independent variable and the dependent, lnREV, is statistically significant.

The F statistic can be used to test the significance of the entire equation and is useful for joint tests of significance. The null hypothesis is that all the parameters are equal to zero. In this case the F value is so high that the null hypothesis can be rejected with almost 100 percent certainty.

One of the assumption of least squares regression specifies the statistical independence of the error terms, i.e. the disturbance term is not auto-correlated. In economic studies such as this one, which involve time-series data this assumption is often violated. The consequence of this is that the variances of the estimates of the b's tend to be overstated, thus the calculation of the confidence interval becomes less reliable. This autocorrelation (or serial correlation) in the data can lead to under estimation of the variance of the b's through two channels. It increases the true variance and decreases the estimate of the variance. This increases the probability of a Type I error. A Type I error is that of rejecting the null hypothesis when it is actually true. In this case, the null hypothesis is that the b's are equal to zero. Another consequence of autocorrelation in ordinary least squares is that the predictions are not efficient, in that they will have a larger variance than other econometric techniques. The Durbin-Watson statistic is a measure of first-order serial correlation. The Durbin-Watson in the OLS equation is 1.83, which is above the critical value of 1.74 (5% level) so the null hypothesis, that first-order serial correlation exists, can be rejected at the 95% level [10,p. X].

One method of correcting for auto-correlation is the Cochrane-Orcutt iterative technique, which in addition to estimating the parameters also estimates the value of *rho*, the first order serial correlation coefficient. When the Cochrane-Orcutt technique was applied to this data the beta coefficients did not change significantly and *rho* was highly insignificant. This reinforces the conclusion of the Durbin-Watson statistic that serial correlation is not a problem in this data.

4.6.3. Least Absolute Deviations Regression

The LABS variables are the same as those used in the OLS equations, except that the OPEC variable has been excluded. Since it is hard (or impossible) to forecast that type of market intervention, it seems reasonable to exclude it from a forecasting model. It is interesting to note the strong influence the announcement effect has on the lease sale revenues. The LABS estimates are derived using a linear programming technique that minimizes the sum of the absolute distance between the actual observations and the predicted ones. The differences between the OLS and the LABS regressions are due to the influence of those highly influential points that occured as a result of an OPEC decision. The OLS estimates are strongly influenced by these observations, which shifts the equation and may bias the forecasts.

Figures 4-8 and 4-9 show the differences between the different methods used to estimate the equation, assuming either a quadratic loss function (OLS) or a linear one (LABS), for the entire data set of 43 observations and the restricted one excluding the 3 highly influential observations. It is interesting to note the differences among the various methods. The OLS regression on 43 cases with the dummy variable clearly does a better job of explaining the variation in LNREV when measured across all 43 observations using either the squared deviations or absolute deviations criteria. However, since the purpose of this section is to develop an equation for forecasting, and interventions such as those modeled by OPEC are hard to foresee, we shall drop the variable OPEC and consider the criteria to be "the best fit on the 40 observations that don't include those highly influential observations." It is apparent that the OLS regression on 40 observations is a better fit with a squared error loss function, and the LABS on 40 observations with a linear loss function. This is as one would expect since each of these methods is intended to minimize the sum of either squared or absolute deviations.

4.6.4. Multicollinearity

The absence of multicollinearity is one of the assumptions behind ordinary least squares regression. The effects of multicollinearity are inconclusive. While multicollinearity does not bias the estimates, the value of the coefficients may become unstable and the standard errors are not accurate. This leads to the danger of mis-specification or excluding a variable because it appears to be insignificant due to its large standard error, when in fact the variable is an important component in explain the changes in the dependent variable. "The reason why multicollinearity is of such importance is that ...it is impossible to determine best linear unbiased estimators of the coefficients of the equation" [24,p. 14]. In this data there is a certain amount of collinearity present. The two variables lnPRC and lnYRB1 appear to be linearly related. This can be detected with two methods. First, the variance inflation factors (VIF) for the variables lnPRC and lnYRB1, which are indicators of multicollinearity, are both high enough to indicate the presence of some kind of collinearity. The VIF is derived from the diagonal of the inverse of the correlation matrix. In a perfectly orthogonal matrix the VIF's are 1.00. In the data matrix used here, the VIF's were 2.72, 1.02, 2.63, and 1.03 for lnPRC, OPEC, lnYRB1, and difPR respectively. The values for lnPRC and lnYRB1 suggest that there is some degree of multicollinearity in the data. Another approach is to examine the squared multiple correlations of the exogenous variables. These are effectively the R-squared values when one of the variables is regressed on the others. For this data, they are 0.632, 0.023, 0.620, and 0.035 in the same order as above. The values for lnPRC and lnYRB1 again suggest that some form of linear relationship exists in the data.

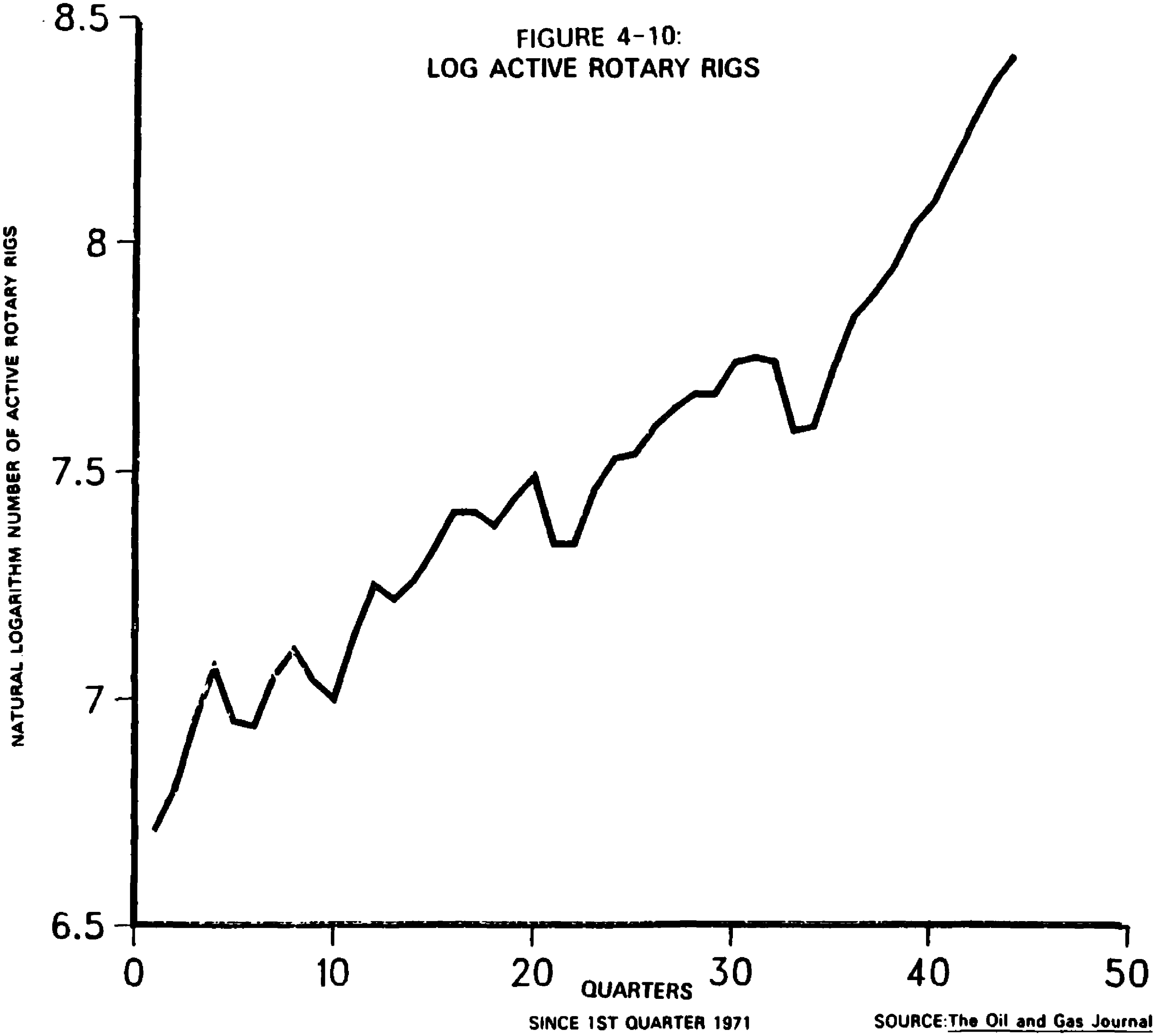
Multicollinearity is very often a problem in economic data. It makes it difficult to estimate the separate effects of the variables with any precision. In addition, variables that appear to be insignificant and are thus dropped from the analysis, may in fact have valuable explanatory power. While multicollinearity affects the individual coefficients, it does not affect the the predictive accuracy of the equation, as long as "the pattern of interrelationships among the explanatory variables is the same in the forecast period as in the sample period" [27,p. 453]. Multicollinearity affects the variables that are included in the regression equation. Those variables which are highly coiiinear will tend to displace each other in the regression equation. The theory suggests that there are a number of variables that may influence the decision of how many tracts to bid on and what to pay, but many of them are linearly related to others and this makes it difficult to include them in an equation.

One way around this problem is to develop principal components from the variables and then regress these on the dependent variable, total revenue. Principal components are linear combinations of the variables and are derived in such a way as to "explain as much of the total variations in the data as possible with as few of the factors [principal components] as possible" [34,p. 389]. These principal components are orthogonal to each other, meaning they are perfectly uncorreiated.

When LNREV is regressed on these principal components, the percentage of the variation in LNREV that is explained is higher than when using just variables in the equation. Since principal components is a data reduction technique and may reduce the dimensionality of the data space, it is difficult to interpret the principal components. However, they can be usefully employed in prediction with the understanding that if the assumption of a constant relationship among the variables in the components is violated, the prediction will be in error.

Looking at table 4-5 again, we can see that the principal component regression is better at fitting the data than any of the models that use standard variables. Here again we have the choice of using linear error loss, or squared error loss, depending on how deviations from the estimated regression line are to penalized. The principal components OLS regression is noted in Table 4-6 along

FIGURE 4-10:
LOG ACTIVE ROTARY RIGS



SOURCE: The Oil and Gas Journal

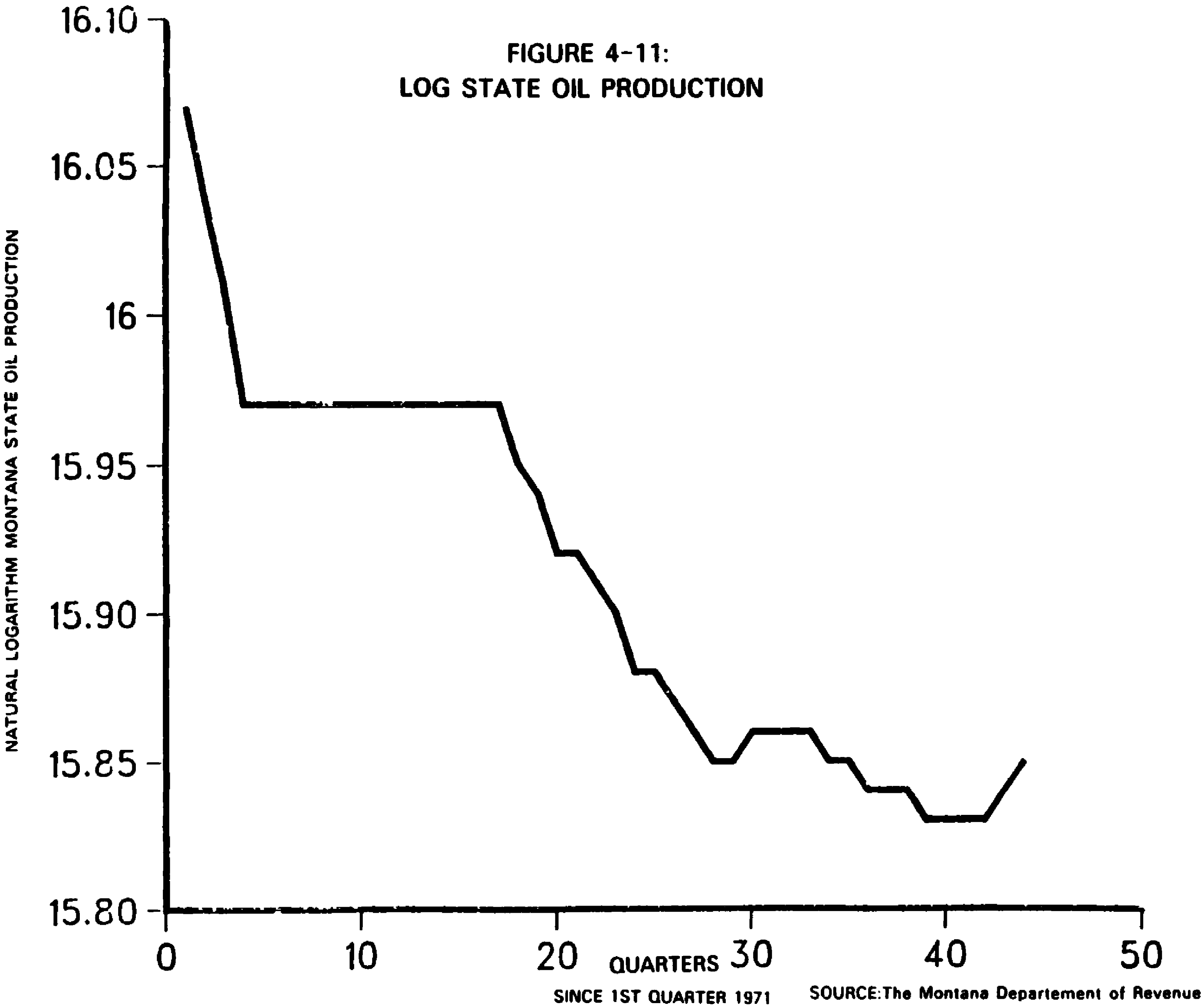


FIGURE 4-11:
LOG STATE OIL PRODUCTION
NATURAL LOGARITHM MONTANA STATE OIL PRODUCTION
16.10
16.05
16
15.95
15.90
15.85
15.80
0
10
20
30
40
50
QUARTERS
SINCE 1ST QUARTER 1971
SOURCE:The Montana Departement of Revenue


FIGURE 4-12:
LOG ONE YEAR TREASURY BILLS
MARKET RATE
NATURAL LOGARITHM ONE YEAR TREASURY BILLS
2.5
2
1.5
0
0
10
20
QUARTERS
30
40
50
SINCE 1ST QUARTER 1971
SOURCE:FEDERAL RESERVE SYSTEM

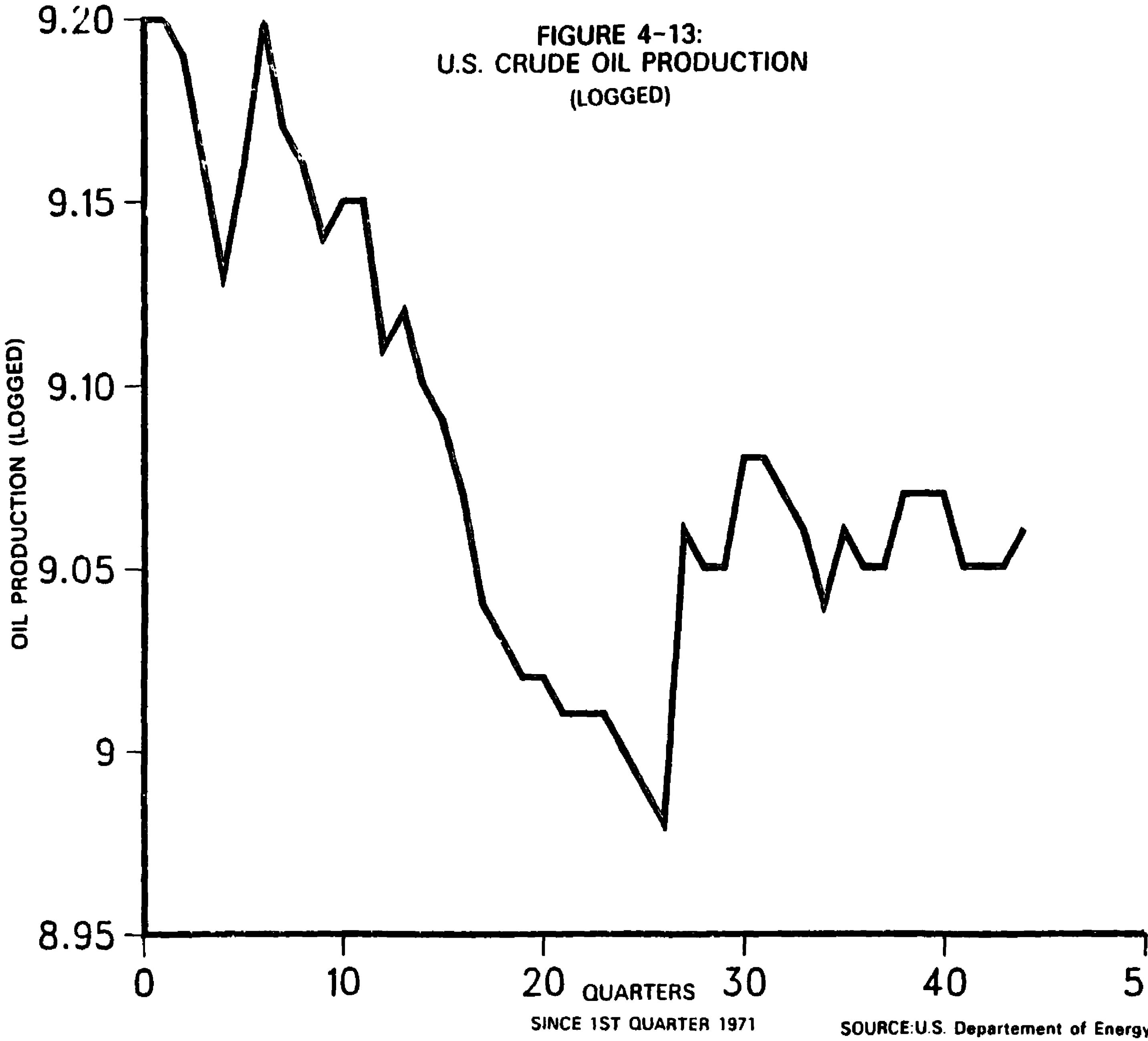


FIGURE 4-13:
U.S. CRUDE OIL PRODUCTION
(LOGGED)

SOURCE:U.S. Departement of Energy

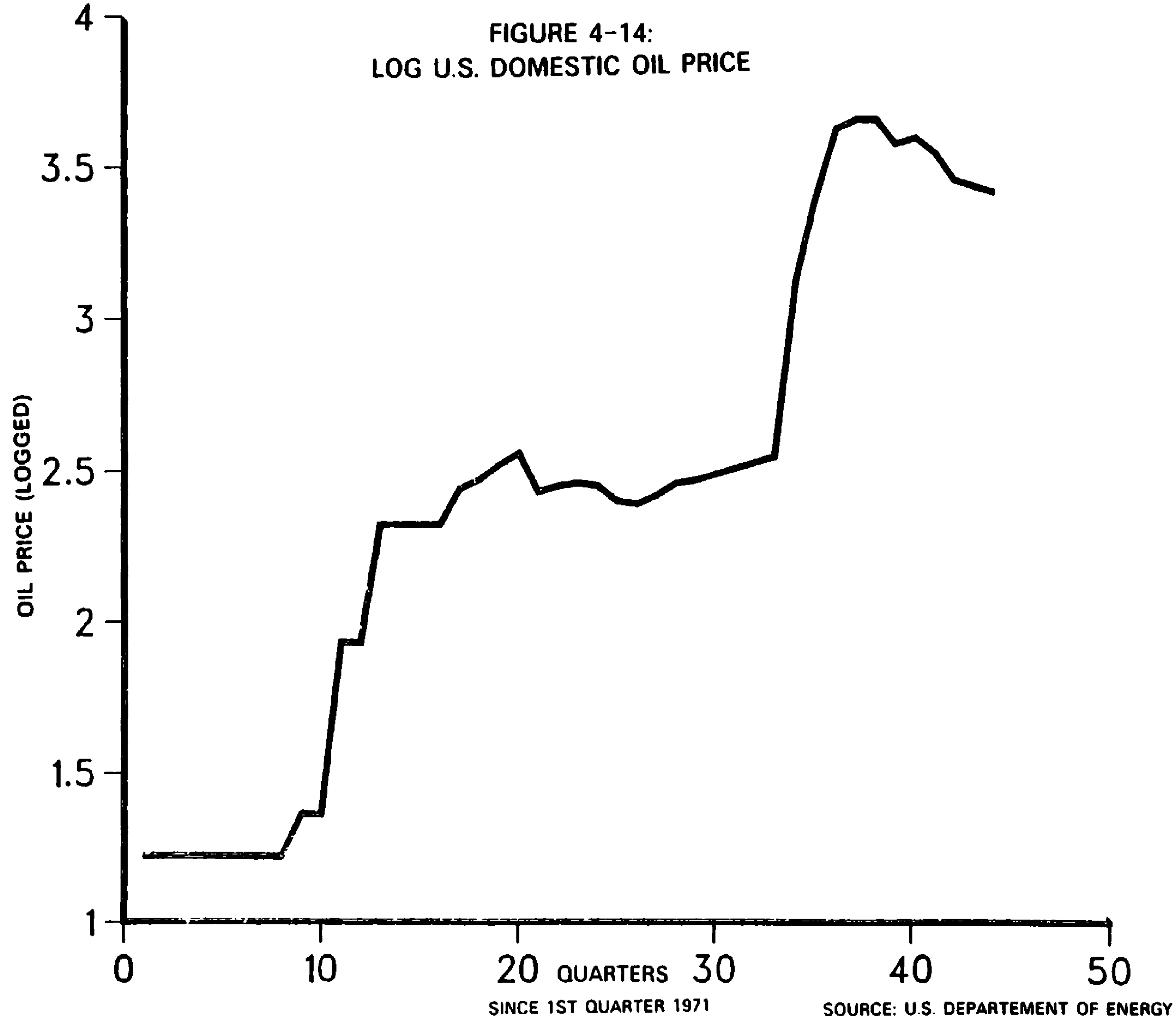


FIGURE 4-14:
LOG U.S. DOMESTIC OIL PRICE

TABLE 4-6:

The final Principal components equation is:

$$\ln REV = 13.26 + 1.05PC1 + 0.439PC2 - 0.365PC3 - 0.311PC4$$

R SQUARE	.81982		
ADJUSTED R SQUARE	.80085	DURBIN-WATSON	2.39006
STANDARD ERROR	.60889	F - STATISTIC	43.22473

VARIABLE	B	SE B	95% CONFDNCE INTRVL B		BETA	SE BETA	T	SIG T
PC1	1.05050	.09395	.86030	1.24070	.76991	.06886	11.181	.0000
PC2	.43909	.09395	.24889	.62929	.32181	.06886	4.673	.0000
PC3	-.36527	.09395	-.55547	-.17507	-.26771	.06886	-3.888	.0004
PC4	-.31061	.09395	-.50081	-.12041	-.22764	.06886	-3.306	.0021
(CONSTANT)	13.26335	.09286	13.07538	13.45133			142.839	.0000

Composition of Principal Components

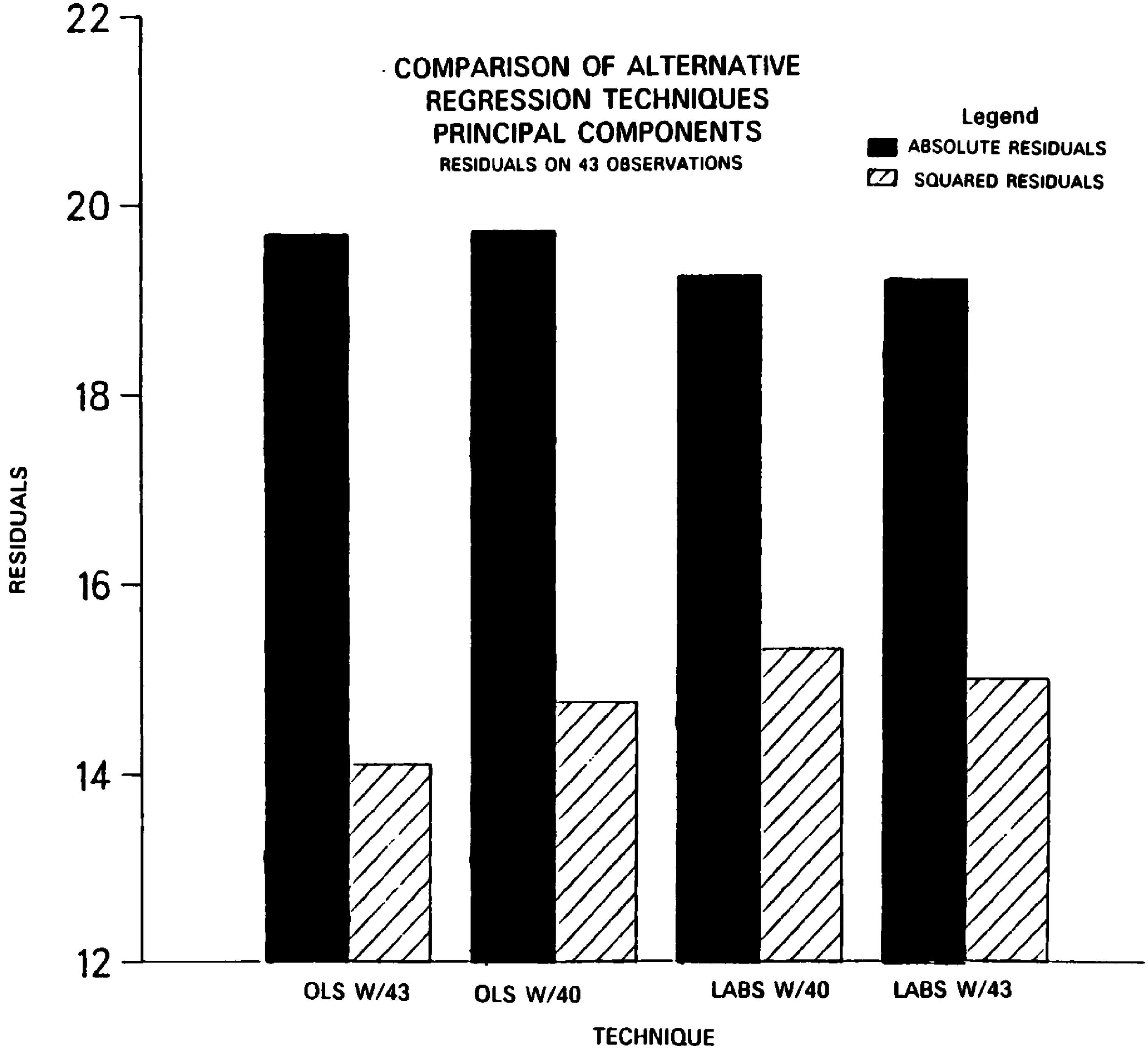
VARIABLE	PC1	PC2	PC3	PC4
LRR	0.96326	0.08734	-0.11703	0.22497
LST	-0.92419	0.08922	0.34784	0.12940
LNYRB1	0.79540	0.57002	0.17211	-0.04424
LNPP	-0.69630	0.69091	-0.17896	-0.00601
LNPRC	0.97050	0.02680	0.17759	-0.06812

with the composition of the principal components. The variables that compose the four factors (or components) are lnRR, the logarithm of the number of active rotary drilling in the U.S., lnST, the logarithm of Montana state oil production, lnYRB1, the logarithm of one year Treasury bills, lnPP, the logarithm of U.S. domestic oil production and lnPRC, the logarithm of U.S. oil prices. These data series are shown if figures 4-10, 4-11, 4-12, 4-13, and 4-14.

The bar charts in figures 4-15 and 4-16, as explained before, show the differences in the total residual for both absolute deviations and squared deviations measured across all 43 observations or the 40 that do not include the outliers. It is evident from these figures that there is not much difference between the LABS w/40 and the LABS w/43 models. Using a absolute deviations criteria, they are consistently better across both the 43 observation series and the 40 non-outlier observation series.

4.6.5. Bootstrap

Another of the important assumptions behind regression analysis is that the random fluctuations or errors are distributed about the true value in a normal or Gaussian distribution. This assumption is both necessary for regression and unverifiable. Efron [12] has developed a technique, called the "bootstrap", used for verifying the results, that does not rely on assumptions of normality. The bootstrap is used to determine the statistical accuracy of parameters determined from the data. The bootstrap method "...require[s] very little in the way of modeling, assumptions, or analysis, and can be applied in an automatic way to any situation, no matter how complicated" [14,p. 36].


COMPARISON OF ALTERNATIVE
REGRESSION TECHNIQUES
PRINCIPAL COMPONENTS
RESIDUALS ON 43 OBSERVATIONS
Legend
ABSOLUTE RESIDUALS
SQUARED RESIDUALS
22
20
18
16
14
12
RESIDUALS
OLS W/43
OLS W/40
LABS W/40
LABS W/43
TECHNIQUE

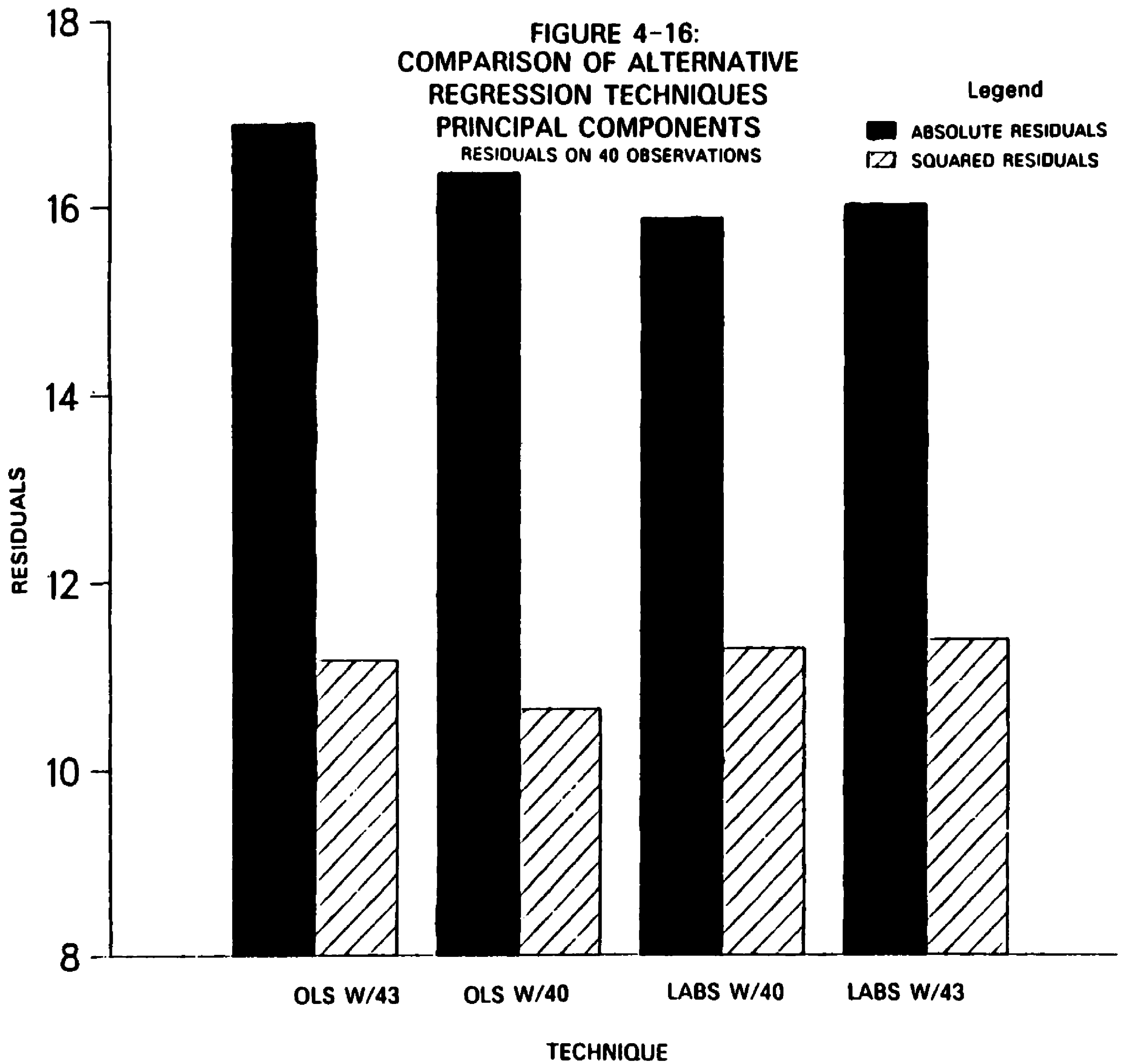


FIGURE 4-16:
COMPARISON OF ALTERNATIVE
REGRESSION TECHNIQUES
PRINCIPAL COMPONENTS
RESIDUALS ON 40 OBSERVATIONS
Legend
ABSOLUTE RESIDUALS
SQUARED RESIDUALS
18
16
14
12
10
8
RESIDUALS
OLS W/43
OLS W/40
LABS W/40
LABS W/43
TECHNIQUE

FIGURE 4-17:
BOOTSTRAP DISTIBUTION OF
LNPRC COEFFICIENT

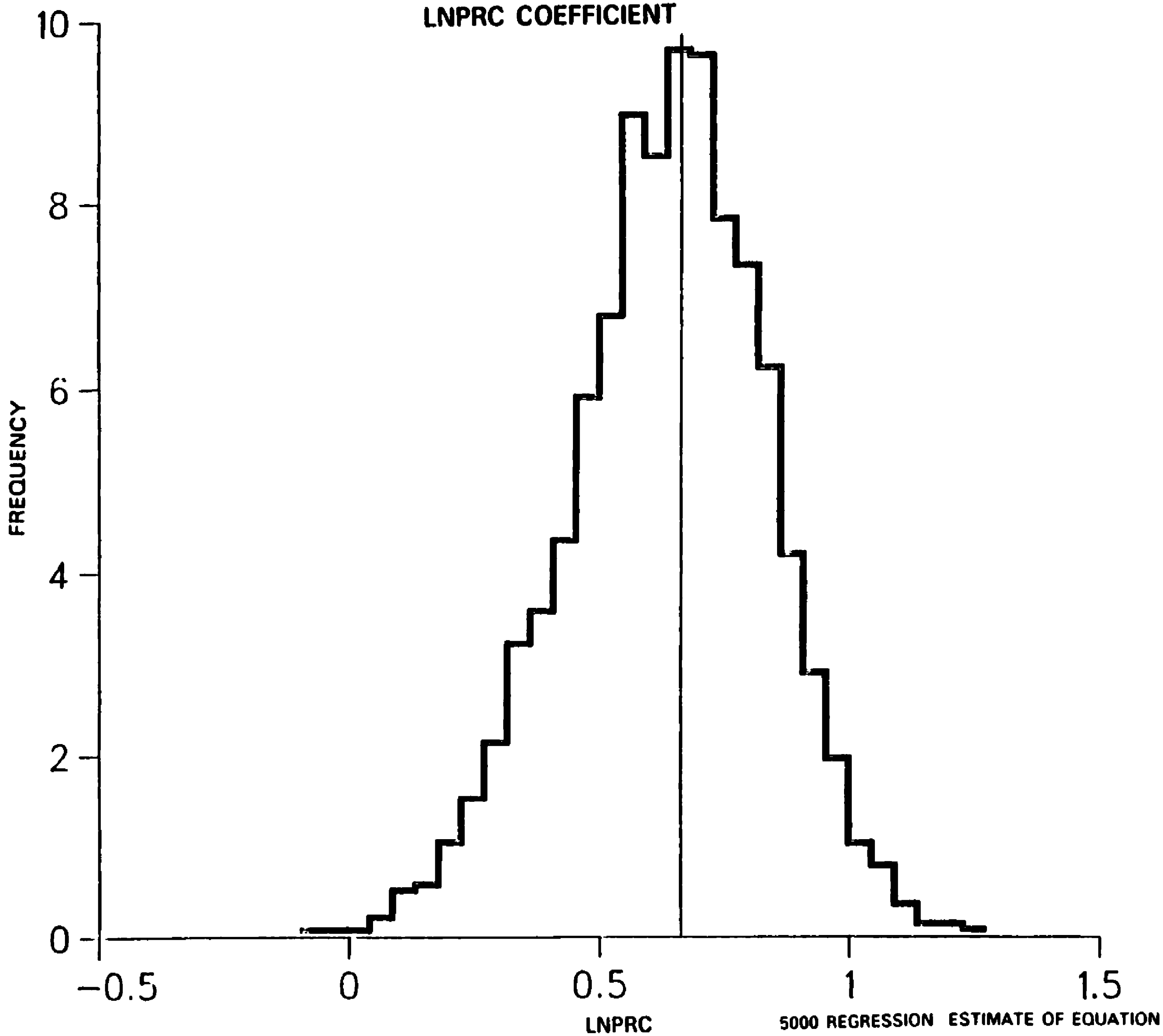


FIGURE 4-18:
BOOTSTRAP DISTIBUTION OF
LNYRB1 COEFFICIENT

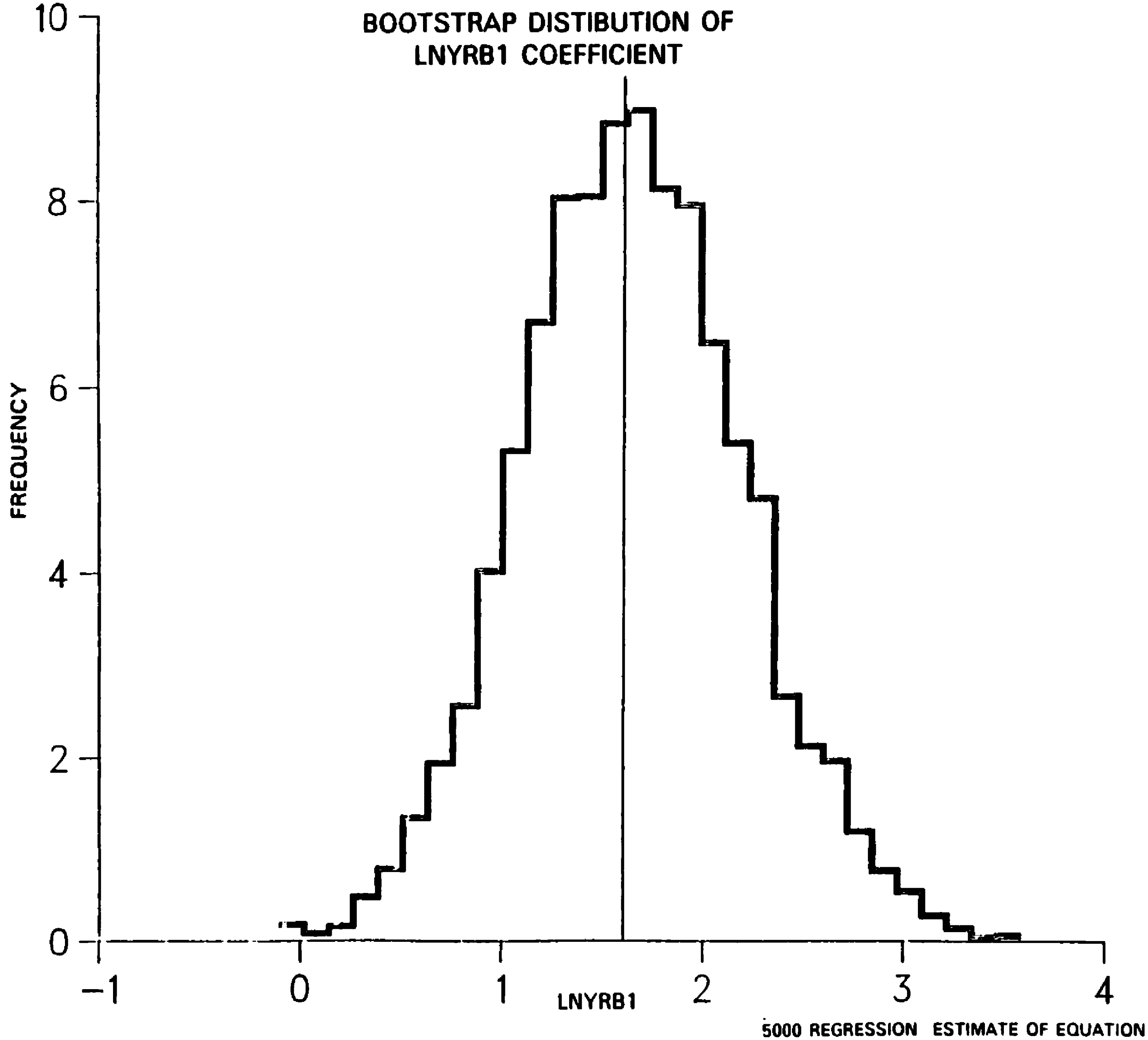
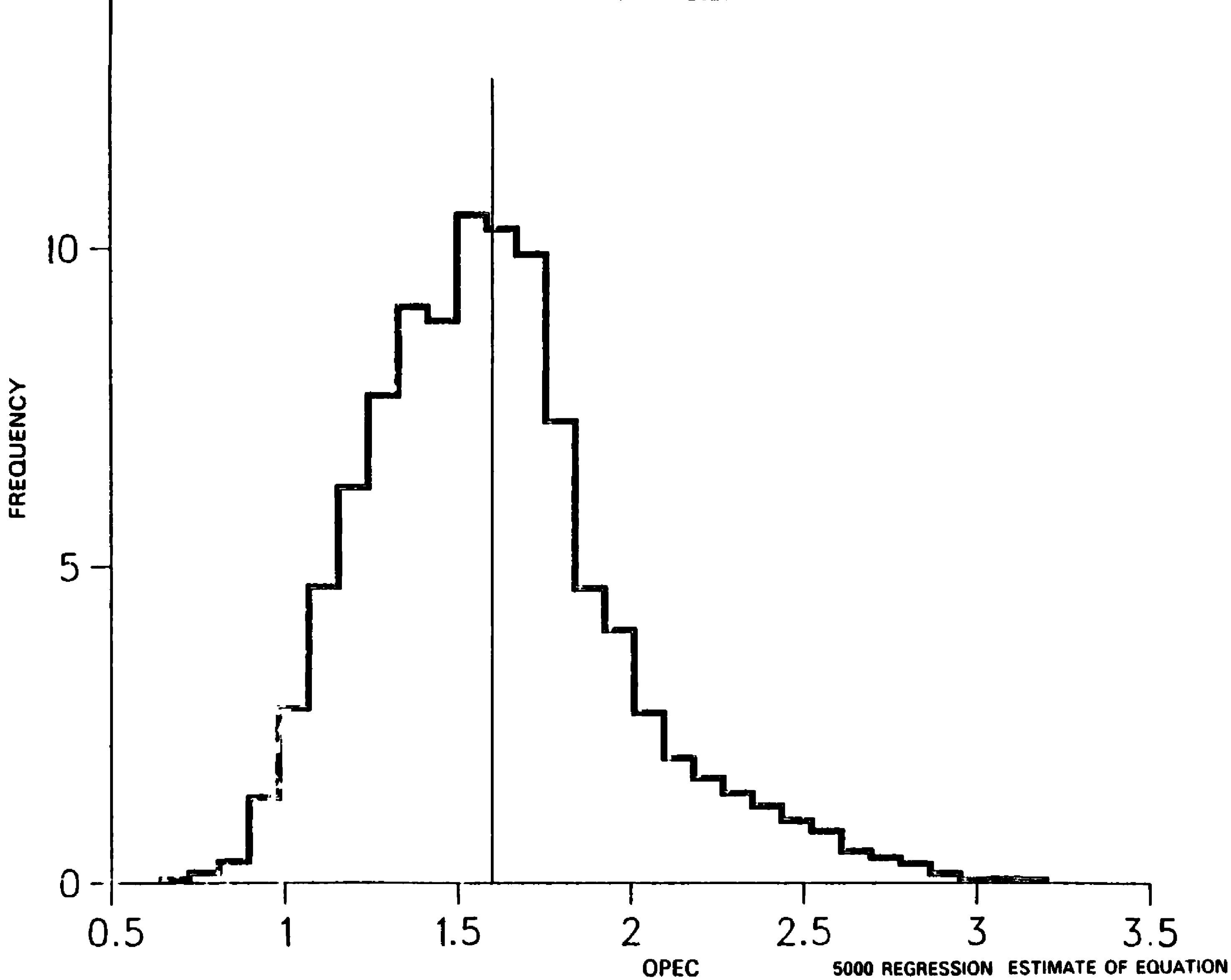


FIGURE 4-19
BOOTSTRAP DISTIBUTION OF
OPEC COEFFICIENT



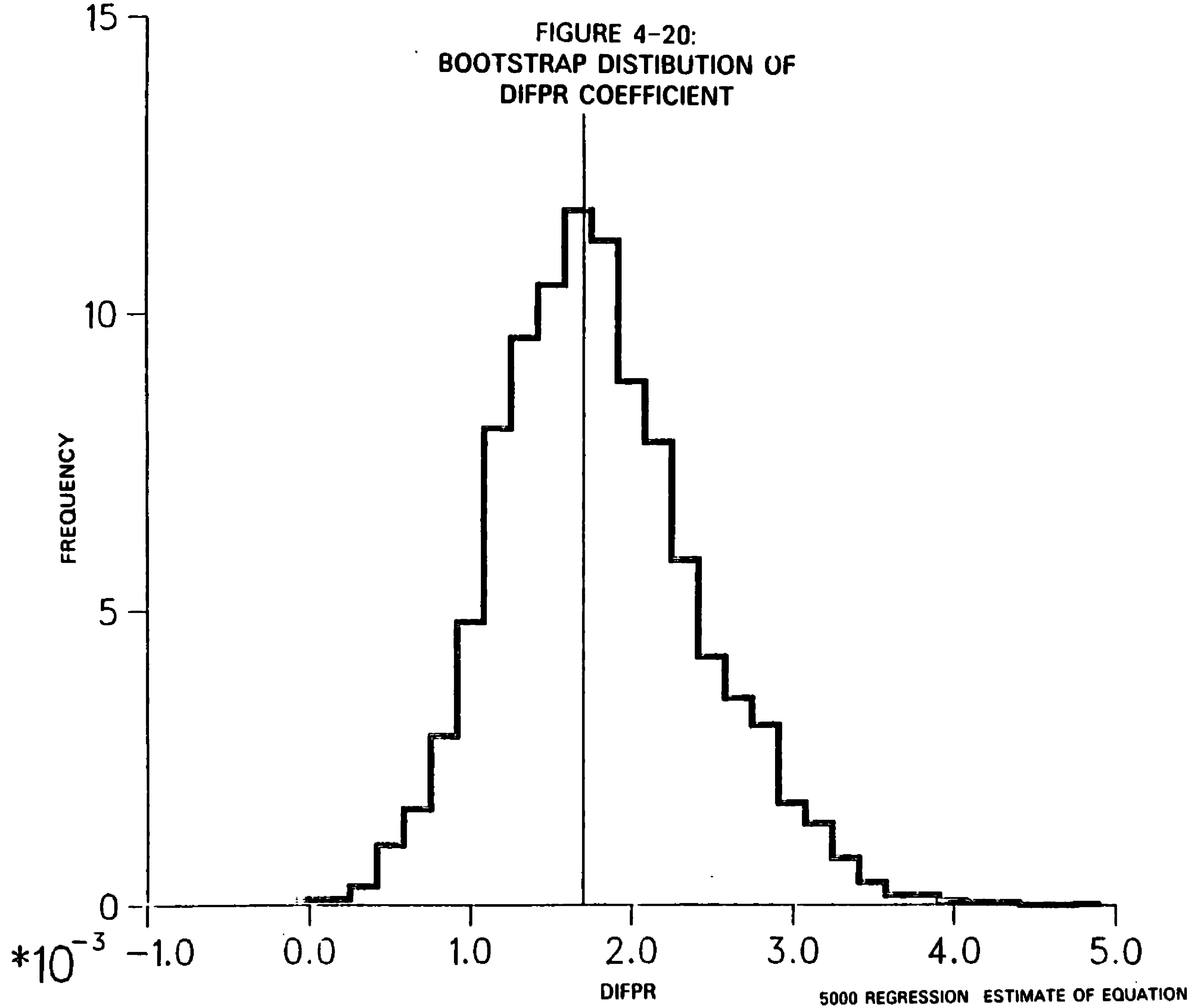


FIGURE 4-20:
BOOTSTRAP DISTIBUTION OF
DIFPR COEFFICIENT

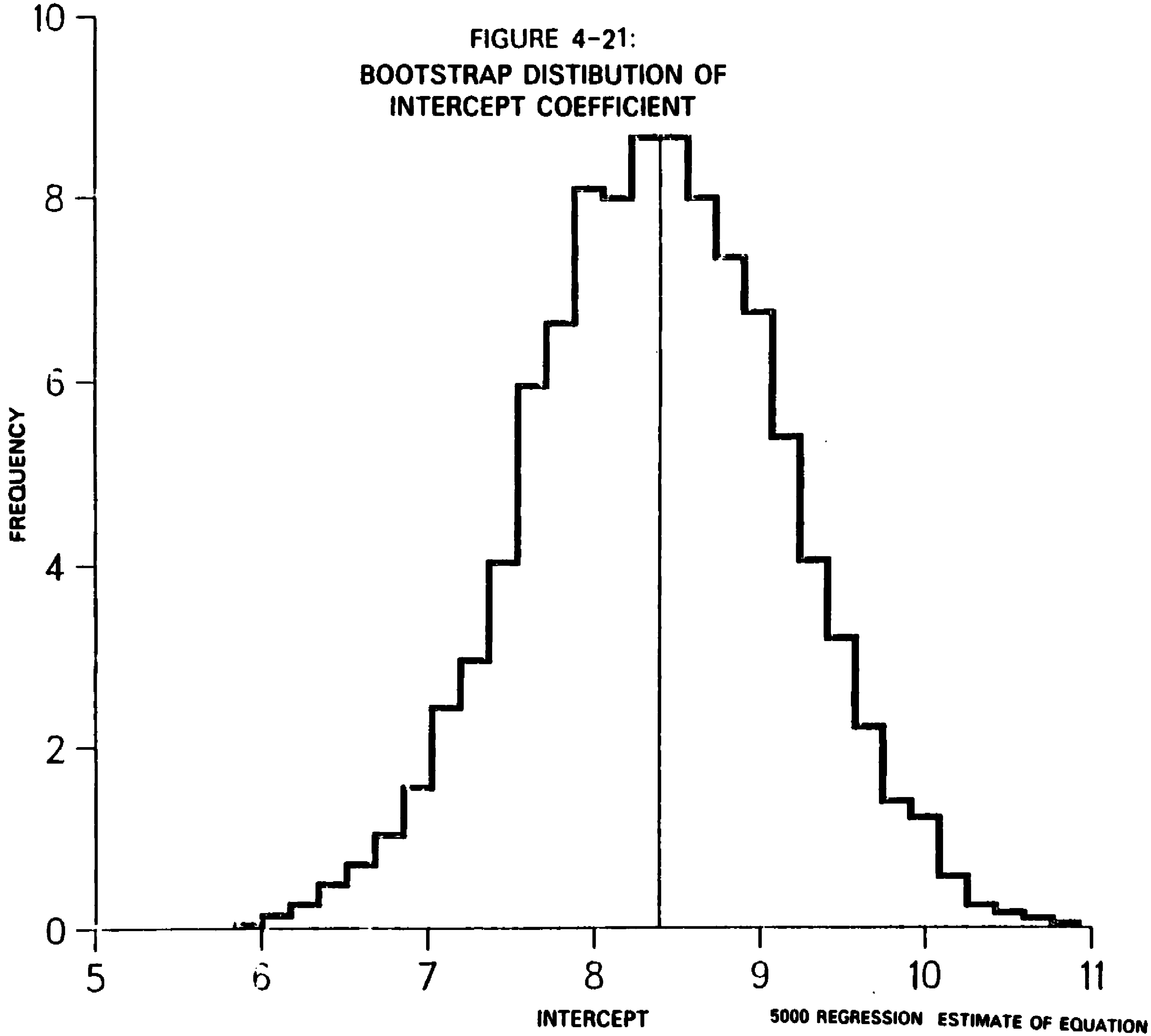


FIGURE 4-21:
BOOTSTRAP DISTIBUTION OF
INTERCEPT COEFFICIENT

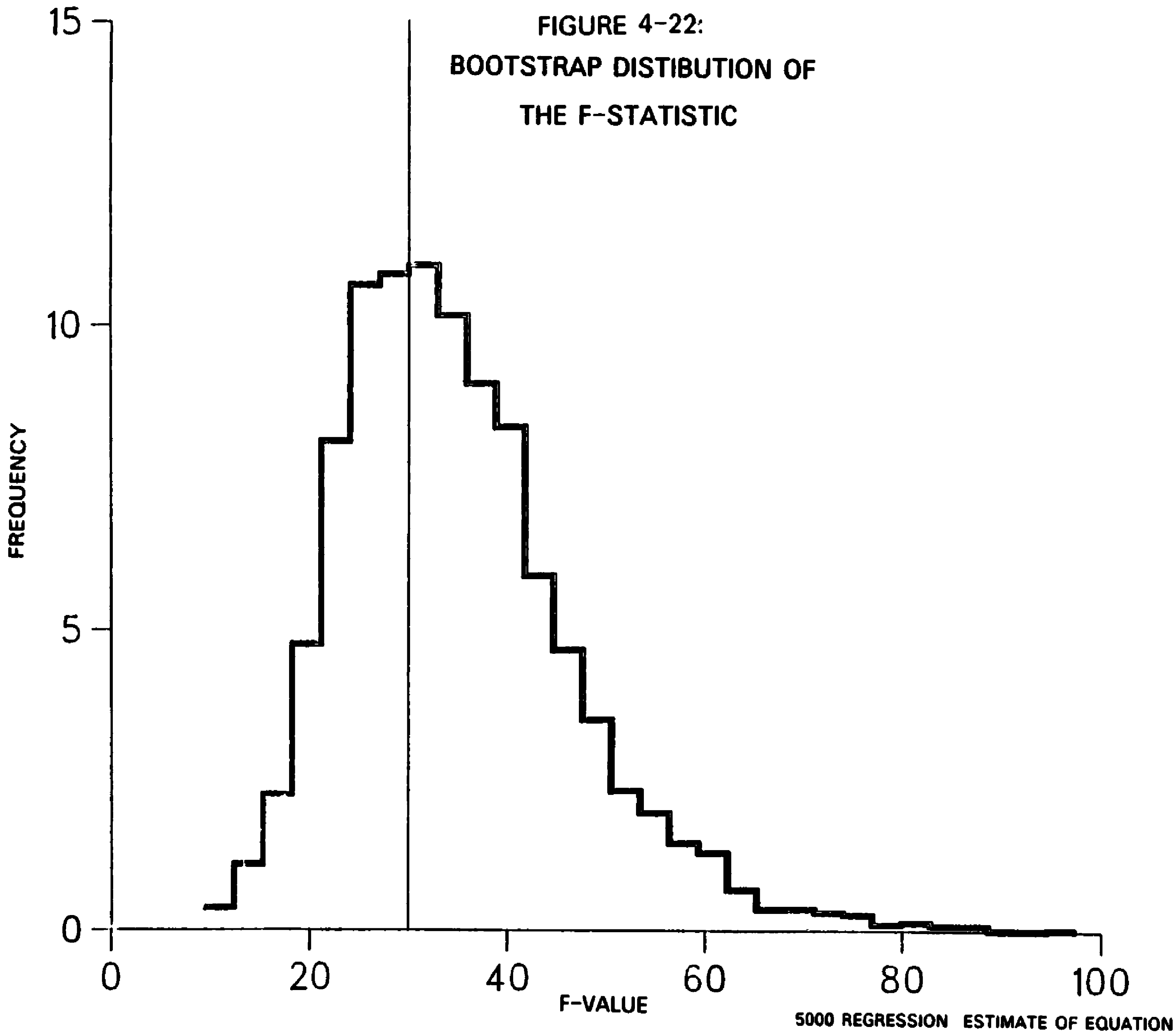
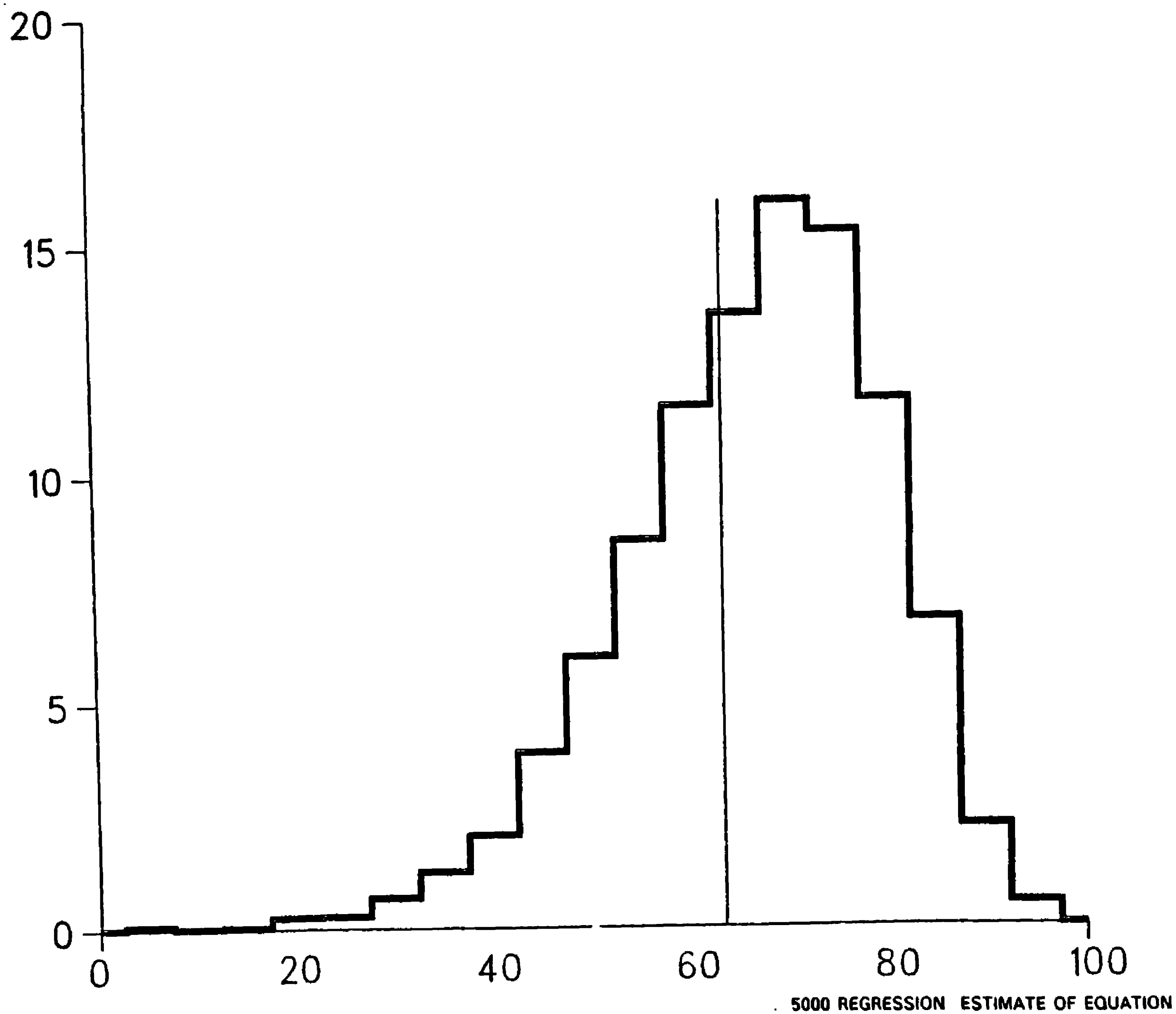


FIGURE 4-22:
BOOTSTRAP DISTIBUTION OF
THE F-STATISTIC

Figure 4-23: Bootstrap Distribution Of R-Squared



For this study, the data set consisted of the 43 quarterly observations already discussed. The data set was used to form 5000 bootstrap samples that were then regressed. The coefficients on the dependent variables, the constant, the R^2, and the F value were then bootstrapped. Some sample bootstrap distribution plot are shown in figures 4-17, 4-18, 4-19, 4-20, 4-21, 4-22, 4-23 for illustrative purposes. The bootstrap values and the bootstrap statistics for the variable regressions are shown in table 4-7 and for the principal component regressions in table 4-8.

Note that many of the statistics bootstrapped are close to the numbers from the original regression. In particular, the coefficient on lnPRC and the coefficient on lnYRB1, and the constant were very close to those found in the regression. These distributions are shown on the graphs, and in most cases the regression coefficient is in the middle of the distribution.

4.7. Forecasting Model

Given the extreme values that occurred with the OPEC announcements, it seems inappropriate to use a quadratic loss function, since these extreme observations are very influential in OLS regressions. The goal of the model is to predict the best all around response in the total lease revenue to changes in market conditions. Since, the "typical" situation does not include OPEC interventions, it does not seem valid to allow them to influence the model as strongly as they do in an OLS regression. Furthermore, the three influential observations are caused by a process (OPEC decision making) that is hard (or impossible) to model, so it seems

Table 4-7: Variable Bootstrap Coefficents

	OPEC	LNPRC	LNYRB1	DIFPR	CONSTANT
BOOTSTRAP COEFFICENTS					
TECHNIQUE					
OLS W/40	-	0.5621	1.8010	0.00171	8.2390
		(.219)	(.582)	(.0006)	(.802)
OLS W/43	-	0.7505	1.5622	0.00180	8.3690
		(.304)	(.703)	(.0007)	(.869)
OLS W/43&D	1.6520	0.6340	1.5990	0.00181	8.3670
	(.550)	(.199)	(.369)	(.0006)	(.773)
LABS W/40	-	0.5466	1.7540	0.00158	8.3780
		(.399)	(.681)	(.0008)	(.873)
LABS W/43	-	0.6756	1.5700	0.00151	8.5200
		(.438)	(1.16)	(.0009)	(1.55)

- - - - - - - - - - -

NOTE:The number in parenthesis is the bootstrap measure.

TABLE 4-8:

ACTUAL AND BOOTSTRAP COEFFICIENTS USING VARIOUS ESTIMATION TECHNIQUES

PRINCIPAL COMPONENTS COEFFICIENTS

	PC1	PC2	PC3	PC4	CONSTANT
COEFFICIENTS					
TECHNIQUE					
OLS W/40	1.0230	0.4024	-0.3118	-0.2450	13.185
OLS W/43	1.0507	0.4394	-0.3654	-0.3113	13.263
LABS W/40	0.9625	0.3864	-0.3820	-0.3032	13.130
LABS W/43	0.9791	0.4235	-0.3405	-0.3602	13.150
BOOTSTRAP COEFFICENTS					
TECHNIQUE					
OLS W/40	1.0220	0.3996	-0.3132	-0.2488	13.180
	(.090)	(.103)	(.072)	(.124)	(.084)
OLS W/43	1.0490	0.4379	-0.3665	-0.3159	13.260
	(.098)	(.104)	(.079)	(.134)	(.090)
LABS W/40	0.9947	0.4041	-0.3056	-0.2640	13.160
	(.124)	(.143)	(.124)	(.162)	(.137)
LABS W/43	1.023	0.4373	-0.3260	-0.3121	13.210
	(.130)	(.153)	(.126)	(.186)	(.143)

- - - - - - - - - - - -

NOTE:The number in parenthesis is the bootstrap measure.

useful to use a technique that is not highly influenced by those extreme observations, but still includes them for the potentially useful information that they contain. Various alternative methods have been explored, and the results have been presented in both statistical as well as graphical form. The variable form of the equation includes variables that are collinear with other variables in the equation and other candidate variables, so a principal components approach was taken using both least squares and least absolute deviations loss functions. All regressions where bootstrapped to examine the sampling effects and each of the methods showed varying degrees of bias.

Given all these considerations, it is the opinion of the writer that the principal component LABS regression built on all 43 observations is the most useful for predictive purposes, i.e.

$$\text{TOTAL REVENUE} = 13.50 + 0.9791PC_1 + 0.4235PC_2 - 0.3405PC - 0.3602PC_4$$

where the prinicipal components are composed of the variables, lnRR, lnST, lnYRB1, lnPP, and lnPRC as discussed earlier.

Chapter 5

The Future World Oil Market

In any long run analysis of the demand for petroleum and hence for drilling rights, it is important to consider what the condition of petroleum supplies will be in the future. The supply of petroleum is clearly related to its price. Conversely, the "market price of crude oil...has always been very sensitive to the laws of supply and demand" [20,p. 6]. As prices increase, there is a greater incentive to invest in exploration and development in order to increase production and thus profits, and if the supply is reduced for a given demand, the price will rise. The supply of oil is the sum of all oil from oil wells plus the supply of synthetic fuels from tar sands, coal liquefaction and shale. These latter sources require certain expensive production processes that are very energy intensive. As the price of energy rises, the cost of producing them also rises, therefore they are relevant only at prices high enough to pay the producer these higher costs and still generate a normal profit. There have been some subsidies paid for minor demonstration synthetic fuels plants, but all the major programs have been cancelled, so there appears to be no real supply implications for the petroleum market from these sources in the next eight to ten years.

5.1. Supply

In the event of large new discoveries in Alaska, the continental shelf or other places around the world, the price of petroleum might remain fairly constant or only decline slightly. Speculation about the crude oil reserve base is as risky as speculation about future consumption levels, and depends on assumptions of accessibility of reserves, future oil prices, discovery rates, efficiency of recovery, size of reserves and the technical details of production in less accessible areas. However, several recent studies allow us to make the following observations about the world supply of oil.

Taken as a group, the non-Communist industrialized countries will experience no significant increases in the production of oil. In fact, by the year 2000, production in these countries may decrease by as much as 50%. It appears that "...geology is the primary limiting factor" [29,p. 35].

I will forego discussion of the developed countries, with the exception of the United States, since it is the largest single producer.

United States oil production in the future will probable arise from four principal sources: (1) primary, and secondary recovery from existing proven reserves of 26.5 billion barrels [29,p. 36], (2) natural gas liquids, (3) primary and secondary recovery from additions to existing reserves and (4) the use of enhanced or tertiary recovery techniques. Primary and secondary recovery from existing reserves can be expected to decrease from 8.1 MBD in 1979 to 4.7 MBD in 1985 and 0.8 MBD in the year 2000. This assumes that all U.S. oil fields produce at a rate of 1/8 of known reserves [29,p. 37]. United States production in the year 2000 may range

Table 5-1: Petroleum Production Forecast For OECD

PETROLEUM PRODUCTION FORECASTS FOR THE DEVELOPED COUNTRIES (MBD)

	1979	1985	2000
United States	10.2	7.2-8.6	4-7
North sea	2.1	2.8-4.0	1.7-3.0
Canada	1.8	1.6-1.8	1-2
other Developed countries	.8	.8_*	.8_*
TOTAL (may not add due to rounding)	14.9	13-15.5	7.5-13

* range of production considered insignificant for estimates of total petroleum availability.

Table 5-2: U.S. Petroleum Production Forecast

U.S. PETROLEUM PRODUCTION FORECASTS (MBD)

	1979	1985	YEAR 1990	1995	2000
Primary and secondary recovery from existing 1979 reserves	8.1	4.7	2.7	1.4	0.8
Primary and secondary recovery from additons to reserves	-	0.8-1.5	0.8-2.1	0.7-2.4	0.7-2.5
Natural gas Liquids	1.7	1.2-1.5	1.1-1.4	1.1-1.3	1.0-1.25
Production from enhanced recovery techniques	0.4	0.5-0.9	0.7-1.4	1.1-2.0	1.5-2.5
TOTALS	10.2	7.2-8.6	5.3-7.6	4.3-7.1	4.0-7.0

(note:column may not sum to totals due to rounding)

Source: pages 35 & 26,
World Petroleum Availability, A Technical Memorandum
Congressional Office of Technology Assessment, Washington

between four and seven million barrels per day (MBD). The high estimate assumes the addition of one billion barrels to proven reserves and the greatly increased use of enhanced (tertiary) recovery techniques. This compares with the current U.S. production of about 10 MBD. Table 5-1 shows the projections of The Congressional Office of Technology Assessment (OTA) for the next twenty years within the Developed Countries, and Table 5-2, the breakdown of the U.S. numbers.

OPEC production is not expected to rise significantly over the next twenty years from its current level of 31 MBD. Since the end of the OPEC oil embargo in 1973, total average annual OPEC oil production has remained fairly constant, changing less than 1 MBD from the 1979 average of 31.4 MBD. Exxon estimated OPEC liquid petroleum production at 33 MBD in 1990 and 2000 [15,p. 38]. OTA estimates a range of 28.5-35 MBD by 1985 and a range of 27-37 MBD in 2000 [29].

Any possibility of increased production within the OPEC nations will have to come from Iran, Saudi Arabia, United Arab Emirates, Kuwait and possibly Iraq. The first four countries have the known reserves to sustain more than marginal increases in production. Iraq has the estimated potential to do so. This group will most likely continue to restrain production for political and social reasons rather than due to resource constraints.

While the Saudi's have the capacity to produce at levels of 12 MBD through 2005 with existing reserves [6], they have announced that their intention is not to exceed 9.5 MBD even under conditions of higher levels of capacity [32]. OTA projects Saudi production to range between 8.5 MBD and 12.0 MBD by 2000 [29].

Iranian production over the last several years has flucuated greatly. In April

1980, the production rate of Iranian crude was reported to be 2.7 MBD, by May of that year it had declined to a reported level of 1.1 MBD [31]. Both of these levels are below the pre-revolution level of 3 MBD. According to the CIA sustained levels of production above 4 MBD are "...unlikely without significant external assistance" [4].

Iraq is the biggest question mark in OPEC. Forecasts for Iraqi production are subject to the twin considerations of political and geological uncertainty. Politically, the Iraqis have expressed opposing views on the future production levels they want to maintain. The CIA reports the Iraqi oil minister has expressed a desire to produce at 60 percent of capacity [3,p. 6]. In addition the Iraqi's are currently involved in a war with the Iranians, a side effect of which has been the destruction of a substantial part of the oil transportation infrastructure at the Shatt al Arab oil terminals. However the Iraqi government is trying to assert some influence in the Third World. Petroleum Intelligence Weekly reports that as of April, 1980 the Iraqi government has announced 15 long term low interest loans in compensation for oil price hikes [30,p.15]. If this is true, the government will want to repair the damaged oil terminals and then increase production in order to use both the produced oil and the revenues from that increased production in order to maintain influence in the developing world.

From a geological point of view, there are a large number of undrilled structures in Iraqi territory. It is certain that at least a portion of these structures will yield oil in profitable quantities. In 1977, the CIA suggested possible production levels in the 5 to 6 MBD area where possible by the year 1986 [3]. In view of the currently war and the weakness in current world demand for petroleum products, these levels seem somewhat optimistic. Current plans call for an increase in sustained production to 4.5 MBD with some possible increase after 1985. OTA projects Iraqi production in the range of 2.7 to 4.5 MBD in 1985 and 3 to 5 MBD in 2000.

Abu Dhabi, the largest producer in the United Arab Emirates, has plans to increase production from 2 to about 3 MBD before the end of decade [28,p. 74]. At the present time government restrictions limit production in Abu Dhabi to 1.4 MBD. The other two emirates, Duban and Sharjah, currently lift about .4 MBD with no increase in production likely. OTA estimates total UAE production will range between the current level of 1.9 MBD to 2.5 MBD if the government restrictions are lifted [29,p. 52].

Kuwait has consistently aimed its production at conserving resources. Production was level during the years 1974-1978 at 2 MBD despite an installed capacity which would have allowed them to greatly increase production. OTA estimates that crude oil production in Kuwait for the rest of the century will range between 1.5 and 2.0 MBD [29,p. 52].

The rest of the countries in OPEC (Algeria, Gabon, Libya, Qatar, Indonesia, Ecuador, Venezuela) are producing at close to the maximum possible rate. While there is a chance for marginal increases in production in some of the countries, these may well be offset by declines in the production rates of other countries. OTA projects levels of 9.5 to 10.5 MBD for these other OPEC countries [29,P. 53]. This compares with a 1979 production average of 10.5 MBD. With the exception of

Libya, current reserves in these remaining OPEC countries are not large enough to maintain these levels of extraction through the year 2000. Thus OTA estimates a decline in production to the 8 to 10 MBD range by 2000.

There has been some discussion over what role OPEC will play in the future. This depends on their ability to maintain their cartel role in the face of increasing non-OPEC production and decline consumption in the OECD countries. Stephen Salent [37] has shown that when a production cartel does not have total control over available reserves of an exhaustible resource, the occurence of monopoly profits creates proportionally larger profits for those producers outside the cartel. This encourages greater production by the "competitive fringe", that group of producers outside the cartel who benefit by the actions of the cartel, but do not have to abide by its rules. In order to maintain price, ceteris paribus, the cartel has to cut back production. Being outside the cartel, the fringe producer has no incentive to cut back, rather the availability of reserves beyond the control of the cartel, coupled with the high rates of return available lead to more exploration and yet a larger supply. In these circumstances, the cartel is faced with either lowering production in order to maintain price, thereby lowering their market share, or reducing their price in an attempt to maintain market share. On March 3, 1983 The Wall Street Journal reported that "U.S. imports of crude oil dropped to an 11-year low in the week ended Feb. 25..." [41,p. 15]. This was due in part to the recession in the United States, and in part to increasing conservations coupled with expanding domestic production.

The higher price of oil also makes substitutes, i.e. alternative sources of energy; nuclear, coal, gas, solar, and conservation[6] more attractive. One important difference between switching to domestic from imported oil and the replacement of oil by substitutes is that many substitutes once in place will not be abandoned without a substantial and perceptibly long term drop in the price of oil. This is largely due to the high fixed cost of switching fuels. In fact, the higher the percentage of fixed (i.e. capital) cost to variable (fuel) cost, the less likely will be a switch back to oil. In the case of increased efficiency (conservation), there will probably never be a switch back to greater energy consumption per unit output over the lifetime of the plant.

All major energy use projections, even those assuming low worldwide growth in economic activity and plausible assumptions of conservation, see a gap between projected supply and demand, unless there is a substantial addition of nuclear power, which does not seem to be on the horizon. This divergence between supply and demand, market disequilibrium, will put upward pressure on oil and gas prices. The timing and extent of the price changes will depend on world economic conditions, the effectiveness of conservation programs, government policies such as taxation and regulation, and any possibility of some kind of production cut-back or embargo. The effect of synthetic fuel subsidies is interesting and somewhat unexpected. The U.S. Synfuels Corporation, the quasi-government corporation that is subsidizing the building of synthetic fuels plants

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[6]In many studies conservation is considered in both the supply and demand for energy. Given that the use of more insulation, or a more efficient car, gets the same "work" done with less energy, thus freeing up supplies of energy for other uses, I will abide by that convention.

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may ultimately be contributing to the problem of a reduced supply and thus higher prices within the continental United States. Baumol and Wolff suggest that subsidies to "innovative energy sources" have a "negative net yield of petroleum" [1,p. 892]. The subsidies cause a net decrease in petroleum yield because the inputs that could have been used in oil production are instead used in the less efficient synthetic fuel project. If the subsidies do not lead to the substitution of energy inputs throughout the economy, then the price of oil must either be high enough to eventually pay for the cost of synthetic fuel oil or the subsidy must extend indefinitely. If the subsidy is removed and the project is unable to compete successfully and folds, there is a loss of liquid fuels to the market. This supply reduction must then lead to higher prices. Thus the subsidies will have the effect of both reducing the supply of petroleum in the long-run and eventually causing an increase in the price of all liquid fuels to the extent that synthetic coal products can be substituted for petroleum products and providing the subsidy is not maintained indefinitely.

OPEC is thus doubly threatened by competition and the loss of market share. First from other producers, which can be countered with price reductions or coercion. Secondly from substitutes, which become more attractive at higher oil prices, which OPEC can not affect except perhaps in the very long run. It is worth noting that since a large percentage of the oil traded in the world market is used for transportation, with the exception of conservation the effect of substitute fuels in the world oil market will be fairly small.

5.2. Demand

The demand for any energy input is a function of two main factors – the price of energy and the level of income. As in the case of many products, price is the main determinant of demand, and with rare exceptions the quantity demanded varies inversely with the price.

The real price of oil declined from the end of World War II until 1967. This had two important effects. First, it accelerated the substitution of oil for coal, and secondly it speeded up the development of energy-intensive technologies and products while simultaneously retarded the development of energy-conserving ones. A study done in 1974 by Houthakker and Kennedy concludes that "if the [real] price of energy in 1970 had been at the 1948 level (i.e. about double the actual 1970 level), consumption in 1970 would have been 20 percent lower than it actually was".

The income effect causes the demand for energy to rise as real income rises [7,p. 34]. The current world-wide recession is having a profound effect on the demand portion of the market. A reduction in GNP has a ripple effect through out the entire economy. Reduced demand, reduced production, reduced income, reduced consumption, all lead to a smaller demand for liquid fuels. Conservation and fuel switching make it unlikely that demand will return to the pre-recession levels for sometime. Some countries have instituted mandatory efficiency levels for automobiles, the EPA fleet average requirements in the United States are one example, or have gone to considerable lengths to obtain secure sources of liquids fuels for domestic use, Brazil's alcohol fuel program and South Africa's coal liquification plants are two other examples. The argument that there exists an iron tight linkage between gross domestic product (GDP) and energy demand seems to have been discredited. During the period 1961–1973, a time when real oil prices were falling, the ratio of energy consumption to GDP rose every year in the industrialized nations. Since 1973 that ratio has been falling [36,p. 9]. A major portion of that decline has been due to reductions in industrial energy consumption. While it is certain that the relationship between gross domestic product and energy consumption is positive, its strength is uncertain. Thus an increase in GDP will tend to cause an increase in energy demand, how much is a question that still remains to be answered.

5.3. Forecasts

In addition to the previous general discussion of future oil price patterns, there are several specific forecasts available. In "World Economic Outlook", the annual review of world economic developments prepared by the staff of the International Monetary Fund, the oil market "is expected to remain weak in" 1986 and 1987, leading to a projected price decline of "2 percent in 1985 and 3.5 percent in 1986" [21,pg. 152]. After about 1990, the report suggest a "greater possibility of an increase in the real price of oil" [21,pg. 155].

The U.S. Department of Energy, Energy Information Administration forecasts the price of oil yearly in "The Annual Energy Outlook". As the forecasts in table 5-3 show DOE/EIA is calling for an increase from the current price of $28.00 in 1984 to $40.00 (in 1984 dollars) by 1995 [8, pg. 219]. This is almost a 43 percent increase in the real price of oil. The last column shows the price of oil in nominal dollars assuming a 4% rate of inflation.

Table 5-3: Petroleum Price Forecasts

YEAR	OIL PRICE (1984 DOLLARS) (DOLLARS PER BARREL)	OIL PRICE (NOMINAL) (DOLLARS PER BARREL)
1984	28.00	28.00
1985	28.00	29.00
1986	27.00	29.00
1987	27.00	30.00
1988	28.00	32.00
1989	29.00	34.00
1990	30.00	37.00
1995	40.00	60.00

Source:U.S. Department of Energy, EIA, "The Annual Energy Outlook"

Note: nominal price calculated by author assuming a 4% rate of inflation.

5.4. Discussion

The effect of these multiple demand and supply considerations is to make it difficult to accurately predict the price of oil. In the short run, it looks like the glut of oil on the market will continue for sometime, thus holding down prices. In the long run, it seems, the price of oil can only go up. Barring an almost unimaginably large discovery or a tremendous reduction in the demand for oil there seems no other conclusion that can reasonably be reached. The problem is one of determining the eventual magnitude of that increase and its timing. These are not topics I intend to pursue. There are a number of models developed by research groups across the United States that attempt to forecast the oil market with varying degrees of success. My purpose here is to present the world oil situation, and a discussion of the future with the implications for Montana resulting mostly from changes in world wide supply and thus on price.

Chapter 6

Perspectives, Policy Implications and Further Research

The primary question throughout this paper, is how the government (i.e. Montana) is to allocate non-renewable resources, using long range forecasting and planning with albeit imperfect alternatives as well as attempting to account for risk while still maximizing the present net value.

6.1. Perspectives

At the first level, there is a choice between centrally managed allocations and market allocations. Centrally managed allocations would not be acceptable to a large number of people and thus are not a politically acceptable alternative in this regard. There was some discussion of risk allocation and whether the government should be the ultimate risk bearer. The answer, on the basis of Pareto optimality criteria; and market allocations under risk, is that the government as ultimate risk bearer is inappropriate in this situation.

Chapter three introduced the concept of risk. It was mentioned that risk, the probability that things may not turn out as planned, maybe due to either inherent risk or to the decision maker's ignorance. In either of these instances, the decision-maker is faced with determining whether to live with the risk, to pay the cost of reducing it, or to compensate someone else for bearing all or a portion it.

It was also noted that risk is a real cost to decision making, and requires that real resources be included in the cost analysis of various policy actions. Thus, at a societal level, the more risk averse its people are, the more costly to society risky situations are. The net result is that whether or not government takes on risky projects, society through the individual bears the risk. The market solution allows the less risk adverse (i.e. risk takers) to specialize in risk taking.

It has been stated that in general with risk averse sellers and bidders, the optimal bidding arrangement is a bonus bid for auction with a prespecified but negotiable royalty. The use of surface rents may have some value in preventing the build up of inventories of un-drilled leases by raising the opportunity cost of holding an undrilled lease, but this will tend to distort investment by firms in those lease inventories unless the rent is kept to some "small" level. If large numbers of leases are being purchased and held as inventory, this suggests that the leasing rate is too rapid. Firms may perceive that it is in their best interest to purchase leases at a lower rate now, anticipating that the price will increase to the point that it pays to hold the leases as an investment. In most cases, the bonus payment will be large enough to encourage fairly rapid development, and coupled with the uncertainty in the price of oil, will reduce the necessity for large surface rents as a policy option.

Chapter four developed an empirically descriptive model that can be employed to predict revenue from the lease auctions in the future given a number of variables. This is a tool that can be used to plan the timing of revenue from those sales in such a fashion as to maximize the return to the state. The coefficient on the OPEC intervention variable indicates that the market responses in a significant way to shocks, such as those produced by the oil embargo and subsequent price hikes. While this type of market intervention is impossible to forecast, it must be kept in mind that any future shocks are likely to also affect the market in a similar fashion.

Chapter five discussed the future world oil situation with an eye toward the effect supply and demand changes will have on the market in Montana.

6.2. Policy Implications

One of the main advantages of using bidding as an allocative device is that it minimizes the amount of information the State (as seller) must have about a specific tract to be leased. There is a trade-off between risk and knowledge. If the rule of not accepting bids on tracts with less than four bidders is followed, as well as other suggestions made previously, the only information the state needs is economic information about the demand for lease tracts. Hopefully, this paper will make that type of analysis a little easier.

In general, the policy options presented throughout this discussion have been fairly straight forward. One can not, however make policy decisions on the basis of economic analysis alone. Some policy implications can be noted for firms and consumers, as well as the government.

Since the level of information that the bidders have is so important the government needs to insure that there is equal access to information by all interested parties. However, this is not to be construed as meaning that the State should disseminate information or that it should require that firms doing exploration disseminate their information. On the contrary, since much of the information is gathered by firms that specialize only in gathering and interpreting that information, these types of requirements would have adverse economic impacts on those very firms that are well qualified to gather such information. Anyone can purchase that information from a firm that has done or will do the research and processing necessary without requiring the bidder to acquire the equipment and expertise to do the work himself.

Assuming these recommendations have been followed the "best" or optimal procedure is to use a sealed discriminatory bid procedure; that is, bids are submitted in sealed envelopes and the highest bid wins. This serves as a precaution against collusive behavior by the bidders, and prevents the free-rider problem among bidders. The amounts bid, but not the names of the unsuccessful bidders, should be published after each auction as this will provide information about the merits of various lease areas to other potential bidders. The requirement of sealed bids will prevent the use of signals between competitors during bidding, and inhibit collusion.

One of the striking results of this analysis is that the government need not engage in gathering information about specific tracts. The only information that the government needs is of an economic nature, as has been developed in this paper. It is certainly easier and cheaper to develop economic data than to gather field data for all the tracts being offered at auction each year.

6.3. Further Research

This study has pointed up several areas in which further research would be useful. The most significant is the whole question of lease timing. As it stands right now, the State of Montana has no way of controlling the timing of tract leases. It would be useful to examine how alternative timing schemes could have altered the discounted net revenue to the state. The model, developed in chapter five, could be employed to examine the effects of alternative lease tract timing. Another area of research that could be examined is the question of why some tracts sell and others don't. Using either discriminant analysis or logit/probit analysis, the researcher could attempt to predict whether a particular tract would sell or not, given certain conditions.

In conclusion, while no specific policy recommendations can be made, a number of suggestions and their rationale have been. It is hoped that the analysis and suggestions presented in this paper will help to clarify the process of oil and gas leasing and acquaint the reader with some of the issues and alternatives that should be considered when discussing the policy options available.

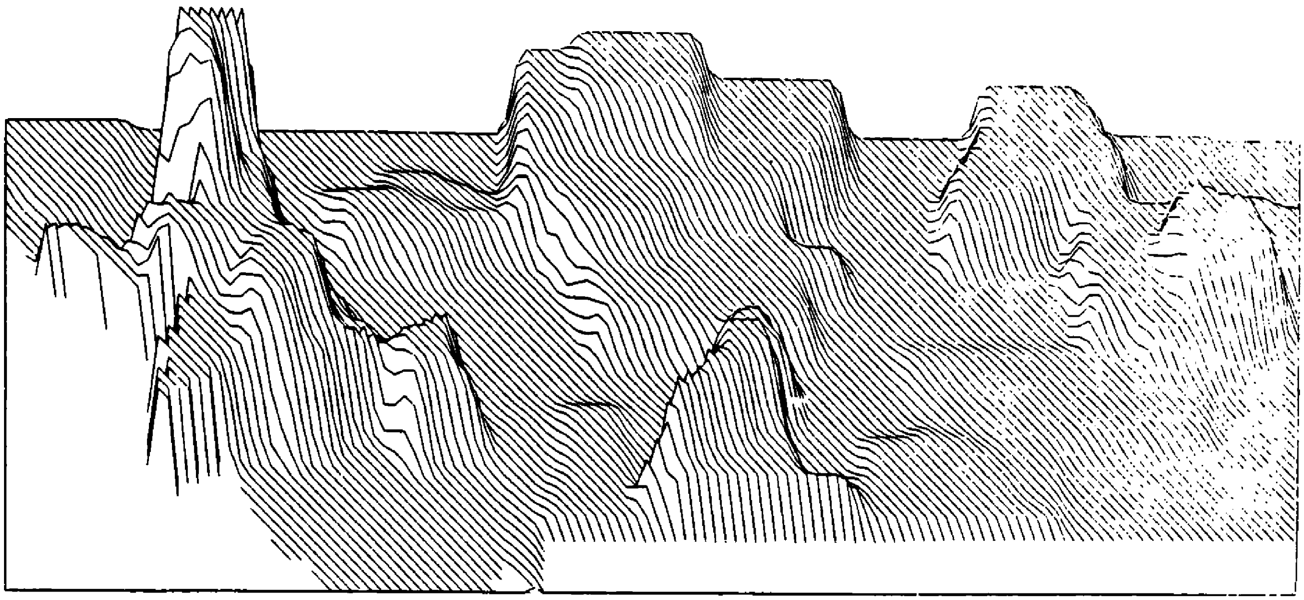
Appendix A

Leasing Patterns

This appendix shows the changing lease patterns across the state during the lease period 1971 - 1981. There are three different approaches illustrated. The first, in figure A-1 shows the acres of land being leased in each county as the vertical axis. The second, figure A-2, shows the price paid per acre in each county, and the third, figure A-3 the total revenue from the sale of the leases in that county.

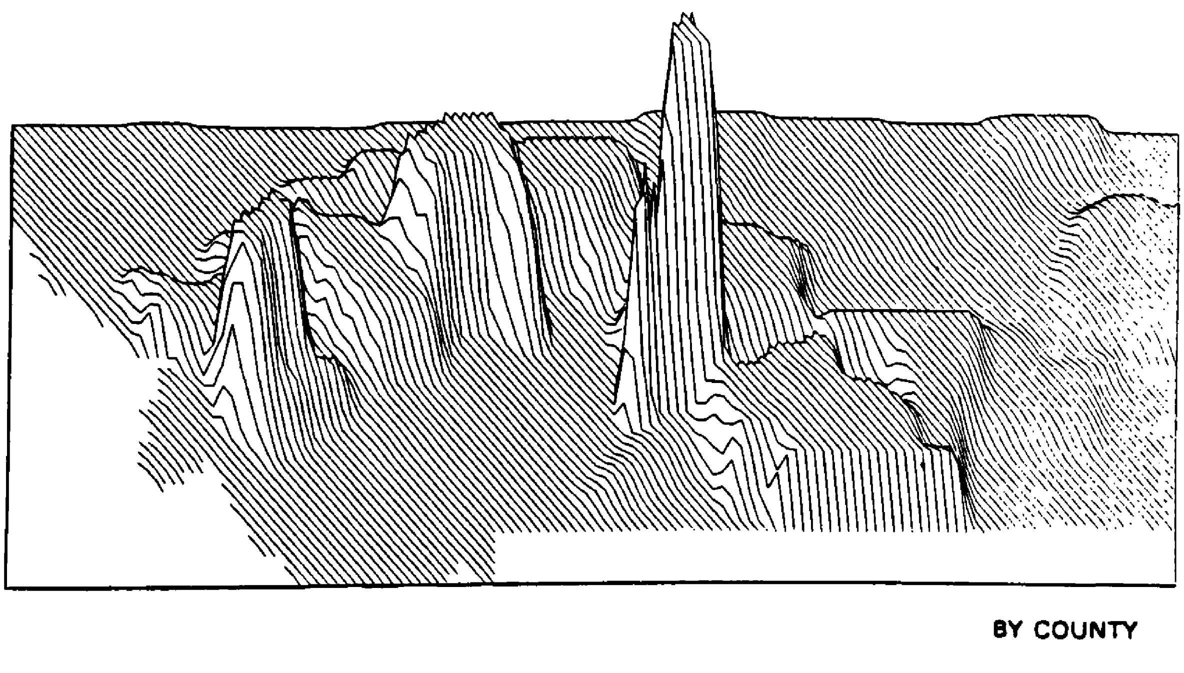
Figure A-1: Lease Acres

TOTAL ACREAGE LEASED - 1971



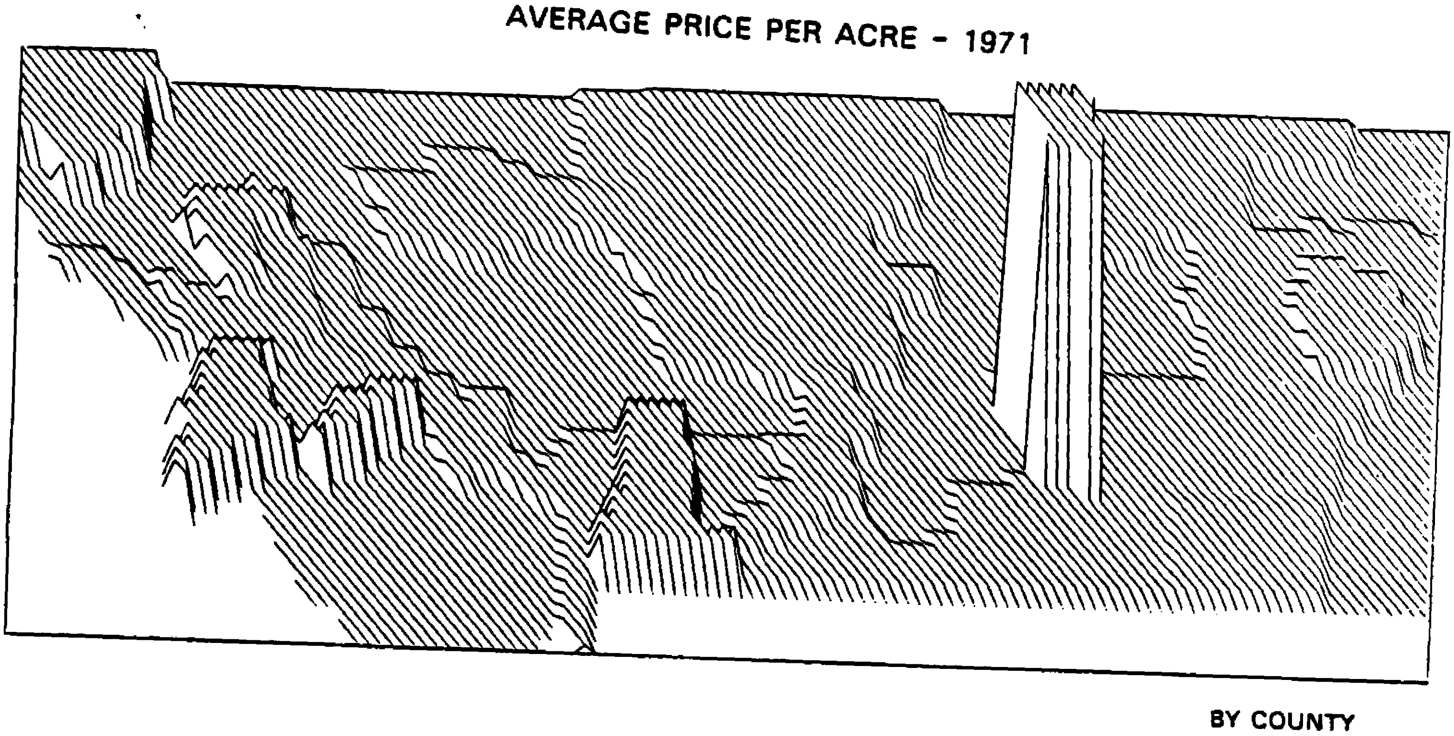
BY COUNTY

TOTAL ACREAGE LEASED - 1981



BY COUNTY

Figure A-2: Price Per Acre



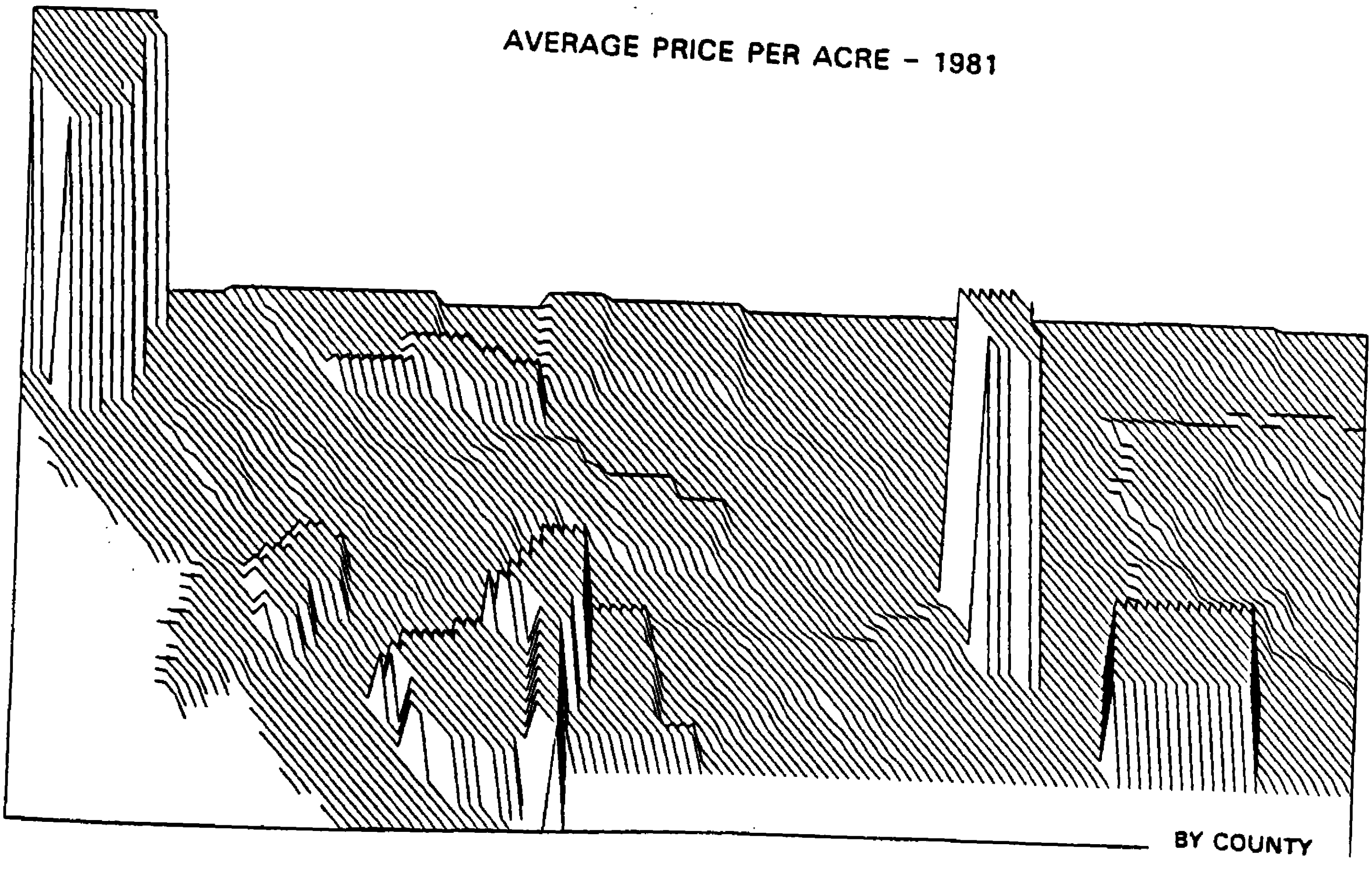
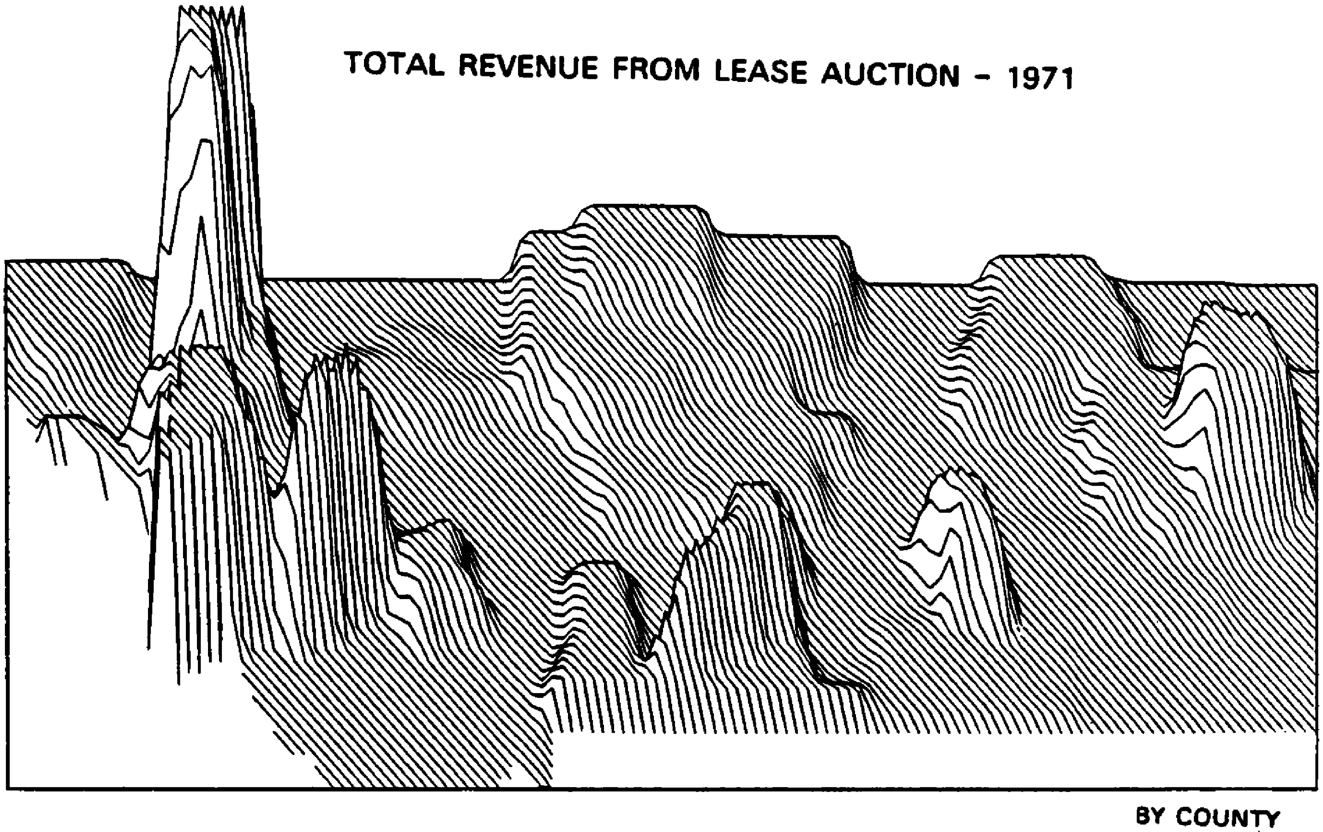
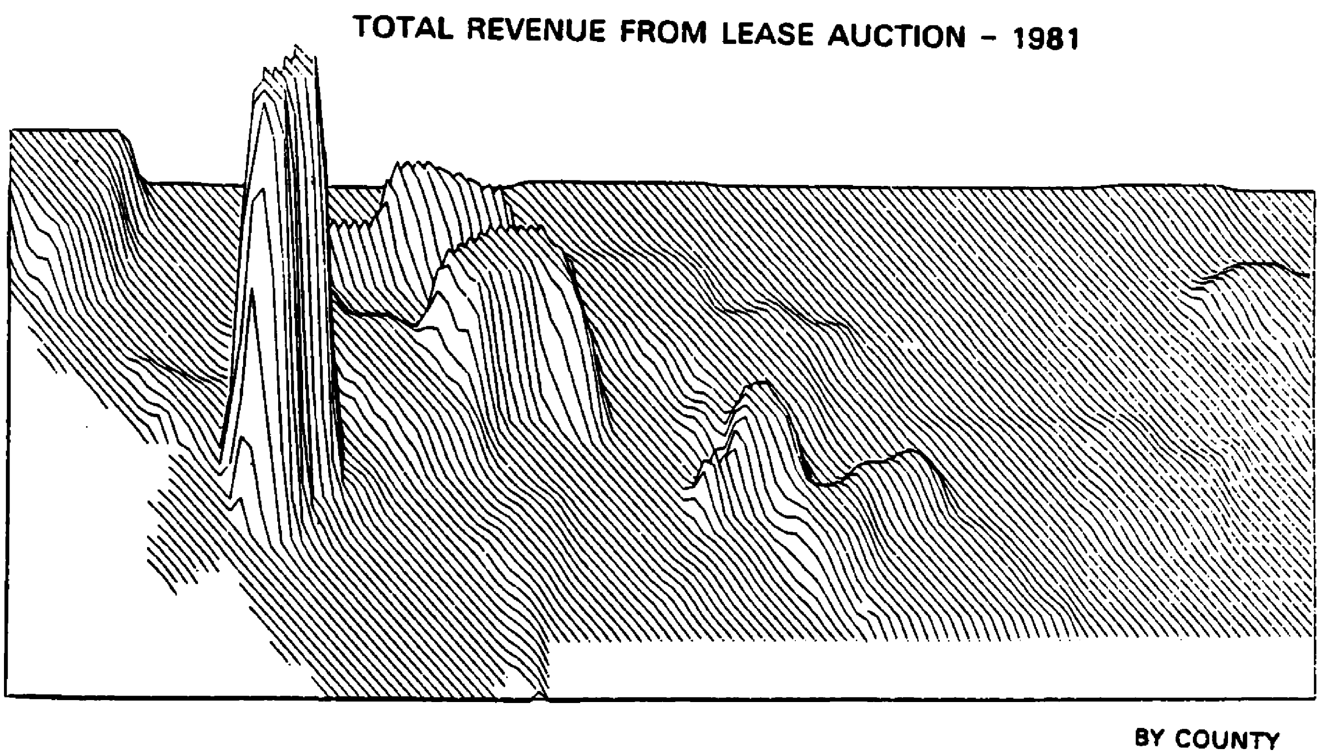


Figure A-3: Total Lease Revenue





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