OPTIMAL PROFIT SHARING RULES FOR PETROLEUM EXPLORATION AND DEVELOPMENT IN JORDAN

By

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B.A. Economics
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(1981)

Submitted to the Sloan School of Management
in Partial Fulfillment of
the Requirements of the Degree of
Master of Science in Managment

at the

Massachusetts Institute of Technology

May 1988

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ABSTRACT

In mid 1986 the Hashemite Kingdom of Jordan signed petroleum exploration and development agreements with two U.S. oil companies. These agreements cover tracts in the Jordan Valley, Azraq and Al Jafr regions of the country. Under the terms of the agreements, a company is required to pay for all exploration and development costs. If oil is discovered , it will receive a fixed share of annual oil production, roughly 25%, plus a phased in recovery of exploration and development costs.

These agreements suffer from two types of incentive problems. Firstly, an exploration effort incentive problem in which a contractor chooses exploration effort levels that are generally too low in relation to the level of effort that maximizes total project expected profits. Secondly, an undercompletion problem in which a contractor chooses to forego development of jointly profitable petroleum discoveries, because its share of development profits is not sufficient to cover the development costs it must bear.

This thesis develops an exploration effort-probability of discovery model which is used to quantify the magnitude of the incentive costs in the Jordanian contracts. These incentive costs are measured as the difference between the expected profits that Jordan would receive under the terms of the 1986 Agreements and under agreements in which Jordan is assumed to have both perfect and imperfect information regarding contractor exploration and development effort.

Thesis Supervisor: Professor John E. Parsons
Title: Assistant Professor of Finance

Acknowledgements

I would like to thank John Parsons and Charles Blitzer for suggesting my thesis topic and providing guidance in dealing with the theoretical and practical issues I encountered while grappling with it. Raghuram Rajan saved me much time and effort by providing me with GAMS routines for the empirical analysis. Mike Lynch and Manoj Shahi of the MIT Energy Lab were especially helpful in my search for realistic exploration and development cost data. Finally, Gordon Kaufman patiently explained to me some of the finer points of state of the art geological models.

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1.0 Introduction

1.1 Problem Definition

In mid 1986 the Hashemite Kingdom of Jordan signed oil and gas exploration and development agreements with two U.S. oil companies.[1] These agreements cover tracts in the Jordan Valley, Azraq and Al Jafr regions of the country.[2] Under the terms of the agreements, a company is required to pay for all exploration and development costs. If oil is discovered, it will receive a fixed share of annual oil production, roughly 25%, plus a phased in recovery of exploration and development costs. The rate of recovery of exploration and development costs is subject to an annual limit equal to 40% of the value of oil production in a given year.[3]

Two types of incentive problems may arise from this agreement sharing rule. Firstly, a contractor may choose a level of exploration effort that is too low in relation to the effort that maximizes total project expected profits. Secondly, a contractor may choose to forego development of a jointly profitable oil discovery, because its share of profits is not sufficient to cover the development costs it must bear. In either case, the resource owner (Jordan) may experience lower expected profits than would be the case under alternate profit sharing rules.

Typically, exploration effort incentive problems arise because a resource owner cannot precisely monitor a contractor's level of exploration effort. If the probability of discovering oil depends direclty on the level of exploration effort, a resource owner must gear its reward structure to discovery size. Thus, only indirectly through a discovery contingent reward mechanism is a contractor induced to undertake a particular level of exploration effort. Depending on the structure of a reward mechanism, a contractor may or may not choose a level of exploration effort that maximizes total project expected profits. Not surprisingly, we see that reward mechanism (sharing rule) design not only influences the relative profits of the parties to an exploration and development agreement, but also the magnitude of total profits to be shared. Note that the exploration effort incentive problem may be exacerbated by the undercompletion problem, because foregone jointly profitable discovery developments reduce the magnitude of total profits available for sharing.

These two types of incentive problems are very likely to occur for the Jordanian exploration and development contracts. The government of Jordan does not possess the necessary technological expertise to develop domestic petroleum reserves itself nor the information to perfectly monitor the activities of an outside contractor. Hence, a contractor is relatively free to choose a level of exploration effort that is in its own interests and not necessarily those of Jordan. Also, after making a discovery a contractor is relatively free to choose whether to develop it because only the contractor possesses the relevent information as to discovery size, development costs and so on.

I propose to quantify the potential incentive problems inherent in the structure of these Jordanian petroleum exploration and development contracts using an approach developed by Grossman and Hart (1983). To achieve this objective, an exploration effort - discovery size probability model is developed to calculate the expected profits to Jordan under three possible sharing rules:

(1) A first best sharing rule under which Jordan can capture all discovery development profits. This requires that Jordan can perfectly monitor exploration effort and thus structure a "forcing contract" which only just compensates a contractor for putting forth a particular level of exploration effort. This level of effort is set so as to maximize the expected value of potential discoveries less exploration costs. Under a first best rule, a contractor receives a fixed payment for its effort, while Jordan recieves an uncertain payment that depends on the amount of oil discovered.[4]

(2) A second best sharing rule under which both Jordan and a contractor "share" the profits of oil discoveries with the contractor bearing all exploration costs. This contract structure recognizes the fact that Jordan cannot perfectly monitor a contractor's exploration effort and must therefore create a reward mechanism that links exploration effort to discovery size. A second best sharing rule is a constrained optimum in the sense that Jordan can structure the rule to maximize its own expected profits subject to some given maximizing behaviour of a contractor.[5] Assumptions regarding a contractor's behaviour toward risk will determine the extent to which second best expected profits are less than first best expected profits.

(3) The 1986 Agreement sharing rule under which both Jordan and a contractor "share" oil production in the manner described above.

Using this framework incentive costs can be measured as the difference between expected profits under a first best sharing rule and expected profits under a proposed alternative. The the closer a contractual sharing rule comes to a first best theoretical optimum the better it is.

Blitzer, Cavoulacos, Lessard and Paddock (1985) and Blitzer, Lessard and Paddock (1984) have identified a number of risk related issues that should be factored into the design of exploration and development contractual arrangements, namely:

(1) commodity price risk;

(2) geological risk;

(3) investment cost risk - cost overruns in both exploration and development;

(4) fiscal risk - risk that the host government will change tax structures, impose exchange controls or institute other fiscal measures that while not directly related to the contract will have a substantive effect on ex post returns.

(5) political risk - risk that the host government will unilaterally change some or all of the contract terms ex post.

They assert that "pareto improvements" in contract structure can be achieved by explicitly allocating specific risks to particular parties according to their ability to bear these risks. For example, if a host country's GNP is highly correlated with oil prices, then a pareto improvement may be achieved by allocating this risk to a multinational oil company, which has investors who can diversify away this risk in international equity markets.

Since the focus of my analysis is on the incentive problems of petroleum exploration and development contracting, the sources of risk mentioned above are not treated explicitly in the analysis, but are taken as given. However, this does not imply that the above issues cannot be treated in a fashion consistent with the framework of Grossman and Hart. Political risk, commmodity price risk and fiscal risk could result in different valuations of oil discovery sizes by both Jordan and a contractor. Oil discovery valuation differences could arise because each party may have different discount rates and a priori probability distributions for key variables. These factors can be explicitly allowed for through alternate specifications of the objective functions and constraints of each party within Grossman and Hart's optimization framework.

1.2 Overview of Study Methodology

The exercise of empirically estimating the incentive problems of the 1986 Jordanian contracts is broken down into three parts.

(1) Valuation of petroleum discovery sizes via a capital budgeting model that calculates the net present value of cash flows for developing a discovery of a given size.

(2) Estimation of an exploration effort - discovery size probability matrix that relates exploration effort, as measured by the number of wildcat wells drilled, to the probability of finding an oil discovery of a given size with an NPV estimated according to (1) above.

(3) Calculation of ex ante benefits to both Jordan and the contractor under first best, second best and the the 1986 Agreement sharing rules. Ex ante benefits will depend on the number of wells drilled and the type of sharing rule employed.[5]

The theoretical and empirical issues required to accomplish (1) through (3) above are addressed in Sections 2.0 to 6.0. Section 2.0 provides an overview of Grossman and Hart's theoretical framework for analysing incentive problems, as well as discusses the strengths and weaknesses of their approach for this particular application. Section 3.0 summarizes the terms and conditions of the 1986 Jordanian contracts and their implications for sharing the benefits of discovery development. Section 4.0 develops a financial model of exploration and development cash flows and overlays a standard capital budgeting methodology to estimate total project value, as well as value under the sharing rule implicit in the 1986 Agreement. Section 5.0 provides estimates of exploration effort - discovery size probability matrices under a number of assumptions about the geological structure of the Jordanian exploration tracts and the productivity of wildcat well drilling. Finally, Section 6.0 provides a number of empirical estimates of the incentive costs of the 1986 Jordanian contracts relative to first best and second best sharing rules using the technology developed in the previous sections.

1.3 Summary Of Empirical Results

The analysis of Section 6.0 reveals that there are potentially large incentive costs under a number of circumstances. If the sharing rule implicit in the 1986 Agreements is implemented, then Jordan's ex ante expected profits are likely to be significantly lower than first best and second best expected profits for low to moderate levels of potential oil discoveries. Specifically, with median oil discoveries of 500 to 2500 barrels per day with logarithmic variance of 20%, the incentive costs of the 1986 Agreement will range between 100% and 30% of first best expected profits and 100% and 12% of second best expected profits.[6] As discovery potential increases, the incentive costs of the 1986 Agreement sharing rule falls. For median discovery levels of 5000 barrels per day, the incentive cost falls to 18% of the first best expected profits and will continue to fall to around 10% of expected profits for median discovery sizes of 25,000 barrels per day or more. For median discovery sizes of 25,000 barrels per day second best incentive costs are in the 1% to 4% range, depending on wildcat probability level. Table 1.1 provides estimates of expected profits to Jordan under first best, second best and 1986 Agreement sharing rules for a number of geological scenarios.

Analysis indicates that second best sharing rules are feasible even for very low median oil discovery levels of around 500 barrels per day and that for median discovery levels of around 1,000 barrels per day their incentive cost is a very respectable 36% of the first best expected profit. As median discovery levels rise to 10,000 barrels per day or more, second best incentive costs fall well below 4% of first best expected profits.

The most striking result of the empirical analysis is that the shape of the 1986 Agreement sharing rule is radically different from the shape of the second best sharing rules. Figures 1.1 and 1.2 sketch the shape of the 1986 Agreement and second best sharing rules. Not surprisingly, we see that the contractual sharing rule is not generous enough relative to the second best sharing rule at low realized discovery sizes (500 to 5,000 barrels per day) and is too generous at high realized discovery sizes (10,000 + barrels per day). These differences result in significantly lower expected profits for Jordan.

Table 1.1

Expected Profits Accruing To Jordan

Median Discovery Size (bbl/day)	1986 Agreement ($ M)	First Best Rule ($ M)	Second Best Rule ($ M)
Wildcat Probability = 0.2			
500	0.0	10.4	7.0
1,000	0.0	36.5	27.4
2,500	110.0	148.4	124.7
5,000	325.0	400.9	356.0
10,000	911.3	1,068.1	989.8
25,000	3,456.7	3,922.5	3,757.8
Wildcat Probability = 0.4			
500	0.0	14.7	11.6
1,000	28.9	42.6	35.5
2,500	129.0	157.0	136.8
5,000	359.8	411.4	381.3
10,000	952.5	1,080.6	1,021.6
25,000	3,499.1	3,937.2	3,835.5
Wildcat Probability = 0.6			
500	0.0	16.6	14.3
1,000	37.9	44.1	39.0
2,500	139.1	160.4	148.1
5,000	368.2	415.6	393.8
10,000	970.7	1,085.4	1,047.7
25,000	3,544.9	3,943.0	3,874.9

Figure 1.1

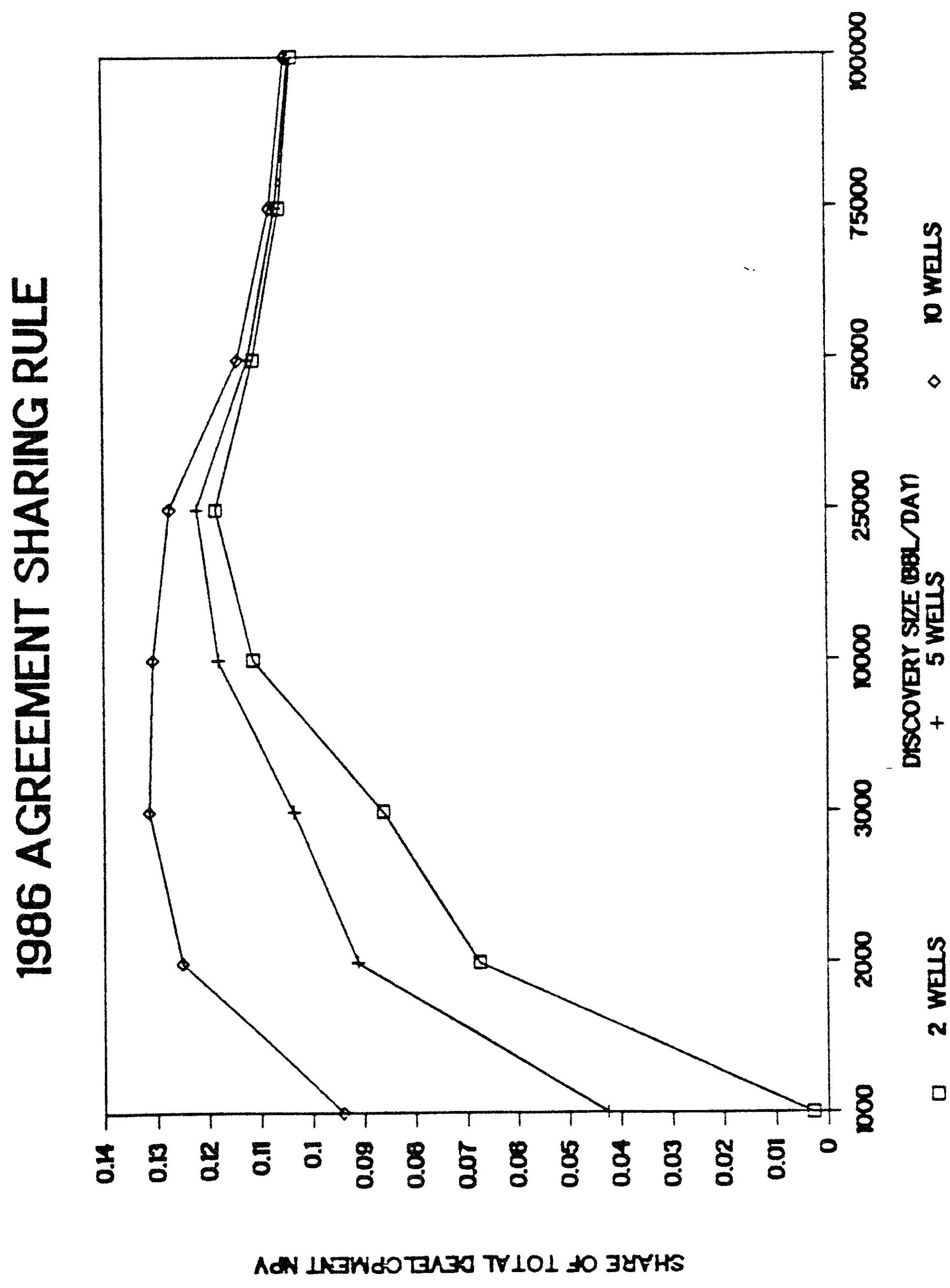
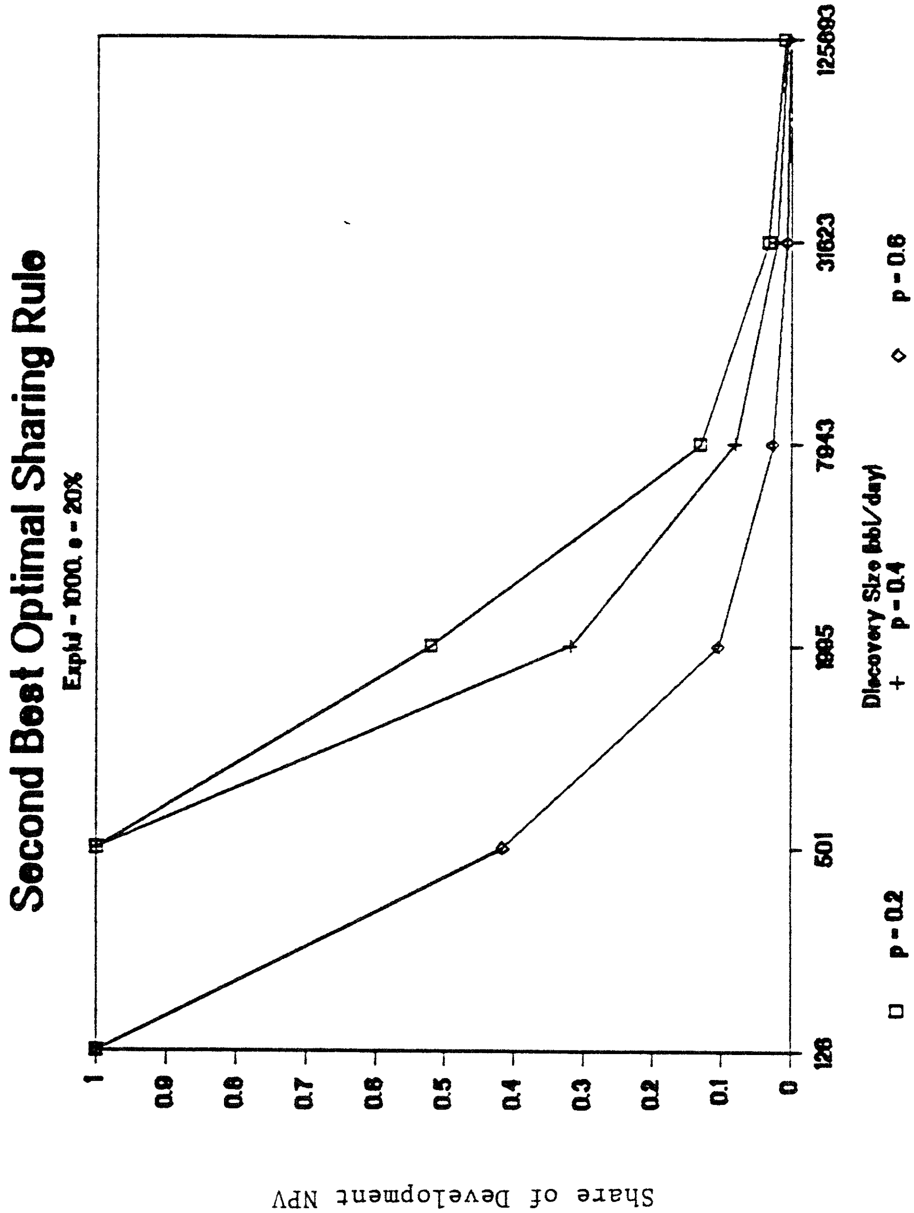

1986 AGREEMENT SHARING RULE
SHARE OF TOTAL DEVELOPMENT NPV
0.14
0.13
0.12
0.11
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
1000
2000
3000
10000
25000
50000
75000
100000
DISCOVERY SIZE (BBL/DAY)
2 WELLS
5 WELLS
10 WELLS

Figure 1.2


Second Best Optimal Sharing Rule
Discovery Size (bbl/day)
Share of Development NPV
126
501
1995
7943
31623
125893
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
p = 0.2
p = 0.4
p = 0.6

2.0 A Framework For The Analysis Of The Exploration Effort Incentive Problem

2.1 A Principal-Agent Approach

The purpose of this section is to introduce both a methodology and a terminology with which to analyze the incentive problems imbedded in the structure of the 1986 Jordanian contracts for petroleum exploration and development. It is of interest to determine whether the production sharing rules outlined in these contracts can be "improved" upon from the perspective of Jordan, the owner of the petroleum resources. "Improved" means whether Jordan's ex ante expected profits can be increased by using alternate petroleum output or cash flow sharing rules.

This exploration and development contracting problem can be examined within the context of the principal-agent literature, where Jordan is considered the principal and the oil company is considered the agent. Grossman and Hart (1983) provide an empirically tractable approach to the principal-agent problem which is briefly summarized in this section. Formally, the principal is assumed to be a risk neutral, expected profit maximizing entity, whereas the agent is assumed to be a risk averse, expected utility maximizing entity. The principal must delegate the running of a project to an agent-manager, whose specific actions (effort levels) cannot be directly observed. However, the principal can observe the outcomes of these actions, which are taken to be the project's possible profit levels. The relationship between an agent's efforts and a project's possible outcomes is characterized by an (n x m) effort-outcome matrix, whose ij-th element denotes the probability of gross profit level j, conditional on action i.

Grossman and Hart's approach decomposes the principal's problem into a computation of the profits of each action taken by an agent and a choice of the profit maximizing action. The principal chooses the incentive scheme which minimizes the expected cost of inducing an agent to choose that action. Under the assumption that an agent's preferences over outcomes are independent of the action taken, the cost minimization problem reduces to a convex programming problem. The principal solves the convex program for each action available to an agent and subtracts the expected cost of inducing an agent to take the action from the expected profits of the action to arrive at a net profit. The action (and accompanying incentive scheme) which yields the highest net profit to the principal, will yield his optimal strategy. Grossman and Hart refer to this optimal strategy as the "second best" outcome, given that the agent's actions are unobservable to the principal.

The principal's programming problem can be represented as follows. Choose $I_1 \ . \ . \ . \ I_n$ to minimize:

$$C(a_k) = \sum_{i=1}^{n} p_i(a_k) I_i \quad ; \tag{1.1}$$

$$\text{s.t.} \quad \sum_{i=1}^{n} p_i(a_k) U(a_k, I_i) \geq U^* \tag{1.2}$$

$$\text{s.t.} \quad \sum_{i=1}^{n} p_i(a_k) U(a_k, I_i) \geq \sum_{i=1}^{n} p_i(a_j) U(a_j, I_i)$$

$$\text{for all } j = 1 \ldots m \text{ actions} \tag{1.3}$$

a_k = cost of actions $k = 1 \ldots m$ available to agent

I_i = outcome contingent renumeration paid by principal to agent

$U(a,I)$ = agent's utility function assumed to be twice continuously differentiable

$p_i(a_k)$ = probability of outcome i conditional on action k

U^* = agent's reservation level of utility

$C(a_k)$ = expected cost to principal of inducing agent to undertake action k

The optimization problem outlined above states that a principal can determine the least cost incentive scheme that induces an agent to undertake a particular action by minimizing expected cost, equation (1.1), subject to the constraint that the agent is an expected utility maximizer, who will not undertake a particular action unless the expected utility from undertaking that action dominates the expected utility from undertaking all other actions, equation (1.3), and yields a utility as least as great as his reservation utility which he forgoes by undertaking the project, equation (1.2).

The set of solutions to the above programming problem can be represented by the ordered triplets $(C_k, a_k, \underline{I}_k)$, $k = 1 \ldots m$. Thus for each action, a_k, the principal can determine the least cost incentive scheme, $\underline{I}_k$ (a vector of incentives for each outcome q_i), which will induce an agent to undertake action a_k at least expected cost, C_k. Hence, a principal's optimal strategy will be the incentive scheme which maximizes his expected profits:

B_k - C_k over all actions k = 1 ... m, where (1.4)

$$B_k = \sum_{i=1}^{n} p_i(a_k)q_i \quad \text{expected gross profit to principal for action } k \tag{1.5}$$

q_i = project outcome to be shared i = 1 . . . n

Denote the optimal strategy as the ordered triplet $(C', a', \underline{I}')$, where $B' - C' = \text{argmax}\ \{k\}\ B_k - C_k$.

Grossman and Hart's analytical framework allows for a relatively straightforward calculation of the costs of employing an agent to manage a project relative to a "first best" situation, where the principal can either directly observe an agent's effort levels or can undertake the project itself. This "agency cost", AC, is calculated as:

$$AC = FB - (B' - C'), \text{ where} \tag{1.7}$$

$$FB = \text{argmax}\ \{k\}\ B_k - a_k \tag{1.8}$$

The "first best" and "second best" expected net profit levels are useful benchmarks with which to compare the expected profits of other contract forms and thus judge their ex ante economic efficiency. Section 2.2 below attempts to motivate the application of this methodology to the 1986 Jordanian contracts.

2.2 Application of The Principal-Agent Framework To The 1986 Jordanian Contracts

Petroleum exploration and development can be viewed as a process in which prior to exploration an oil company faces an a priori probability distribution characterizing the magnitude of potential petroleum discoveries. This a priori probability distribution is based on current information regarding the geological characteristics of the area under investigation. Using this information, a decision is made concerning exploration effort, i.e, how many wildcat wells to drill. After drilling, if a discovery is made, then the magnitude of potential petroleum resources is known to a far greater degree of certainty. However, if no discovery is made, some information concerning the potential magnitude of petroleum reserves is still gained. One can view the exploration process as a Bayesian updating process in which after each round of drilling prior probability distributions concerning the magnitutde of oil discoveries are updated to form posterior distributions, which are in turn used to determine the optimal drilling effort for the next round of exploration. Therefore, in theory at least, the optimal intertemporal drilling program can be solved by means of a dynamic program, in which the economic agent seeks to maximize ex ante expected profits or utility at each point in time in a recursive fashion. In order to fit the general characterization of the exploration and development decision making process into Grossman and Hart's framework, it is necessary to collapse the intertemporal exploration decision problem into a single period decision problem. This can be accomplished by characterizing the exploration-development decision process as follows:

(1) Choose a once and for all level of exploration effort, i.e, number of wildcat wells to be drilled. Drilling may or may not lead to a discovery.

(2) If oil is discovered, choose to develop the discovery, if it is profitable to do so.

The above characterization of the exploration-development process suggests an effort-outcome probability matrix of the type used by Grossman and Hart. This probability matrix can be constructed by determining the "value" of a discovery of a certain size and then using geological data to determine the probabilities of achieving these discovery sizes, given certain levels of drilling effort.

Section 4.0 develops a capital budgeting methodology to estimate the present values of each discovery size for the project as a whole, as well as to Jordan and an agent-contractor under terms of the 1986 Agreement. Section 5.0 develops a methodology to estimate the probabilities of achieving given discovery sizes based on exploration effort, i.e, the number of wildcat wells drilled.

There are two fundamental problems with the approach I am using to estimate incentive costs of exploration and development contracts. Firstly, collapsing the exploration - development decision making process into a static optimization program ignores efficiency gains that could be achieved by using a dynamic decision making process that responds to information as it is revealed. Secondly, there is a potential inconsistency in using an expected utility maximizing framework for the agent in the exploration effort decision and an NPV approach in the discovery development valuation. It would undoubtedly be better to use an expected utility approach throughout, perhaps even for the principal's objective function.

Despite the above mentioned conceptual problems, Jordan's contracting problem still fits nicely into Grossman and Hart's framework. Jordan, clearly the principal in this application, owns the petroleum resources, but cannot exploit them itself, because it lacks the technological expertise to do so. It must rely on experienced contractors, namely, multinational oil companies to accomplish this. If Jordan wishes to maximize expected profits subject to the fact that a given contractor is a risk averse expected utility maximizer facing an exploration effort-discovery size probability matrix of the type described above, a "second best" sharing rule can be constructed to achieve this objective by solving the static programming problem described in equations (1.1) - (1.3) above.

It is natural enough to ask, under what conditions is it reasonable to apply this approach to the 1986 Jordanian contracts? One possible explanation is that the managers of the contracting companies are risk averse and that they project their own personal risk aversion into their analyses exploration decision. Recent organizational behaviour literature suggest that this may indeed be true. In the spirit of Grossman and Hart, I will assume this as given.

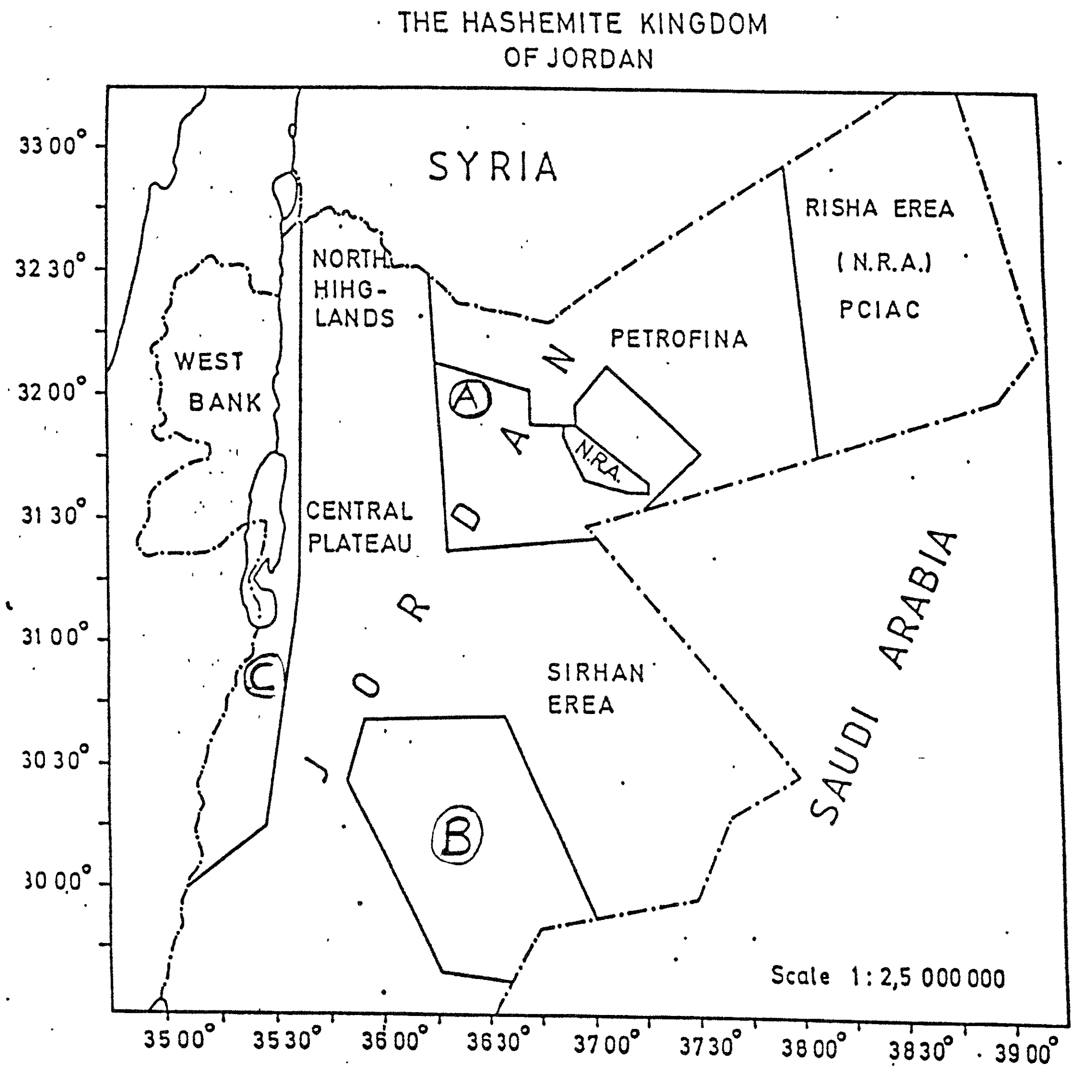
3.0 Terms and Conditions Of The 1986 Jordanian Contracts

The petroleum exploration and development agreements signed by the two U.S. oil companes are for contract areas of 10,950 and 8,806 square kilometers within Jordan. The Natural Resources Authority of Jordan (NRA) is the official signatory on the part of Jordan and is responsible for overseeing Jordanian interests throughout the duration of the contracts. Because the details of these agreements are confidential, as well as different for each company, I will not disclose which agreement is associated with which company nor with which specific geographic region within Jordan. It will suffice to mention that the agreements cover tracts in the Jordan Valley, Azraq and Al Jafr regions of the country. See Figure 3.1 for a map of these areas.

To date some 43 exploratory wells have been drilled within Jordan, 5 of which are current producers of oil. Production ran at a rate of 42,000 barrels per year in the first half of 1986 - the last period for which officially published figures are available. The geology of the Jordan Valley, Azraq and Al Jafr areas are all quite different. See Table 3.1 for details. Further geological and seismological data are available in an NRA publication "Petroleum Exploration Opportunities In Jordan". The interested reader is referred to this source for additional information.

I propose to provide a detailed analysis of only one of the exploration and development agreements, given that a similar analysis could be conducted on the other. The basic structure of each agreement is close enough that the general conclusions concerning the

Figure 3.1



A = Azraq Region
B = Al-Jafr
C = Jordan Valley

incentive problems in each case would more than likely be the same. For the above mentioned reasons of confidentiality, I will refer to the agreement under consideration as Agreement A and the associated company as Company A. The salient features of Agreement A are outlined below.

Table 3.1

Summary Of Exploration Area Geology

Azraq

Plays:	downthrown Fuluk block, upthrown Fuluk block en echelon anticlines, west margin updip anticlines
Reservoirs:	Triassic sand and carbonates, Albian-Aptian sandstones Cenomanian-Turonian carbonates, Capanian sandstones
Source Rock:	Cenomanian-Turonian marls, Triassic shales Paleozoic shales
Seal:	shales Evaporites

Jordan Valley

Plays:	en-echelon folds, horsts, drape
Reservoirs:	tertiary
Source:	Maestichtian
Seal:	salt

Al-Jaer

Plays:	basement arches with drape
Reservoirs:	Paleozoic
Source:	silurian
Seal:	shales

Source: Natural Resources Authority of Jordan, "Petroleum Exploration Opportunities In Jordan", Amman, Jordan, 1986.

Agreement A is divided into two phases, an exploration period and and a commercial development period. The initial duration of the exploration period is 3 years, if no commercial discovery is made, the exploration period may be extended twice at the option of the contractor for 2 years and 2 1/2 years, respectively.

There are a number of minimum exploration commitments, which are as follows:

- o minimum $2 M exploration expenditure and one wildcat well drilled during the initial 3 year exploration period
- o minimum 2 wildcat wells drilled and 750 line km of seismic data processed during each extension period

Also, the contractor must relinquish 25% of the original exploration area during each extension period.

The contractor is responsible for all exploration and development costs. These are recoverable from 40% of discovered crude oil production ("cost petroleum") according to a recovery formula. This recovery formula divides "cost petroleum" on a pro rata basis between Jordan and Company A according to the total each party has outstanding in the cost recovery pool. In the case of Company A, exploration costs, development costs factored in at a depreciation rate determined by Jordanian tax law, and production costs would be included in its portion of the cost recovery pool. In the case of Jordan, recoverable costs include a $13 M seismic and exploration data "fee" that is only recoverable if a commercial discovery is made. The remaining 60% of crude oil production plus any cost petroleum not used for cost recovery ("shared petroleum") is divided between Jordan and Company A according to the sharing rules listed in Table 3.2 below.

Table 3.2

Incremental Oil Production Sharing Rules[1]

Production Level	Jordan	Contractor
0 - 25,000 bbl/day	.75	.25
25,000 - 50,000 bbl/day	.78	.22
50,000 + bbl/day	.80	.20

1. These sharing rules imply that Company A receives 25% of the first 25,000 barrels per day of oil, 22% of the next 25,000 and 20% of all remaining daily production. These sharing rules are applied to the 60% of total production available for sharing. The remaining 40% of production is used for cost recovery, until all costs are recovered, then it is shared as above. A full example is presented below.

The contractor must also pay a number of bonuses to Jordan that are dependent on discovery size. These bonuses are considered non-recoverable payments under the conditions of the contract. Table 3.3 below outlines the bonus payment scheme. In addition, the contractor must pay a $40,000 per year advanced education scholarship to Jordanian nationals during the exploration period increasing to $160,000 per year if a commercial discovery is made. The contractor is subject to Jordanian income taxes computed at an effective rate of 66% on provisional income defined as total revenues under the sharing agreement less revoverable expenses.

A number of issues relating to the legal structure of the relationship between the contractor and Jordan are included in the agreement. However, they appear to have no substantive effect on the form of sharing rules employed. For example, on commencement of commercial oil production a joint venture company, "Joram", is supposed to take over management of the oil fields. Joram in all likelihood will be staffed and run by employees of the contractor with the contractor paying all operating costs. NRA officials will have some nominal say in operational decisions. Thus, despite this legal veil, the contractor is still actively managing all aspects of the project. Discussion of hidden costs, if any, of these types of legal arrangements is beyond the scope of this paper.

Table 3.3

Bonus Payment Rules

Production Level	Incremental	Total
0 - 25,000 bbl/day	$1M	$1M
25,000 - 50,000 bbl/day	$1M	$2M
50,000 - 75,000 bbl/day	$1M	$3M
75,000 - 100,000 bbl/day	$1M	$4M
100,000 + bbl/day	$1M	$5M

In order to illustrate how the terms and conditions of Company A's exploration and development agreement translate into a sequence of cash flows, sample output from a financial model used to determine discovery size NPV's is presented below.[1] A complete discussion of the capital budgeting methodology underlying the financial model is left until Section 4.0. The following discussion is limited to the mechanics of the sharing rules employed in the agreement.

Table 3.4 below lists the annual cash flows to the contractor and Jordan under a scenario in which 2 wildcat wells are drilled at a cost of $1.64M, leading to a discovery of a 50,000 barrel per day field for which the prevailing wellhead price is $11.00 per barrel. The exploration period is assumed to have an expected life of three years and the development period an expected life of two years, thus causing expected commercial production to begin in year 6.

Under terms of the agreement, Company A has initial recoverable costs of 1.64 + 136.08 + 136.08 = $273.80 M, which are equal to total exploration and development costs. Annual production costs of $13.60 M are added to this pool each year. Jordan has a recoverable cost of $13 M (its exploration data "fee"). Total annual oil production is 50,000 barrels per day, which is divided into a 60% shared pool and a 40% cost recovery pool. Company A receives 23.5% of the 60% shared oil pool. This 23.5% figure is calculated as 20% of the first 25,000 barrels of oil and 22% of the next 25,000 barrels of oil, resulting in a 23.5% weighted average share.

The 40% cost recovery pool is divided between Jordan and Company A on a pro rata basis in which Company A recieves 95% and Jordan 5%, according to the size of their relative claims. Thus in the first year of commercial operations, Company A receives .235 x .60 + .95 x .40 = 52.1% of total oil production. This figure falls gradually to 23.5% as Company A recovers its exploration and development costs over time. This observation is borne out by the data in Table 3.4A, which shows Company A's cash flows declining from $88.32 M in year 6 to $23.62M in year 25.

Column 1 of Table 3.4A shows cash outflows of $2.46 M (PV of exploration expenditures) and $0.04 M (scholarship payments) in year 1 for the contractor. Because the $0.04 M is a transfer from the contractor to Jordan, the net cash flows for the project as a whole are only -$2.46 M. Oil field development expenditures of $136.08 M are shown to occur in years 4 and 5, which comprise the two year expected development period. These exploration and development expenditures and all production related expenses borne by the contractor are recoverable from cost petroleum. Column 6 of Table 3.4 B shows an initial cost recovery on the part of the contractor of $76.78M and on the part of Jordan of $3.52 M according to the pro rata sharing rules described above. Recall that a $13M seismic "fee" is considered a recoverable cost for Jordan. Total recoverable costs of $80.4 M amount to 40% of the value of all oil produced ($200.75 M) leaving the remaining oil production of $120.45 M to be shared between the contractor and Jordan according to the 23.5% sharing rule yielding allocations of $28.31 M and $92.14 M, respectively.

Section 4.2 below provides a detailed treatment of inflation, discount rates, oil prices, exploration costs, development costs, production costs, depreciation rates, effective income tax rates and other assumptions used in the financial model of the 1986 Agreement.

Table 3.4A

Project Net Cash Flows
(Assumptions Listed On Next Page)

	Contractor	Jordan	Project
1	(1.68)	0.04	(1.64)
2	(0.04)	0.04	0.00
3	(0.04)	0.04	0.00
4	(136.11)	0.04	(136.08)
5	(136.11)	0.04	(136.08)
6	88.32	98.83	187.15
7	90.65	96.50	187.15
8	91.59	95.56	187.15
9	88.48	98.67	187.15
10	35.79	151.36	187.15
11	32.13	155.02	187.15
12	29.56	157.59	187.15
13	27.76	159.39	187.15
14	26.50	160.65	187.15
15	25.62	161.53	187.15
16	25.01	162.14	187.15
17	24.57	162.58	187.15
18	24.27	162.88	187.15
19	24.06	163.09	187.15
20	23.91	163.24	187.15
21	23.81	163.34	187.15
22	23.74	163.41	187.15
23	23.69	163.46	187.15
24	23.65	163.50	187.15
25	23.62	163.53	187.15
NPV at 10%	97.57	793.87	891.44

Table 3.4B

FINANCIAL MODEL OF THE EXPLORATION AND DEVELOPMENT AGREEMENT
BETWEEN THE KINGDOM OF JORDAN AND OIL COMPANY A

KEY ASSUMPTIONS

NO. OF WELLS DRILLED	2	EXPLORATION COST ($/WELL)	819,729
EXPECTED WORLD OIL PRICE	$13.00	DEVELOPMENT COST ($/BBL/DAY)	$5,443
TRANSPORTATION FROM WELLHEAD	$2.00	ANNUAL OPERATING COSTS ($/BBL/DAY)	$272
EXPECTED WELLHEAD PRICE	$11.00	OIL FIELD OUPUT (BBL/DAY)	50,000
REAL DISCOUNT RATE	10.00%		

($ MILLIONS)
OIL COMPANY A CASH FLOWS IN $U.S.

(YEAR)	1	2	3	4	5	6	7	8
OIL REVENUES	0.00	0.00	0.00	0.00	0.00	28.31	28.31	28.31
RECOVERABLE COSTS	0.00	0.00	0.00	0.00	0.00	76.78	76.10	77.05
CONTRACTUAL PAYMENTS:								
TRAINING AND SCHOLARSHIP	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.16)	(0.16)	(0.16)
BONUS PAYMENTS	0.00	0.00	0.00	0.00	0.00	(3.00)	0.00	0.00
PRODUCTION EXPENSES	0.00	0.00	0.00	0.00	0.00	(13.60)	(13.60)	(13.60)
EXPLORATION EXPENSES	(1.64)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DEVELOPMENT EXPENSES	0.00	0.00	0.00	(136.08)	(136.08)	0.00	0.00	0.00
JORDANIAN INCOME TAXES	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NCF TO TOTAL CAPITAL	(1.68)	(0.04)	(0.04)	(136.11)	(136.11)	88.32	90.65	91.59
NPV AT 10%	97.57	99.32						

Table 3.4B

FINANCIAL MODEL OF THE EXPLORATION AND DEVELOPMENT AGREEMENT
BETWEEN THE KINGDOM OF JORDAN AND OIL COMPANY A

KEY ASSUMPTIONS

NO. OF WELLS DRILLED	2	EXPLORATION COST ($/WELL)	819,729
EXPECTED WORLD OIL PRICE	$13.00	DEVELOPMENT COST ($/BBL/DAY)	$5,443
TRANSPORTATION FROM WELLHEAD	$2.00	ANNUAL OPERATING COSTS ($/BBL/DAY)	$272
EXPECTED WELLHEAD PRICE	$11.00	OIL FIELD OUPUT (BBL/DAY)	50,000
REAL DISCOUNT RATE	10.00%		

($ MILLIONS)
KINGDOM OF JORDAN CASH FLOWS IN $U.S.

	1	2	3	4	5	6	7	8
OIL REVENUES	0.00	0.00	0.00	0.00	0.00	92.14	92.14	92.14
RECOVERABLE COSTS	0.00	0.00	0.00	0.00	0.00	3.52	4.20	3.25
CONTRACTUAL RECEIPTS:								
TRAINING AND SCHOLARSHIP	0.04	0.04	0.04	0.04	0.04	0.16	0.16	0.16
BONUS PAYMENTS	0.00	0.00	0.00	0.00	0.00	3.00	0.00	0.00
INCOME TAXES PAID BY A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SHARED PRODUCTION COSTS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OTHER	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NCF TO TOTAL CAPITAL	0.04	0.04	0.04	0.04	0.04	98.83	96.50	95.56
NPV AT 10%	793.87							
NCF OF PROJECT	(1.64)	0.00	0.00	(136.08)	(136.08)	187.15	187.15	187.15
NPV OF PROJECT AT 10%	891.44							

Table 3.4C

RAW FINANCIAL DATA

(YEAR)	1	2	3	4	5	6	7	8
AVLBL OIL PRODN (bbl/day)	0	0	0	0	0	50,000	50,000	50,000
AVAILABLE OIL REVENUE ($)	0.00	0.00	0.00	0.00	0.00	200.75	200.75	200.75
WELLHEAD OIL PRICE	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00
SHARING RULE	23.50%	23.50%	23.50%	23.50%	23.50%	23.50%	23.50%	23.50%
COST PETROLEUM ($)	0.00	0.00	0.00	0.00	0.00	80.30	80.30	80.30
COMPANY A PETROLEUM ($)	0.00	0.00	0.00	0.00	0.00	28.31	28.31	28.31
JORDAN PETROLEUM ($)	0.00	0.00	0.00	0.00	0.00	92.14	92.14	92.14

TAX MODEL FOR COMPANY A

REVENUES	0.00	0.00	0.00	0.00	0.00	28.31	28.31	28.31
RECOVERABLE COSTS	0.00	0.00	0.00	0.00	0.00	(76.78)	(76.10)	(77.05)
PROVISIONAL INCOME	0.00	0.00	0.00	0.00	0.00	(48.47)	(47.80)	(48.74)
EFFECTIVE TAX RATE	66.67%	66.67%	66.67%	66.67%	66.67%	66.67%	66.67%	66.67%
TAXES PAYABLE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

COST RECOVERY MODEL FOR COMPANY A

CURRENT EXPENSES (t):	1.64	0.00	0.00	46.27	46.27	13.60	13.60	13.60
CURRENT DEPRECIATION (t)	0.00	0.00	0.00	26.94	45.80	32.06	22.44	15.71
ACCUM. POOL (t-1)	0.00	1.64	1.64	1.64	74.85	166.92	135.80	95.74
CURRENT RECOVERY (t)	0.00	0.00	0.00	0.00	0.00	76.78	76.10	77.05
ACCUM. POOL (t)	1.64	1.64	1.64	74.85	166.92	135.80	95.74	48.00

Table 3.4C

RAW FINANCIAL DATA

(YEAR)	1	2	3	4	5	6	7	8
COST RECOVERY MODEL FOR JORDAN								
CURRENT ADDN'S:								
EXPLORATION REIMBSMNT	0.00	0.00	0.00	3.25	3.25	3.25	3.25	0.00
OTHER	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACCUM. POOL (t-1)	0.00	0.00	0.00	0.00	3.25	6.50	6.23	5.28
CURRENT RECOVERY (t)	0.00	0.00	0.00	0.00	0.00	3.52	4.20	3.25
ACCUM. POOL (t)	0.00	0.00	0.00	3.25	6.50	6.23	5.28	2.03
PRO RATA SHARING OF RECOVERABLE COSTS								
TOTAL COST PETROLEUM	0.00	0.00	0.00	0.00	0.00	80.30	80.30	80.30
TOTAL RECOVERABLE COSTS	1.64	1.64	1.64	78.10	173.42	222.33	181.32	130.33
COMPANY A RECOV. COSTS	1.64	1.64	1.64	74.85	166.92	212.58	171.84	125.05
NRA RECOV. COSTS	0.00	0.00	0.00	3.25	6.50	9.75	9.48	5.28
COMPANY A SHARE	100.00%	100.00%	100.00%	95.84%	96.25%	95.61%	94.77%	95.95%
NRA SHARE	0.00%	0.00%	0.00%	4.16%	3.75%	4.39%	5.23%	4.05%

TAX DEPRECIATION ACCOUNTS FOR COMPANY A

	1	2	3	4	5	6	7	8
% DEVLPMNT EXP DEPRCBL	66.00%							
% OF PRODN EXP DEPRECBL	0.00%							
ANNUAL DEPRECIATION RATE:	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%	30.00%
ADDN'S TO POOL (t)	0.00	0.00	0.00	89.81	89.81	0.00	0.00	0.00
DEPN POOL (t-1)	0.00	0.00	0.00	0.00	62.87	106.87	74.81	52.37
CURRENT DEPR. EXP. (t)	0.00	0.00	0.00	26.94	45.80	32.06	22.44	15.71
DEPN POOL (t)	0.00	0.00	0.00	62.87	106.87	74.81	52.37	36.66

4.0 Valuation Of Petroleum Discoveries

4.1 Capital Budgeting Methodology

This section employs some standard capital budgeting techniques to estimate discovery size net present values (NPV's). The capital asset pricing model (CAPM) developed by Sharpe (1964), Lintner (1965) and numerous other financial economists is the framework chosen for the analysis. Any modern corporate finance textbook such as Brealy and Myers (1984) or Copeland and Weston (1983) provide excellent treatments of the theory underlying this approach, therefore I will only briefly summarize its salient features.

Application of CAPM to project evaluation requires the calculation of expected (probability weighted) project cash flows on a year by year basis. These cash flows are then adjusted to certainty equivalent levels using an adjustment factor that depends on a project's covariance with the market portfolio (i.e, portfolio of all other investment opportunities available). The certainty equivalent cash flows are then discounted at a risk free discount rate. Alternatively, if it is difficult to compute the covariance of project's cash flows with the market portfolio, the expected cash flows can be discounted at a rate which accurately reflects their "activity risk" in relation to the market portfolio. This can be accomplished by "observing" a cost of capital for an activity with risk characteristics similar to that of the project in question.

The fundamental equilibrium relation underlying CAPM which characterizes expected rates of return required by capital is:

$$E[r_i] = r_f + B_i [E[r_m] - r_f]$$

where, $B_i = cov(r_i, r_m)/var(r_m)$, r_f is the risk free rate of return, $E[r_m]$ is the expected return on the market portfolio and $E[r_i]$ is the required expected rate of return on the i-th investment activity. In theory at least, a discount rate appropriate for oil exploration and development activity in Jordan can be estimated by computing the beta (B_i) of stochastic project cash flows with the international market portfolio.

Key variables which may contribute to project covariance with the international market portfolio are oil prices, physical capital prices, wage rates and exchange rates. Exploration risk will not be correlated with the market portfolio and hence will not affect the discount rate, even though it will affect the expected value calculations of the cash flows.

There are a number of other considerations, some of which were alluded to in Section 1.0, which may effect discovery size value. These include:

- o ability to diversify commodity price risk in international capital markets
- o ability to diversify exploration risk in international capital markets
- o economic externalities arising from foreign investment in Jordan, i.e, access to previously unavailable technologies

If Jordan's national income is highly correlated with oil prices, then Jordan may place a lower value on oil related income given an inability to diversify this risk away in international capital markets. This is not an unreasonable assumption given that its major trading partners all have oil dependent economies. In a similar vein, Jordan may not be able to diversify away exploration risk, thus again putting downward pressure on oil income valuation. Within the context of CAPM, these types of market imperfections would manifest themselves in a higher discount rate for oil related cash flows for Jordan relative to a multinational oil company acting as agent-contractor. On the other hand, the presence of economic externalities due to technology transfer, expenditure multiplier effects and so on could serve to raise the valuation of a project by a host government relative to an agent-contractor. Economic externalities may or may not offset the effects of potentially higher discount rates due to inability of the host government to diversify certain types of risk.

It is important to note that there exits a substantial literature on the use of social as opposed to private discount rates for the evaluation of public sector projects. For example, Harberger (1963) argues that the appropriate social discount rate should be the opportunity cost of the marginal source of public funds. He allows for foregone income tax, sales tax, tariff, foreign exchange and labour externalities in his calculation of an average cost of public funds. However, he does not treat activity risk explicitly in his analysis.

In the interests of simplicity, a real discount rate of 10% is applied to project cash flows to determine discovery size NPV's. This figure was estmitated using the returns to shareholders equity published in Company A's 1986 annual report. It is assumed to be the same for both Jordan and an agent-contractor. Considerations of the type outlined above, while beyond the scope of this analysis, could most certainly be allowed for in further work.

4.2 Summary Of Parameter Assumptions For The Financial Model Of 1986 Jordanian Contracts

This section presents a brief documentation of all assumptions used in the financial model. These are listed in point-form under a number of subject headings below.

Time Horizon

- The total time horizon is 25 years, broken down into a 3 year exploration period, a two year development period and a 20 year production period after which oil field title reverts to Jordan.

Real Discount Rates

- 10% real discount rate for both Jordan and contractor
- No allowance for interest tax shields due to leverage. Jordan does not allow for interest tax shields within the contract structure, however, a contractor's host country more than likely allows for such deductions.

Oil Price Expectations

- The oil price process is assumed to have a martingale type structure, in which case the current value is equal to the expected future value.
- The expected oil price is set equal to the average of the F.O.B. Persian Gulf prices quoted in the March 15 issue of the Wall Street Journal, roughly $13.00 U.S. per barrel
- The wellhead price is assumed to be $13.00 less a $2.00 transportation cost to the point of shipment, roughly $11.00. This can be viewed as a somewhat conservative expected price structure.

Treatment Of Inflation

- All analysis is conducted in constant 1988 U.S. dollars. Inflation will have an effect on the real value of recoverable costs, however, these effects are judged to be small given low inflation forecasts.

Exploration, Development And Production Cost Assumptions

- o Exploration, development and production cost assumptions were derived using a methodology similar to that in Adelman (1986)

- o An average output of 250 barrels per day was assumed for oil wells in Jordan. This figure is similar to average daily output rates in neighbouring countries such as Syria and Egypt. Exploration, development and production costs were scaled up from figures derived for this typical sized well.

- o An average well depth of 10,800 feet was assumed, similar to average well depths in Syria and previous wells drilled in Jordan. Using U.S. Department of Energy's "Indexes and Estimates of Domestic Well Drilling Costs" a total drilling cost of $819,760 per well was derived.

- o Adelman (1986) estimates that total development costs are roughly 166% of drilling costs, thus development costs of $1,360,000 per 250 barrel per day well are assumed. This is equal to a development cost of $5,443/barrel/day.

- o Annual production costs are assumed to be 5% of development costs, $272/barrel/day.

Recoverable Cost Assumptions

- o 66% of development expenditures are classified as depreciable, the remaining 34% are eligible for immediate recovery.

- o 30% declining balance depreciation rate is applied to depreciable expenditures implying that 30% of the pool of depreciable expenditures is recoverable each year.

Jordanian Income Tax Calculations

- o taxable income is computed as oil revenues less recoverable costs

- o an effective tax rate of 66 1/3% is applied to taxable income greater than zero. No loss carryforwards are permitted.

4.3 Minimum Commercially Viable Discovery Sizes And The Undercompletion Problem

Table 4.1 below lists the smallest discovery sizes viable for commercial development given that exploration costs are sunk. These minimum viable discovery sizes were computed by finding the oil production level at which the NPV of financial cash flows became zero under the assumptions of the financial model described in Sections 4.1 and 4.2. Column 1 shows the minimum viable discovery size necessary for a "first best" situation in which one party can capture all project benefits.

The data indicate that the discovery sizes which yield a project NPV of at least zero are quite small, ranging from 45 barrels per day for a discount rate of 5% to 94 barrels per day for a discount rate of 20%. However, under terms of the 1986 Jordanian contracts the minimum viable discovery size for commercial development from the point of view of Company A is an order of magnitude larger than that for the project as a whole.

The data in columns 2, 3 and 4 indicate that the minimum viable discovery size for Company A is is quite sensitive to both the discount rate and the number of wells drilled. Recall that recoverable costs are a function of exploration and development expenditures, thus for fixed development expenditures higher levels of sunk exploration expenditures will lead to larger cash flows in the development phase for a contractor. For example, with five exploration wells drilled and a discount rate of 5% the minimum viable discovery size is 450 barrels per day for Company A, whereas for a discount rate of 20% the minimum viable discovery size is 2,500 barrels per day. Clearly, the minimum viable discovery size under terms of the 1986 Jordanian contract is not only an order of magnitude larger, but also much more sensitive to changes in the discount rate than is the project minimum viable discovery size for the total project.

These results appear to indicate that an agent-contractor would forego development of jointly profitable oil fields, because the sharing rule under the terms of the 1986 Jordanian agreements is not sufficiently generous for small to moderate discovery sizes. As we will see in Sections 6.2 and 6.3, foregone development opportunities will lead to significantly lower ex ante expected profits on the part of Jordan as well as to lower than optimal levels of exploration effort on the part of the agent-contractor. Wolfson (1985) terms this an undercompletion problem. Note that the undercompletion problem is an ex post incentive problem with ex ante implications for drilling effort.

Table 4.1

Smallest Discovery Sizes Viable For Commercial Development Given That Exploration Costs Are Sunk (bbl/day)

Discount Rate	Min Discovery Size For Total Project	Min Discovery Size For Company A Under Conditions Of 1986 Agreement		
		2 Wells	5 Wells	10 Wells
5.00%	45	600	490	385
10.00%	59	975	740	600
15.00%	75	2,300	1,650	1075
20.00%	94	14,600	11,950	5,450

5.0 Estimation Of Exploration Effort-Discovery Size Probability Matrices

The purpose of this section is to discuss the calculations used to construct exploration effort - discovery size probability matrices which lie at the heart of an analysis of the effort related incentive problems inherent in the structure of the 1986 Jordanian contracts. As mentioned in Section 2.2, some simplifying assumptions must be made concerning the ex ante decision making process in order to construct a Grossman and Hart (1983) effort-outcome probability matrix. Namely, the "real-world" intertemporal exploration-development decision problem must be collapsed into a single period decision problem, in which the level of exploration effort chosen this period will affect the probability of achieving a given discovery size next period. This decision problem can be characterized by an effort-outcome matrix of the type shown below.

Table 5.1

Exploration Effort-Discovery Size Probability Matrix

Outcome:	q_1 npv_1	q_2 npv_2	q_3 npv_3	. . . .	q_m npv_m
Effort					
a_1	$P(1 \mid a_1)$	$P(2 \mid a_1)$	.	. .	$P(m \mid a_1)$
	.				.
a_2					
		.			.
.			.		.
.				.	.
.					.
a_n					$P(m \mid a_n)$

In keeping with a number of approaches used in the exploration geology literature, i.e, Adelman et al. (1983), the amount of discoverable oil is assumed to follow a lognormal distribution with paramenters u and s. This implies that the logarithm of the discovery size (expressed as a production rate in barrels per day) is normally distributed with mean u and variance s^2 or equivalently discovery size is lognormally distributed with mean $\exp(u+.5s^2)$ and variance $\exp(u+.5s^2)^2 \times (\exp(s^2)-1)^2$. Discovery size is expressed as a daily production rate in order to be consistent with the sharing rules outlined in the 1986 Jordanian contracts.

Because the lognormal distribution is a skewed distribution in which the median lies to the left of the mean, it is conceptually helpful to use the median as the location parameter of interest rather than mean. For example, if median discovery size were 1,000 barrels per day with a log standard deviation of of 20%, then the mean or expected discovery size would be $\exp(6.91 + .5\text{x}1.38^2) = 2{,}591$ barrels per day, where $6.91 = \log(1000)$ and $1.38 = .20 \times 1{,}000$.

As a second step in costructing an effort-outcome probability matrix, I have chosen an 8 point discretization of the lognormal discovery size probability distribution where each point is exactly one standard deviation apart from the next on the log scale. In terms of the logarithm of discovery size, the eight points in question begin -3.5 standard deviations to to the left of the mean and progress to 3.5 standard deviations to the right of the mean in units of one standard deviation. A discretization of the data from the example given above, would yield points in terms of the logarithm of discovery size of 2.07, 3.45, 4.84, 6.22, 7.60, 8.98, 10.36 and 11.74 (log bbl/day), where the points are generated according to the equation $(6.91 - 3.5 \times 1.38) + (N+1) \times 1.38$ (N is equal to to the n-th point). In terms of original units we would have discovery sizes of 8, 32, 126, 501, 1,995, 7,943, 31,623, and 125,893 barrels per day occurring with probabilities of 0.0013, 0.0214, 0.136, 0.3413, 0.3413, 0.136, 0.0214 and 0.0013, respectively. The expected discovery size according to the discretization is 2,790 barrels per day which is fairly close to the 2,591 barrels per day predicted by the continuous distribution.

A binomial probability distribution is used to relate exploration effort as measured by the number of wildcat wells drilled to the discovery size probability distribution. For example, if the wildcat probability is p, then there is a conditional probability, p, of finding oil according to the lognormal probability distribution, if one well is drilled. If two wells are drilled then the probability is $1 - (1-p)^2$; if three wells are drilled then the probability is $1 - (1-p)^3$, and so on. Therefore, the total probability of a given discovery size conditional on k wells being drilled is simply $1 - (1-p)^k$ multiplied by the appropriate discrete probability determined according to the procedure outlined above. Thus, given a lognormal discovery size distribution with median 1000 and a logarithmic standard deviation of 20%, the discrete probability of finding a field with output 501 barrels per day would be $0.3413 \times (1 - (1-p)^k)$. Similar calculations can be made for all other points of the discrete approximation to the lognormal distribution. The mean discovery size would be $2{,}790 \times (1 - (1-p)^k)$.

The binomial model relating exploration effort to the probability of discovery is a well behaved concave function with a number of desirable properties. Firstly, it exhibits a diminishing marginal return to exploration effort in that the gain in ex ante expected discovery size decreases with increasing k. Given that exploration costs increase with the number of wells drilled, a diminishing marginal return to exploration will ensure that there is an upper bound on exploration effort for any ex ante profit or utility maximizing economic agent. Secondly, the effectiveness of exploration effort can be readily characterized by the binomial probability, p. This feature will prove useful for the discussions concerning the conditions under which incentive problems inherent in the 1986 Jordanian contract structure are large. Thirdly, this binomial model bears some semblance to actual exploration reality in that wildcat well drilling is very much a discrete activity with binomial type outcomes.

Sample exploration effort-discovery size probability matrices are shown in Tables 5.2 and 5.3 below.[1] Figure 5.1 shows how the shape of the probability distribution for discovery size changes as the level of exploration activity is varied. Net present values for discovery size were computed according to the capital budgeting methodology outlined in Section 4.0. If the NPV of a particular discovery size is found to be less than zero, then it is assumed that the well is not commercial viable and hence will not be developed. As

Figure 5.1

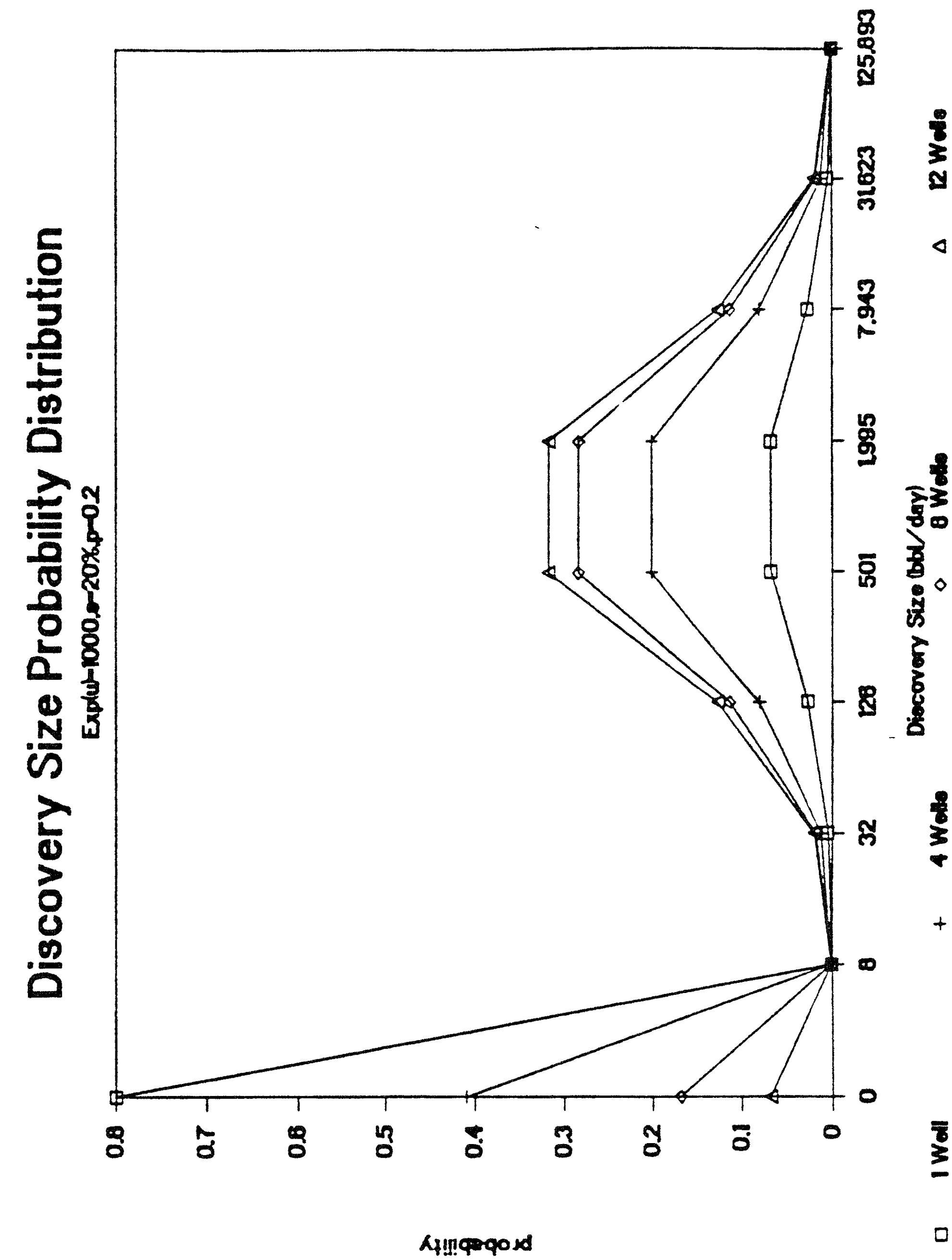

Discovery Size Probability Distribution
Exp(u)=1000,s=20%,p=0.2
probability
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
8
32
128
501
1,995
7,943
31,623
125,893
Discovery Size (bbl/day)
1 Well
4 Wells
8 Wells
12 Wells

Table 5.2

EXPLORATION EFFORT - DISCOVERY SIZE PROBABILITY MATRIX

EXP(U) = 1000 S = 20.00% P = 0.2

SIZE (BBL/DAY):		0	8	32	126	501	1,995	7,943	31,623	125,893	EXPECTED	EXPECTED	VARIANCE
NPV ($M):		0	0.00	0.00	1.57	8.95	36	142	565	2,249	PROFIT	DISCOVERY	OF DISCOVERY
NO. OF WELLS DRILLED	TOTAL COST										OF PROJECT	VALUE	VALUE
1	0.82	0.8000	0.0003	0.0043	0.0272	0.0683	0.0683	0.0272	0.0043	0.0003	9.1	9.9	3,221
2	1.64	0.6400	0.0005	0.0077	0.0490	0.1229	0.1229	0.0490	0.0077	0.0005	16.3	17.9	5,655
3	2.46	0.5120	0.0006	0.0104	0.0664	0.1666	0.1666	0.0664	0.0104	0.0006	21.8	24.3	7,511
4	3.28	0.4096	0.0008	0.0126	0.0803	0.2015	0.2015	0.0803	0.0126	0.0008	26.1	29.4	8,938
5	4.10	0.3277	0.0009	0.0144	0.0914	0.2295	0.2295	0.0914	0.0144	0.0009	29.3	33.4	10,042
6	4.92	0.2621	0.0010	0.0158	0.1003	0.2518	0.2518	0.1003	0.0158	0.0010	31.8	36.7	10,901
7	5.74	0.2097	0.0010	0.0169	0.1075	0.2697	0.2697	0.1075	0.0169	0.0010	33.6	39.3	11,573
8	6.56	0.1678	0.0011	0.0178	0.1132	0.2840	0.2840	0.1132	0.0178	0.0011	34.8	41.4	12,101
9	7.38	0.1342	0.0011	0.0185	0.1177	0.2955	0.2955	0.1177	0.0185	0.0011	35.7	43.1	12,517
10	8.20	0.1074	0.0012	0.0191	0.1214	0.3047	0.3047	0.1214	0.0191	0.0012	36.2	44.4	12,846
11	9.02	0.0859	0.0012	0.0196	0.1243	0.3120	0.3120	0.1243	0.0196	0.0012	36.4	45.5	13,106
12	9.84	0.0687	0.0012	0.0199	0.1267	0.3178	0.3178	0.1267	0.0199	0.0012	36.5	46.3	13,313
13	10.66	0.0550	0.0012	0.0202	0.1285	0.3225	0.3225	0.1285	0.0202	0.0012	36.3	47.0	13,478
14	11.48	0.0440	0.0012	0.0205	0.1300	0.3263	0.3263	0.1300	0.0205	0.0012	36.1	47.6	13,608
15	12.30	0.0352	0.0013	0.0206	0.1312	0.3293	0.3293	0.1312	0.0206	0.0013	35.7	48.0	13,713
16	13.12	0.0281	0.0013	0.0208	0.1322	0.3317	0.3317	0.1322	0.0208	0.0013	35.2	48.3	13,796
17	13.94	0.0225	0.0013	0.0209	0.1329	0.3336	0.3336	0.1329	0.0209	0.0013	34.7	48.6	13,862
18	14.76	0.0180	0.0013	0.0210	0.1336	0.3352	0.3352	0.1336	0.0210	0.0013	34.1	48.8	13,915
19	15.58	0.0144	0.0013	0.0211	0.1340	0.3364	0.3364	0.1340	0.0211	0.0013	33.4	49.0	13,957
20	16.40	0.0115	0.0013	0.0212	0.1344	0.3374	0.3374	0.1344	0.0212	0.0013	32.8	49.2	13,991

Table 5.3

EXPLORATION EFFORT - DISCOVERY SIZE PROBABILITY MATRIX

EXP(U) = 2500 S = 20.00% P = 0.4

SIZE (BBL/DAY):		0	10	50	239	1,143	5,467	26,141	125,000	597,720	EXPECTED	EXPECTED	VARIANCE
NPV ($M):		0	0.00	0.00	4.21	20.42	98	467	2,233	10,676	PROFIT	DISCOVERY	OF DISCOVERY
NO. OF WELLS DRILLED	TOTAL COST										OF PROJECT	VALUE	VALUE
1	0.82	0.6000	0.0005	0.0086	0.0544	0.1365	0.1365	0.0544	0.0086	0.0005	65.6	66.4	110,751
2	1.64	0.3600	0.0008	0.0137	0.0870	0.2184	0.2184	0.0870	0.0137	0.0008	104.6	106.3	172,967
3	2.46	0.2160	0.0010	0.0168	0.1066	0.2676	0.2676	0.1066	0.0168	0.0010	127.7	130.2	208,772
4	3.28	0.1296	0.0011	0.0186	0.1184	0.2971	0.2971	0.1184	0.0186	0.0011	141.2	144.5	229,707
5	4.10	0.0778	0.0012	0.0197	0.1254	0.3148	0.3148	0.1254	0.0197	0.0012	149.0	153.1	242,070
6	4.92	0.0467	0.0012	0.0204	0.1297	0.3254	0.3254	0.1297	0.0204	0.0012	153.4	158.3	249,417
7	5.74	0.0280	0.0013	0.0208	0.1322	0.3317	0.3317	0.1322	0.0208	0.0013	155.6	161.4	253,799
8	6.56	0.0168	0.0013	0.0210	0.1337	0.3356	0.3356	0.1337	0.0210	0.0013	156.7	163.2	256,420
9	7.38	0.0101	0.0013	0.0212	0.1346	0.3379	0.3379	0.1346	0.0212	0.0013	157.0	164.4	257,988
10	8.20	0.0060	0.0013	0.0213	0.1352	0.3392	0.3392	0.1352	0.0213	0.0013	156.8	165.0	258,929
11	9.02	0.0036	0.0013	0.0213	0.1355	0.3401	0.3401	0.1355	0.0213	0.0013	156.4	165.4	259,492
12	9.84	0.0022	0.0013	0.0214	0.1357	0.3406	0.3406	0.1357	0.0214	0.0013	155.8	165.7	259,830
13	10.66	0.0013	0.0013	0.0214	0.1358	0.3409	0.3409	0.1358	0.0214	0.0013	155.2	165.8	260,033
14	11.48	0.0008	0.0013	0.0214	0.1359	0.3410	0.3410	0.1359	0.0214	0.0013	154.4	165.9	260,155
15	12.30	0.0005	0.0013	0.0214	0.1359	0.3411	0.3411	0.1359	0.0214	0.0013	153.7	166.0	260,228
16	13.12	0.0003	0.0013	0.0214	0.1360	0.3412	0.3412	0.1360	0.0214	0.0013	152.9	166.0	260,271
17	13.94	0.0002	0.0013	0.0214	0.1360	0.3412	0.3412	0.1360	0.0214	0.0013	152.1	166.0	260,298
18	14.76	0.0001	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	151.3	166.0	260,313
19	15.58	0.0001	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	150.4	166.0	260,323
20	16.40	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	149.6	166.0	260,329

a result, the lower bound placed on discovery size NPV's is zero. Note that as mentioned in Section 4.0, no abandonment option values are included in these NPV calculations should oil prices fall below levels at which it is economically viable to produce oil. However, these option values are likely to be small since there are no capital expenditures other than the initial development expenditures, and as well, operating costs are small in relation to current oil prices .

6.0 Calculation Of The Ex Ante Incentive Effects Of The 1986 Jordanian Contracts

6.1 First Best Sharing Rule: Empirical Results

Table 6.1 below presents first best results for a number of scenarios of the exploration effort - discovery size model. Recall from the discussion of Section 2.0 that a first best outcome occurs when the ex ante expected profits of the project are maximized, i.e, expected value of discovery size less exploration costs. A first best outcome assumes that there are no incentive costs. It can be implemented by selling the entire project to an expected profit maximizing agent-contractor or if this is not feasible, by designing a sharing rule - such as a forcing contract - that just compensates the contractor for the costs of drilling on an ex ante basis. For example, if $p = 0.2$ and $e^u = 1000$, then the first best level of drilling effort is 12 wells, which will yield an expected profit of $36.48M to the project as a whole. As the exploration effort - discovery size probability matrix indicates, if one more (less) well is drilled the expected profit expected profit will fall by $0.80 M . In this case, it would be optimal for Jordan to sell all development rights to a contractor for $36.48 M and thus avoid any incentive costs due to imperfect monitoring of a contractor's effort. As mentioned previously, incentive costs arise when a contractor whose effort cannot be perfectly monitored is risk averse in the sense of exhibiting expected utility maximizing behaviour .

The data indicate that optimal drilling effort increases as the location parameters of the lognormal discovery size distribution increase and decreases with the productivity of drilling effort as expressed by the wildcat probability parameter, p. These results are not surprising, since a greater expected discovery size increases the expected marginal value of additional drilling effort, while a greater wildcat probability parameter decreases the expected marginal value of additional drilling effort. A rough rule of thumb seems to be that doubling the wildcat probability parameter causes optimal drilling effort to fall by a factor of one-half.

We will see that the expected profits accruing to Jordan as a percentage of total project expected profits under a second best sharing rule or the 1986 Agreement sharing rule decrease as both median discovery size (e^u) increases and drilling effort productivity (p) increases. Intuitively, one would expect this result because the sensitivity of first best expected profits to drilling effort decreases as both these parameters increase. This point can be illustrated by the fact that for a median discovery size of 25,000 barrels per day, 98% of first best expected profits can be achieved by drilling only 4 wells, even though optimal drilling effort required to reach a first best solution is 32 wells. Each additional well drilled increases expected project profits only by a small amount. A perusal of the effort - probability of discovery matrices in Appendix A will confirm this observation.

Table 6.1

First Best Results

Median Discovery Size (bbl/day)	First Best Drilling Effort (wells)	Cost Of Drilling ($ M)	Expected Value Of Discovery ($ M)	Expected Profit To Jordan ($ M) [1]
Wildcat Probability = 0.2				
500	8	6.56	16.96	10.40
1,000	12	9.84	46.32	36.48
2,500	17	13.94	162.29	148.35
5,000	21	17.21	418.09	400.88
10,000	26	21.31	1,089.41	1,068.10
25,000	32	26.23	3,948.29	3,922.05
Wildcat Probability = 0.4				
500	5	4.10	18.80	14.70
1,000	7	5.74	48.35	42.61
2,500	9	7.38	164.36	156.98
5,000	11	9.02	420.45	411.43
10,000	13	10.66	1,091.30	1,080.64
25,000	16	13.12	3,950.31	3,937.19
Wildcat Probability = 0.6				
500	3	2.46	19.08	16.62
1,000	4	3.28	47.38	44.10
2,500	6	4.92	165.35	160.43
5,000	7	5.74	421.29	415.55
10,000	8	6.56	1,091.98	1,085.42
25,000	9	7.38	3,950.38	3,943.00

1. In the notation of Section 2.0, expected first best profit to Jordan, FB = argmax $\{k\}$ $B_k - a_k$.

6.2.0 Second Best Sharing Rule

6.2.1 Contractor Risk Aversion And Choice Of Utility Function

Grossman and Hart (1983) consider separable utility functions of the form G(a) + K(a)V(I), where 'a' denotes effort, I denotes monetary income, V is an increasing concave function and K is strictly positive. They derive a number of results relating the probability structure of the effort-outcome matrix to the shape of the sharing rule based on this form of utility function and a number of other technical conditions. The negative exponential utility function, $-e^{-b(I-a)}$, is of the separable form considered by Grossman and Hart. Its parameter 'b' is a measure of local absolute risk aversion. Hence, greater 'b' implies greater risk aversion.

A number of second best scenarios were run using alternate values of 'b'. It was found that values in the neighbourhood of 0.01 yielded the most sensible results, in that for median discovery sizes of 1000 to 5000 barrels per day with logarithmic variance of 20%, a feasible second best sharing rule could be found. Values of 'b' greater than 0.1 tended to be infeasible, whereas values less than 0.003 tended to give results that are close to risk neutral - meaning the agent acts almost as if it were an expected profit maximizer.

A logarithmic utility function was tested as an alternative to the negative exponential utility function and was found to give remarkably similar results. For example, the optimal levels of drilling effort tended to differ by at most one well for utility specifications that were logarithmic with intial wealth of $30 M, or negative exponential with $b = .01$. In these cases the optimal sharing rules were virtually identical thereby yielding virtually identical expected profits to Jordan.

Logarithmic utility within the context of the Grossman and Hart framework has a number of desirable properties. Firstly, initial wealth can be interpreted as the agent's budget constraint. For example, if a particular manager or department within an oil company has a target budget which cannot be exceeded, then the logarithmic utility function will "blow-up" if losses on the project exceed the initial wealth (budget) that is specified. It "blows-up" in the sense that the marginal utility of additional income becomes infinite, yielding infeasible solutions to the second best optimization program. The logarithmic utility function can be thought of as a penalty (benefit) function assigned by management to potential losses (gains) from a project. As loss levels approach the budget constraint, higher and higher penalties are assigned.

Grossman and Hart's second best algorithm imposes no restrictions on the sign of the payments that an agent-contractor can receive. Thus, an agent may receive a negative payment, i.e, it must pay the principal a positive amount should a particular outcome be realized. Experimentation with the second best algorithm revealed that negative payments to the agent tended to occur for outcomes with both low effort related probability and low discovery levels. This caused proportionate sharing rules to be "humped" shaped with negative initial shares.

There is reason to believe that negative sharing rules, which can be viewed as penalty payments for low discovery sizes, are unacceptable for institutional reasons.[1] Casual observation indicates that no such contract structures are in force. Therefore, non-negativity constraints were imposed on the the second best sharing rule, i.e, a lower bound of zero was set. Also, the payouts to the agent were bounded from above by the total outcome NPV, i.e, by 100% of available profits. Experimentation revealed that these boundary conditions had virtually no effect on second best drilling effort and a small effect, in the order of 5%, on the expected payouts to the agent-contractor.

6.2.2 Empirical Results

Table 6.2 below presents second best results for a number of scenarios of the exploration effort - discovery size model.[2] These were calculated assuming logarithmic utility with an initial wealth of $30 M. The results reveal that as median discovery size and wildcat probabilities increase, the incentive cost of a second best sharing rule decreases. For example, second best expected profits to Jordan are 68% of first best profits for a median discovery size of 500 barrels per day with a wildcat probability of 0.2. Alternatively, the incentive cost is 32% of first best expected profits. This incentive cost decreases to 4% of first best expected profits as median discovery size increases to 25,000 barrels per day. For a median discovery size of 500 barrels per day and a wildcat probability of 0.6, the incentive cost of a second best sharing rule is only 15%

Table 6.2

Second Best Algorithm Results

Median Discovery Size (bbl/day)	Optimal Drilling Effort (wells)	Cost Of Drilling ($ M)	Expected Payment To Contractor ($ M)	Expected Profit To Jordan ($ M)	First Best Expected Profit ($ M)
Wildcat Probability = 0.2					
500	4	3.28	5.01	7.03	10.40
1,000	6	4.92	9.26	27.44	36.48
2,500	9	7.38	19.12	124.69	148.35
5,000	12	9.84	36.93	356.03	400.88
10,000	14	11.48	54.52	989.81	1,068.10
25,000	17	13.94	98.23	3,757.80	3,922.05
Wildcat Probability = 0.4					
500	3	2.46	4.42	11.57	14.70
1,000	4	3.28	7.81	35.49	42.61
2,500	6	4.92	21.48	136.81	156.98
5,000	6	4.92	20.96	381.34	411.43
10,000	8	6.56	52.83	1,021.60	1,080.64
25,000	8	6.56	57.32	3,835.50	3,937.19
Wildcat Probability = 0.6					
500	2	1.64	2.83	14.29	16.62
1,000	2	1.64	2.82	38.96	44.10
2,500	3	2.46	7.35	148.09	160.43
5,000	4	3.28	17.45	393.83	415.55
10,000	4	3.28	17.40	1,047.70	1,085.42
25,000	5	4.10	37.75	3,874.90	3,943.00

of first best expected profits. These data indicate that for low median discovery sizes 500 to 2,500 barrels per day and low wildcat probabilities in the order of 0.2, second best sharing rules while feasible yield high incentive costs. Figure 6.1 provides a graphical illustration of how incentive costs vary with median discovery size and wildcat probability.

Table 6.3 below shows the optimal second best sharing rules in dollar amounts for the scenarios listed in Table 6.2, while Figures 6.2 to 6.4 provide graphical illustrations of these sharing rules. Note that the second best sharing rules expressed as a percentage of discovery size NPV roughly have the shape of a rectangular hyperbolas in that they start off near 100% for small discovery sizes and decline monotonically to very low levels for large discovery sizes.

Consider, the scenario where e^{u} = 1000 and p = 0.2. For discovery sizes of 8 and 32 barrels per day it is not optimal to develop the oil field. For discovery sizes of 126 and 501 barrels per day, it is optimal to give the agent-contractor 100% of the project NPV. For the remaining four higher discovery sizes, the agent-contractor receives a share that declines from 50% to 0.92% of the total project NPV. Under this scenario, the second best sharing rule achieves an expected profit of $27.44 M for Jordan, roughly 75% of the first best expected profit level. The $9.26 M payment to the contractor consists of

$4.92 M compensation for drilling costs and $4.34 M compensation for risk aversion imbedded in the expected utility function.

Figure 6.1

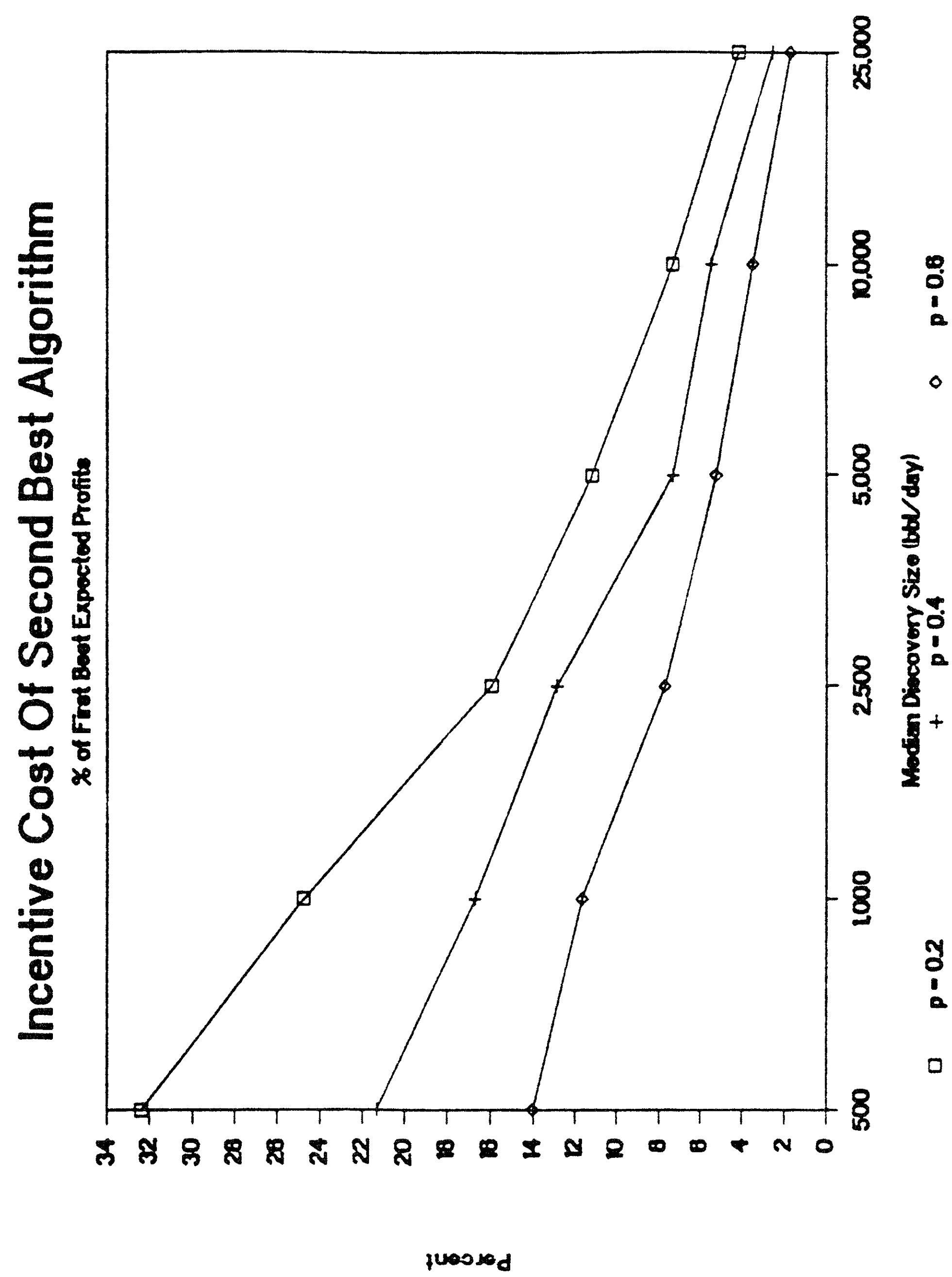

Incentive Cost Of Second Best Algorithm
% of First Best Expected Profits
Percent
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
500
1,000
2,500
5,000
10,000
25,000
Median Discovery Size (bbl/day)
p - 0.2
p - 0.4
p - 0.6

Table 6.3

Second Best Sharing Rule

Median Discovery Size (bbl/day)	Wildcat Probability	Optimal Drilling Effort (wells)	Outcome From Exploration Effort Probability Matrix (Column Number Corresponds To Discovery Size) Contractor's NPV ($ Millions)							
			1	2	3	4	5	6	7	8
500	0.2	4	0.00	0.00	0.44	4.80	13.56	13.54	13.55	15.17
500	0.4	3	0.00	0.00	0.44	4.80	7.87	7.86	7.85	8.28
500	0.6	2	0.00	0.00	0.44	3.93	3.93	3.93	3.95	3.80
1,000	0.2	6	0.00	0.00	1.57	8.95	18.57	18.55	18.54	20.73
1,000	0.4	4	0.00	0.00	1.57	8.95	11.40	11.40	11.42	10.88
1,000	0.6	2	0.00	0.00	1.57	3.73	3.73	3.73	3.75	3.60
2,500	0.2	9	0.00	0.00	4.21	20.42	29.03	29.08	29.13	33.62
2,500	0.4	6	0.00	0.00	4.21	20.42	29.99	29.98	29.71	29.56
2,500	0.6	3	0.00	0.00	4.21	8.65	8.65	8.66	8.60	9.65
5,000	0.2	12	0.00	0.28	6.94	38.11	51.43	51.36	51.67	48.03
5,000	0.4	6	0.00	0.28	6.94	25.02	25.02	25.00	24.77	24.87
5,000	0.6	5	0.00	0.28	6.94	20.16	20.15	20.17	20.27	18.90
10,000	0.2	14	0.00	0.96	11.27	65.93	65.92	66.09	67.03	51.09
10,000	0.4	8	0.00	0.96	11.27	61.87	61.99	62.02	62.70	173.52
10,000	0.6	4	0.00	0.96	11.27	19.33	19.33	19.33	19.29	19.30
25,000	0.2	17	0.00	2.32	21.40	111.52	116.78	122.24	104.44	5465.30
25,000	0.4	8	0.00	2.32	21.40	57.31	57.33	57.52	57.33	167.36
25,000	0.6	5	0.00	2.32	21.40	41.87	41.87	41.85	41.94	41.65

Figure 6.2

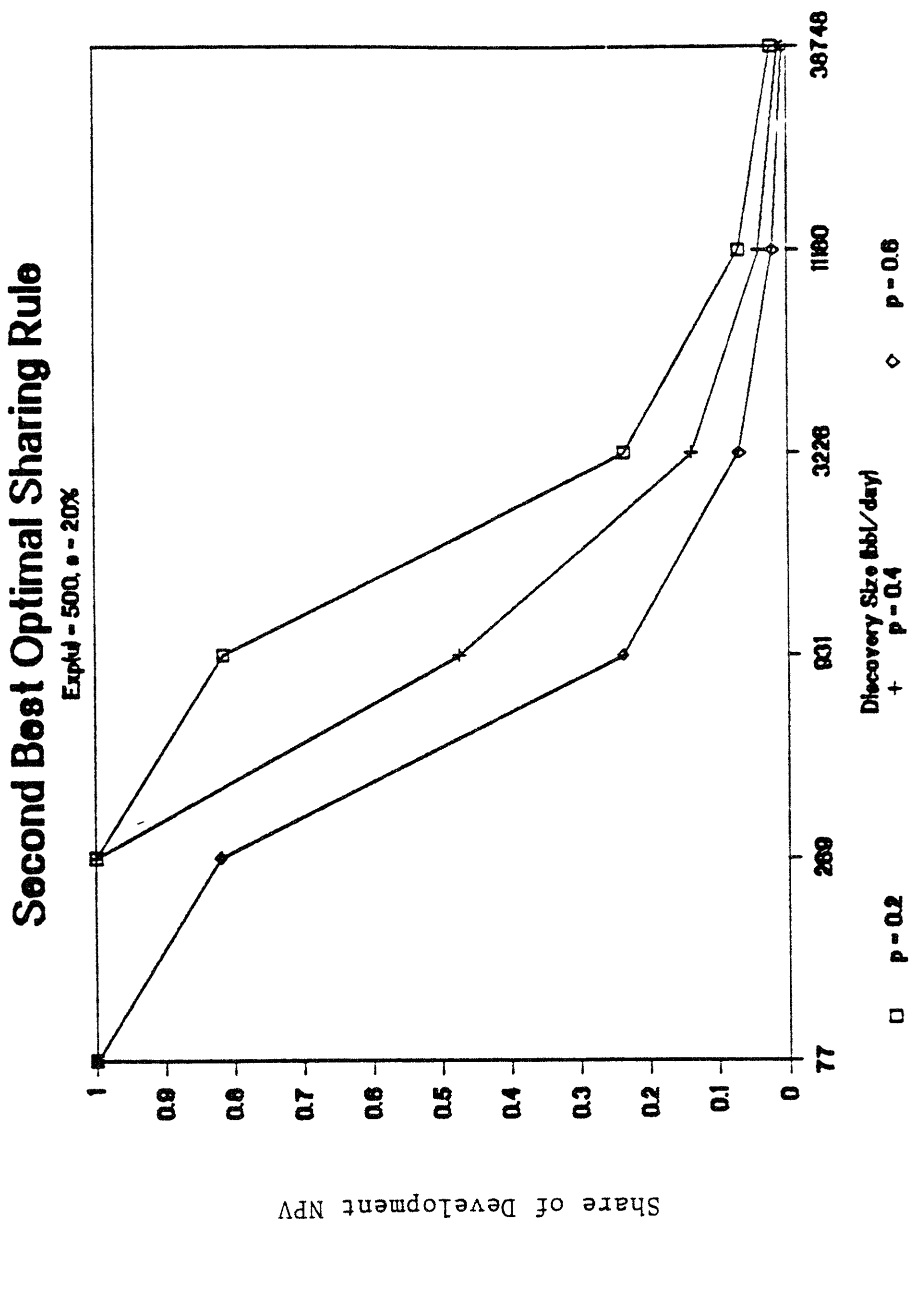

Second Best Optimal Sharing Rule
Discovery Size (bbl/day)
p = 0.2
p = 0.4
p = 0.6
Share of Development NPV

Figure 6.3

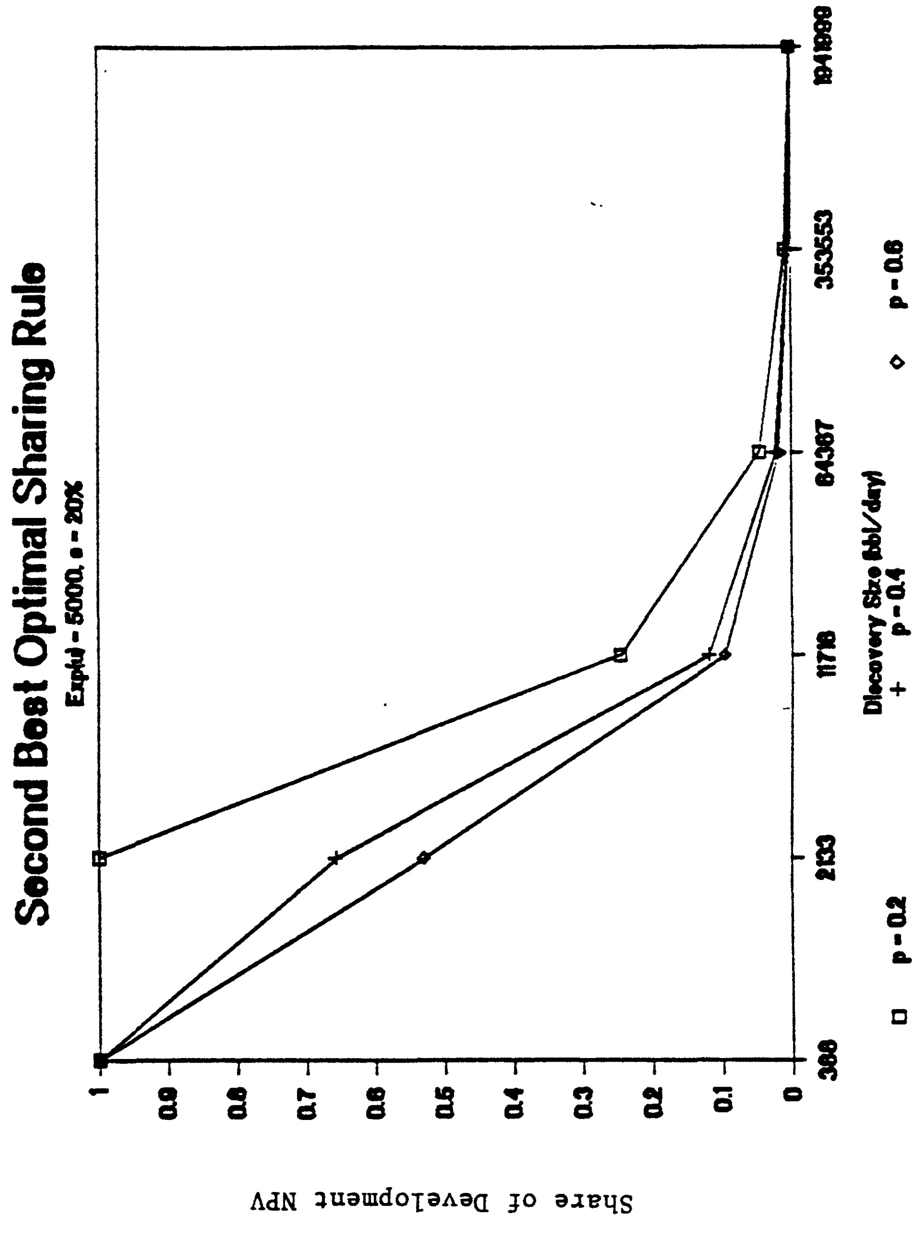
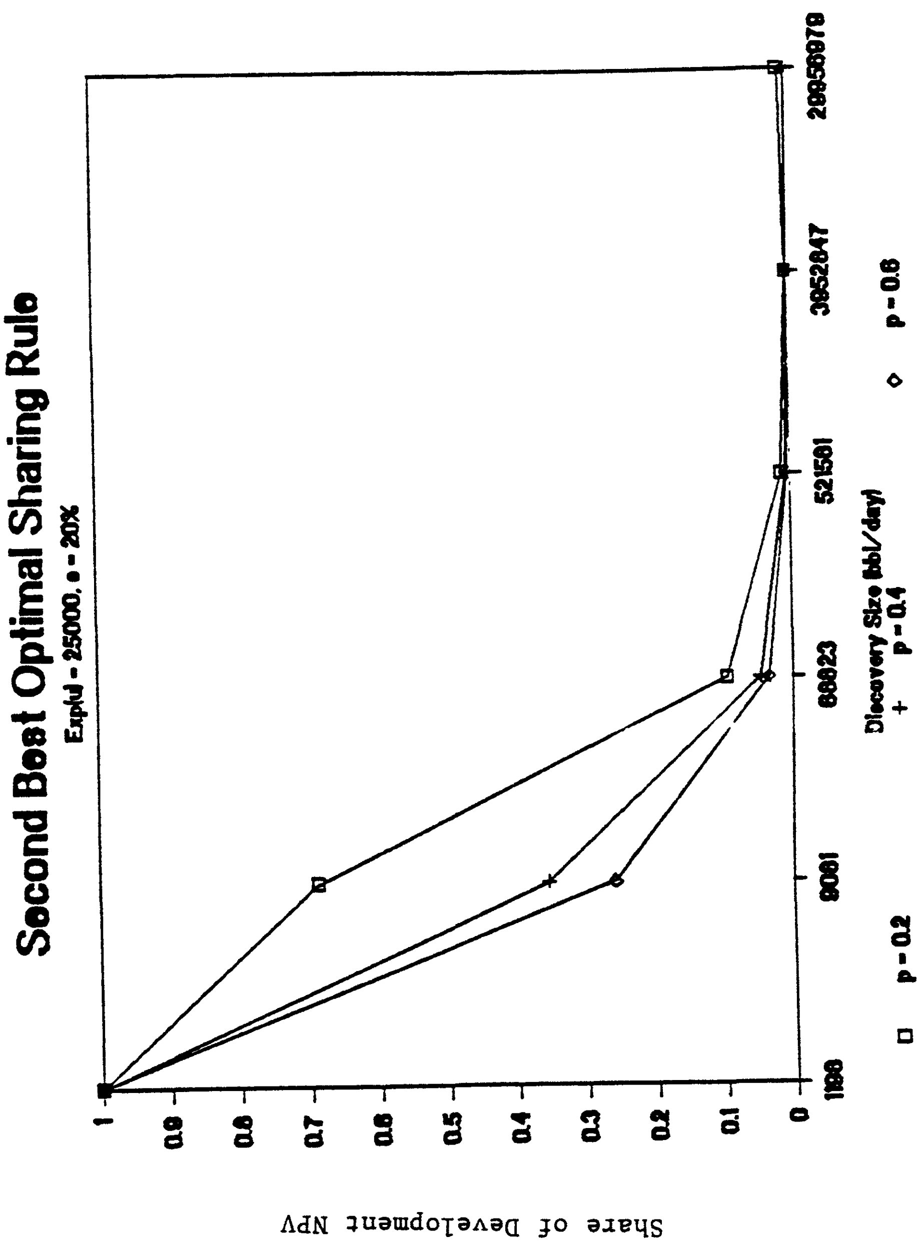

Second Best Optimal Sharing Rule
Discovery Size (bbl/day)
Share of Development NPV
p = 0.2
p = 0.4
p = 0.6
368
2133
11718
64367
353553
1941999
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

Figure 6.4


Second Best Optimal Sharing Rule
Exp(u) - 25000, e - 20%
Share of Development NPV
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1186
9061
68823
521581
3952847
29958979
Discovery Size (bbl/day)
p - 0.2
p - 0.4
p - 0.6

6.3 Sharing Rules Implicit In The 1986 Jordanian Contracts

Table 6.4 below lists the discovery size NPV's that would be captured by Company A under the terms of its agreement with Jordan according to the assumptions outlined in Sections 3.0 and 4.0. In NPV terms, the contractual sharing rule increases in output in an almost linear fashion. As a percentage of total project NPV, Company A's share rises monotonically until it peaks at around 25,000 bbl per day then falls gradually to a level of roughly 10%. This "humped" shape to the percentage shares can be explained by the fact that the contractor receives a smaller portion of incremental output as total oil production increases. Recall that the contractor's incremental share falls from 25% of "shared petroleum" at production rates of under 25,000 bbl/day to 20% at production rates over 100,000 bbl/day.

In discovery size ranges from 1,000 to 25,000 bbl per day, one can think of the percentage sharing rule as rising monotonically at a decreasing rate to an asymptote of around 12% (see Figure 6.5). This percentage sharing rule is the complete inverse of the second best sharing rules determined by Grossman and Hart's algorithm which tend to start close to 100% and then decrease montonically to an asymptote. The inverted structure of the contractual sharing rule tends to result in lower than optimal exploration levels due to lower ex ante expected gains from exploration on the part of the contractor. In addition, an ex post undercompletion problem arises when smaller sized discoveries are made, namely, in the 600 to 6,000 barrel per day range.

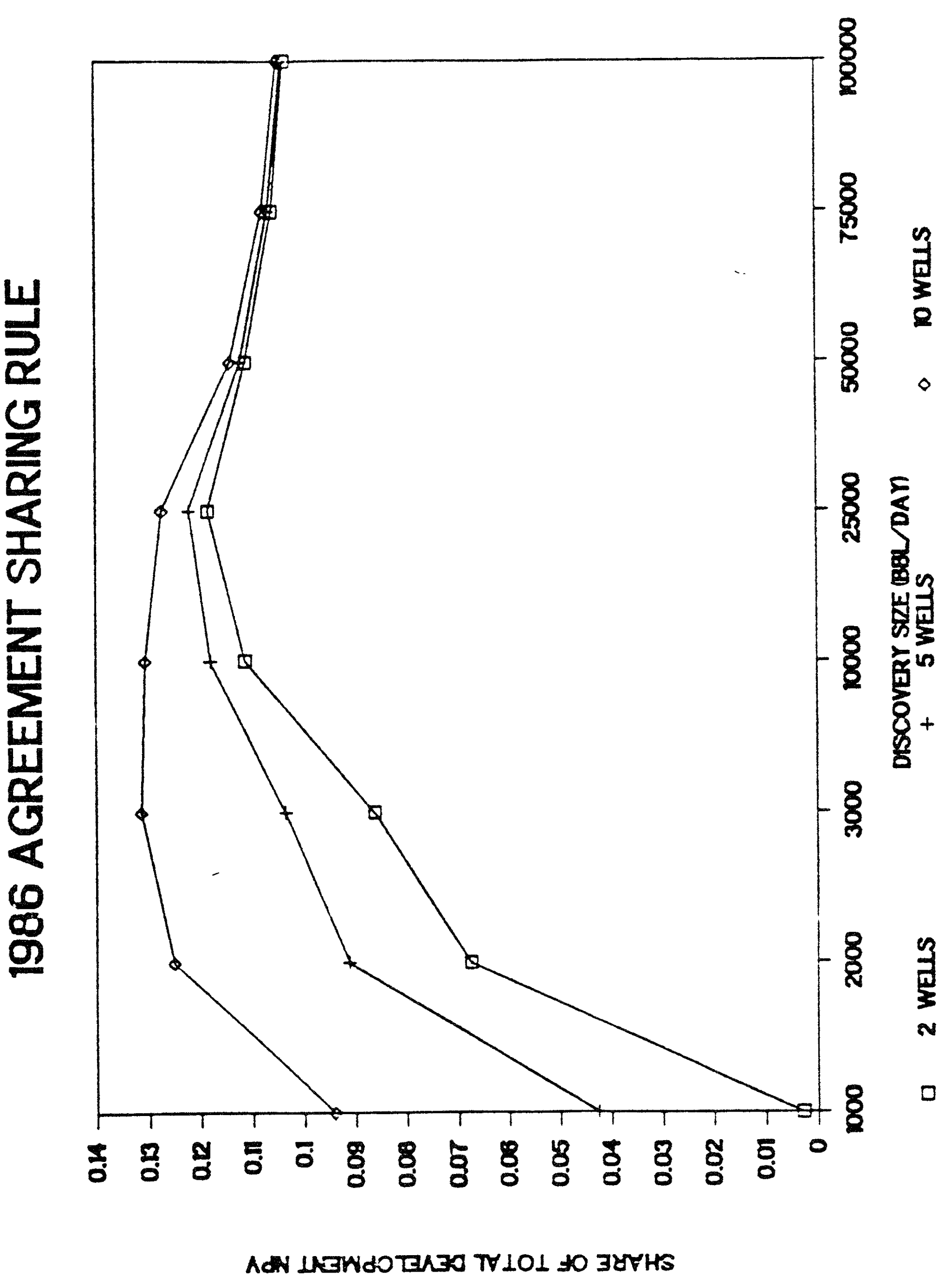
Table 6.4

1986 Agreement Sharing Rule

Discovery Size	NPV To Project	NPV To Contractor[1]		Share Of Project Benefits	
		2 Wells	10 Wells	2 Wells	10 Wells
1,000	17.86	0.05	1.68	0.28%	9.41%
2,000	35.72	2.41	4.47	6.75%	12.51%
3,000	53.58	4.62	7.04	8.62%	13.14%
10,000	178.62	19.90	23.34	11.14%	13.07%
25,000	446.54	52.93	56.90	11.85%	12.74%
50,000	893.08	99.32	101.96	11.12%	11.42%
75,000	1339.62	142.16	144.55	10.61%	10.79%
100,000	1786.16	184.96	187.37	10.36%	10.49%

1. Exploration costs are assumed sunk for the purposes of the sharing rule.

Figure 6.5


1986 AGREEMENT SHARING RULE
SHARE OF TOTAL DEVELOPMENT NPV
0.14
0.13
0.12
0.11
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
1000
2000
3000
10000
25000
50000
75000
100000
DISCOVERY SIZE (BBL/DAY)
2 WELLS
5 WELLS
10 WELLS

6.4 <u>Contractor's Optimal Exploration Effort Under Terms 1986 Jordanian Contracts</u>

The ex ante expected profits to Jordan of the 1986 Agreement it signed with Company A are <u>low in relation to both first and second best sharing sharing rules for low to moderate potential discovery levels</u> as measured by the location parameters e^u and s. As the level of potential discoveries increases the differences in ex ante profits between the 1986 Agreement and first and second best sharing rules decrease in relative terms, while remaining large in absolute terms. The 1986 Agreement has a high incentive cost because it misallocates risk and suffers from an under completion problem. The analysis of Section 6.2 suggests that a proper allocation of project risk requires that the contractor be given relatively high shares of project benefits at low discovery levels and low shares at high discovery levels. The sharing rule implicit in the 1986 agreement achieves the exact opposite of this result. Also, as pointed out in Section 4.3, the 1986 Agreement suffers from an under completion problem at low discovery levels, thus causing a further decrease in ex ante expected profits to Jordan.

Table 6.5 below provides some illustrations of the incentive costs of the 1986 Agreement under a number of scenarios. At median discovery levels of 1,000 barrels per day and under, an expected utility maximizing contractor would not even choose to enter into an agreement. At a median discovery size of 2,500 barrels per day the incentive cost varies from roughly 30% of first best expected profits for a wildcat probability of 0.2 to 12% for a wildcat probability of

0.6. As median discovery size increases to 25,000 barrels per day, incentive costs fall to a level of 10% of first best expected profits. Figure 6.6 provides a graphical summary of the data in Table 6.5.

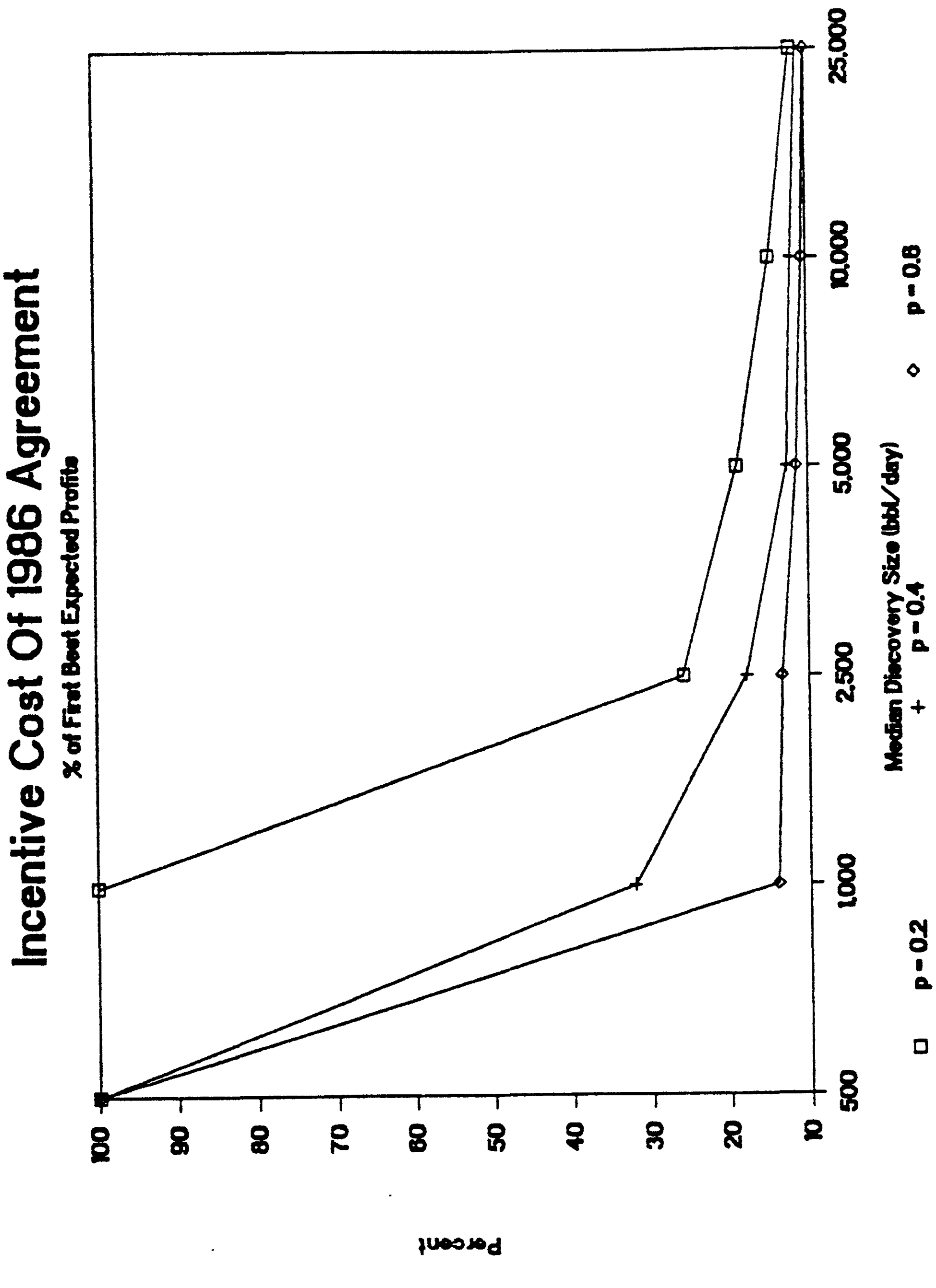
Table 6.5

Relationship Between Optimal Drilling Effort And Expected Profit To Jordan Under The 1986 Agreement Sharing Rule

Median Discovery Size (bbl/day)	Optimal Drilling Effort (wells)	Cost Of Drilling ($ M)	Expected Payment To Contractor ($ M)	Expected Profit To Jordan ($ M)
Wildcat Probability = 0.2				
500	0	0.00	0.00	0.00
1,000	0	0.00	0.00	0.00
2,500	6	4.92	12.55	110.00
5,000	9	7.38	40.31	325.04
10,000	12	9.84	106.28	911.33
25,000	16	13.12	383.54	3,456.65
Wildcat Probability = 0.4				
500	0	0.00	0.00	0.00
1,000	2	1.64	2.93	28.90
2,500	4	3.28	15.46	129.05
5,000	6	4.92	42.55	359.75
10,000	7	5.74	109.58	952.53
25,000	8	6.56	385.93	3,499.12
Wildcat Probability = 0.6				
500	0	0.00	0.00	0.00
1,000	2	1.64	3.84	37.94
2,500	3	2.46	16.33	139.07
5,000	4	3.28	43.02	368.16
10,000	5	4.10	110.86	970.65
25,000	6	4.92	390.31	3,544.92

1. Wildcat binomial probability = 0.2
2. Initial wealth = $30 M.

Figure 6.6



Incentive Cost Of 1986 Agreement
% of First Best Expected Profits
Percent
100
90
80
70
60
50
40
30
20
10
500
1,000
2,500
5,000
10,000
25,000
Median Discovery Size (bbl/day)
p = 0.2
p = 0.4
p = 0.8

6.5 Policy Recommendations And Conclusions

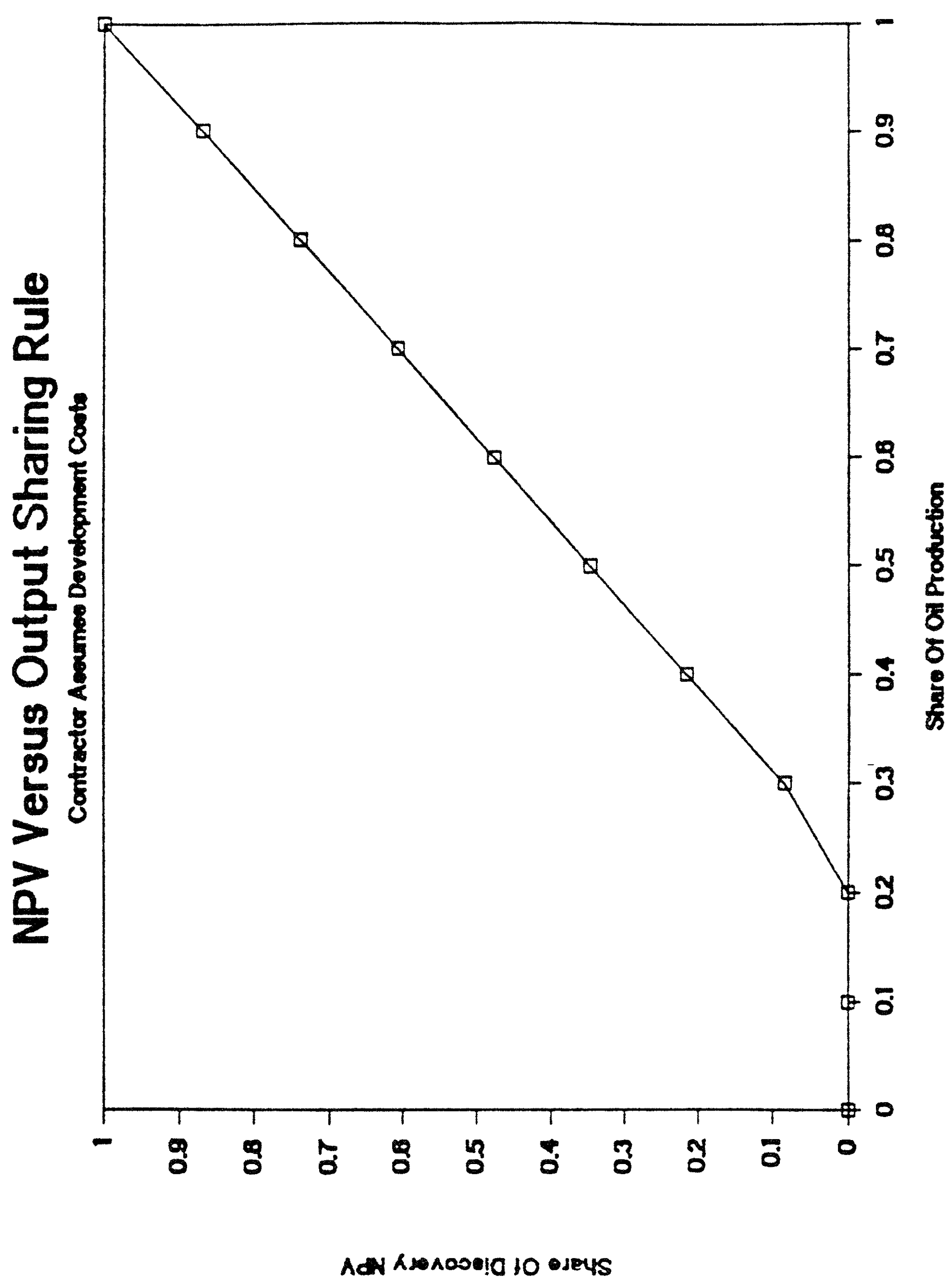
An analysis of the 1986 Jordanian Agreements reveals that there are potentially large incentive costs under a number of circumstances. If the sharing rule implicit in the 1986 Agreements is implemented, then Jordan's ex ante expected profits are likely to be significantly lower than first best and second best expected profits for low to moderate levels of potential oil discoveries. Specifically, with median oil discoveries of 500 to 2500 barrels per day with logarithmic variance of 20%, the incentive costs of the 1986 Agreement will range between 100% and 30% of first best expected profits and 100% and 12% of second best expected profits. As discovery potential increases, the incentive costs of the 1986 Agreement sharing rule falls. For median discovery levels of 5000 barrels per day, the incentive cost falls to 18% of the first best expected profits and will continue to fall to around 10% of expected profits for median discovery sizes of 25,000 barrels per day or more.[3] Note that for median discovery sizes of 25,000 barrels per day second best incentive costs are in the 1% to 4% range, depending on wildcat probability level.

The analysis of Section 6.2 indicates that second best sharing rules are feasible even for very low median oil discovery levels of around 500 barrels per day and that for median discovery levels of around 1,000 barrels per day their incentive cost is a very respectable 36% of the first best expected profit. As median discovery levels rise to 10,000 barrels per day or more, second best incentive costs fall well below 10% of first best expected profits.

A striking result of Section 6.3 was that the shape of the 1986 Agreement sharing rule is radically different from the shape of the second best sharing rules. Not surprisingly, we see that the contractual sharing rule is not generous enough relative to the second best sharing rule at low realized discovery sizes (500 to 5000 barrels per day) and is too generous at high realized discovery sizes (10000 + barrels per day). These differences result in significantly lower ex ante expected profits for Jordan.

It is easy enough to convert the second best discovery development NPV sharing rules into oil output sharing rules using the financial model discussed in Section 4.0. Figure 6.7 provides such a conversion. The structure of the financial model is such that for feasible discovery sizes of 100+ barrels per day, shares of discovery NPV's can be converted into shares of oil production in a roughly linear fashion. For example, a 50% NPV share roughly corresponds to a fixed 60% share of annual oil production, a 60% NPV share to a 73% share of oil production and so on. Thus we see that the second best sharing rules can be structured in a fashion consistent with output sharing.

Figure 6.7


NPV Versus Output Sharing Rule
Contractor Assumes Development Costs
Share Of Oil Production
Share Of Discovery NPV

Endnotes

1-1 These agreements will be referred to as the 1986 Agreements, 1986 Jordanian contracts or simply the agreements throughout the remainder of the text. For the purposes of confidentiality, the names of the companies signatory to these agreements will not be used.

1-2 Section 3.0 provides a more detailed description of the areas in Jordan covered by the exploration and development agreements.

1-3 As will become evident in Section 3.0, the actual sharing rule used in these agreements is a great deal more complicated than the above description indicates. However, this brief introductory description conveys the general sense of the sharing rule.

1-4 Expected profits achieved under a first best sharing rule place and upper bound on the expected profits achievable under any possible sharing rule.

1-5 Grossman and Hart assume that a contractor is an expected utility maximizer, whereas the resource owner is an expected profit maximizer. This particular objective function structure will cause an exploration effort incentive problem, because of a contractor's higher degree of risk aversion relative to the resource owner. In general, the magnitude of the incentive costs of a sharing rule will depend on:

(i) the structure of the exploration effort - discovery size probability matrix;

(ii) the objective function of the principal;

(iii) the objective function of the agent-contractor.

Within this framwork it is also possible to examine situations in which the contractor and the resource owner are expected utility maximizers.

1-6 Section 5.0 provides an explanation of what is meant by median discovery levels and logarthmic variance.

3-1 A financial model of the 1986 Agreement was developed on a Lotus 123 spread sheet. This spreadsheet formed the basis of all numerical calculations involving 1986 Agreement sharing rules. This spreadsheet can be made available on request.

5-1 A Lotus 123 spreadsheet was developed to estimate the exploration effort - discovery size probability matrices. This spreadsheet can be made available on request

6-1 Note that a contractor will choose not to develop a discovery if he receives a negative payment (NPV) from doing so.

6-2 These were calculated using the GAMS optimization package developed by Kendrick and Meeraus (1985). Raghuram Rajan (Sloan School of Management, MIT) kindly made available coded GAMS routines to facilitate the analysis.

6-3 These figures assume a wildcat probability of 0.2.

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APPENDIX A

Second Best Sharing Rules For Alternate Exploration Effort-Discovery Size Probability Matrices

Contents

Table 1.0

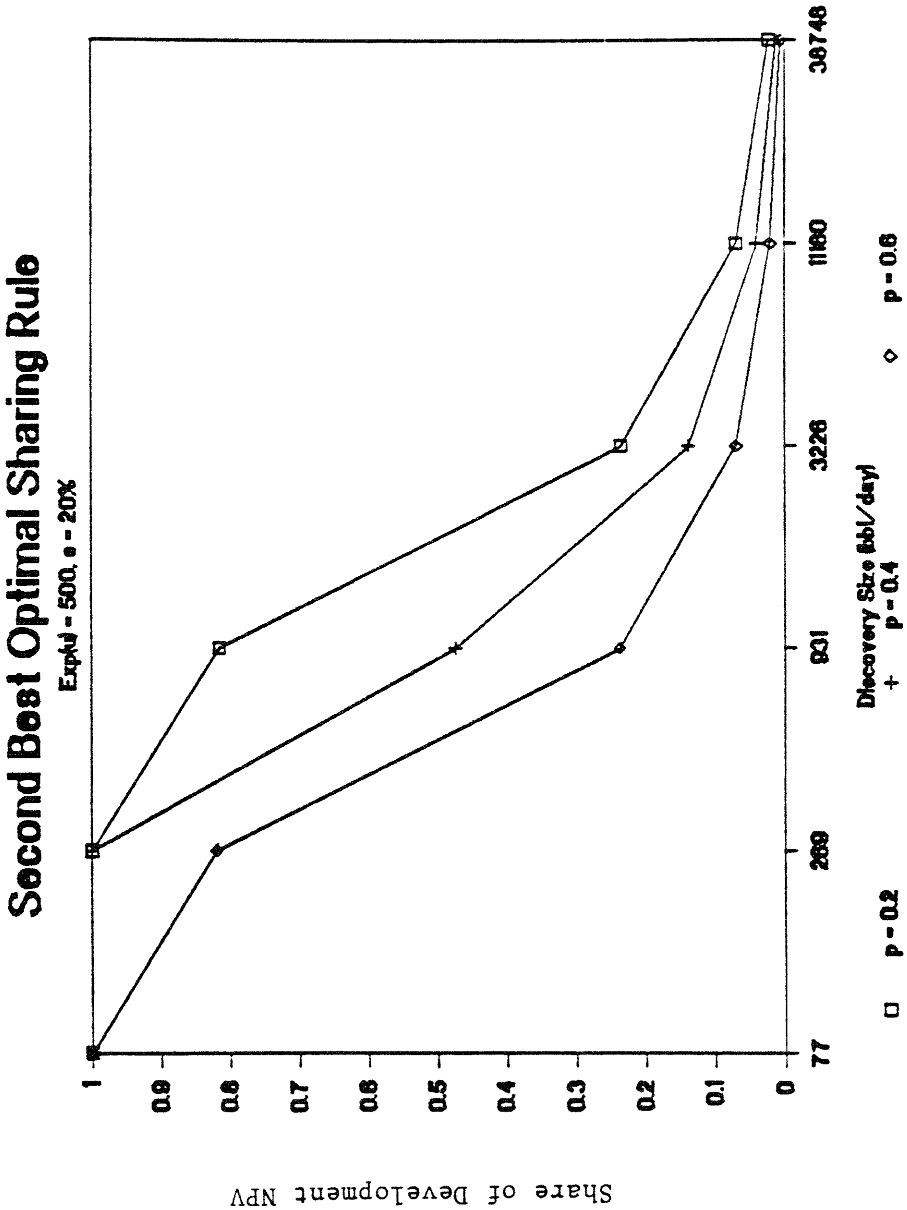
Second Best Optimal Sharing Rule
Explvl = 500, e = 20%
Share of Development NPV
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
77
269
931
3226
11180
38748
Discovery Size (bbl/day)
p = 0.2
p = 0.4
p = 0.6

Table 1.1

EXPLORATION EFFORT - DISCOVERY SIZE PROBABILITY MATRIX

EXP(U) = 500 S = 20.00% P = 0.2

SIZE (BBL/DAY):		0	6	22	77	269	931	3,226	11,180	38,748	EXPECTED	EXPECTED	VARIANCE
NPV ($M):		0	0.00	0.00	0.44	4.80	17	58	200	692	PROFIT	DISCOVERY	OF DISCOVERY
NO. OF WELLS DRILLED	TOTAL COST										OF PROJECT	VALUE	VALUE
1	0.82	0.8000	0.0003	0.0043	0.0272	0.0683	0.0683	0.0272	0.0043	0.0003	3.3	4.1	389
2	1.64	0.6400	0.0005	0.0077	0.0490	0.1229	0.1229	0.0490	0.0077	0.0005	5.7	7.3	677
3	2.46	0.5120	0.0006	0.0104	0.0664	0.1666	0.1666	0.0664	0.0104	0.0006	7.5	9.9	892
4	3.28	0.4096	0.0008	0.0126	0.0803	0.2015	0.2015	0.0803	0.0126	0.0008	8.8	12.0	1,054
5	4.10	0.3277	0.0009	0.0144	0.0914	0.2295	0.2295	0.0914	0.0144	0.0009	9.6	13.7	1,177
6	4.92	0.2621	0.0010	0.0158	0.1003	0.2518	0.2518	0.1003	0.0158	0.0010	10.1	15.0	1,272
7	5.74	0.2097	0.0010	0.0169	0.1075	0.2697	0.2697	0.1075	0.0169	0.0010	10.4	16.1	1,345
8	6.56	0.1678	0.0011	0.0178	0.1132	0.2840	0.2840	0.1132	0.0178	0.0011	10.4	17.0	1,402
9	7.38	0.1342	0.0011	0.0185	0.1177	0.2955	0.2955	0.1177	0.0185	0.0011	10.3	17.6	1,446
10	8.20	0.1074	0.0012	0.0191	0.1214	0.3047	0.3047	0.1214	0.0191	0.0012	10.0	18.2	1,481
11	9.02	0.0859	0.0012	0.0196	0.1243	0.3120	0.3120	0.1243	0.0196	0.0012	9.6	18.6	1,508
12	9.84	0.0687	0.0012	0.0199	0.1267	0.3178	0.3178	0.1267	0.0199	0.0012	9.1	19.0	1,530
13	10.66	0.0550	0.0012	0.0202	0.1285	0.3225	0.3225	0.1285	0.0202	0.0012	8.6	19.3	1,547
14	11.48	0.0440	0.0012	0.0205	0.1300	0.3263	0.3263	0.1300	0.0205	0.0012	8.0	19.5	1,561
15	12.30	0.0352	0.0013	0.0206	0.1312	0.3293	0.3293	0.1312	0.0206	0.0013	7.4	19.7	1,572
16	13.12	0.0281	0.0013	0.0208	0.1322	0.3317	0.3317	0.1322	0.0208	0.0013	6.7	19.8	1,580
17	13.94	0.0225	0.0013	0.0209	0.1329	0.3336	0.3336	0.1329	0.0209	0.0013	6.0	19.9	1,587
18	14.76	0.0180	0.0013	0.C210	0.1336	0.3352	0.3352	0.1336	0.0210	0.0013	5.3	20.0	1,593
19	15.58	0.0144	0.0013	0.0211	0.1340	0.3364	0.3364	0.1340	0.0211	0.0013	4.5	20.1	1,597
20	16.40	0.0115	0.0013	0.0212	0.1344	0.3374	0.3374	0.1344	0.0212	0.0013	3.8	20.1	1,601

Table 1.2

EXPLORATION EFFORT - DISCOVERY SIZE PROBABILITY MATRIX

EXP(U) = 500 S = 20.00% P = 0.4

SIZE (BBL/DAY):		0	6	22	77	269	931	3,226	11,180	38,748	EXPECTED	EXPECTED	VARIANCE
NPV ($M):		0	0.00	0.00	0.44	4.80	17	58	200	692	PROFIT	DISCOVERY	OF DISCOVERY
NO. OF WELLS DRILLED	TOTAL COST										OF PROJECT	VALUE	VALUE
1	0.82	0.6000	0.0005	0.0086	0.0544	0.1365	0.1365	0.0544	0.0086	0.0005	7.3	8.2	745
2	1.64	0.3600	0.0008	0.0137	0.0870	0.2184	0.2184	0.0870	0.0137	0.0008	11.4	13.0	1,129
3	2.46	0.2160	0.0010	0.0168	0.1066	0.2676	0.2676	0.1066	0.0168	0.0010	13.5	16.0	1,336
4	3.28	0.1296	0.0011	0.0186	0.1184	0.2971	0.2971	0.1184	0.0186	0.0011	14.5	17.7	1,452
5	4.10	0.0778	0.0012	0.0197	0.1254	0.3148	0.3148	0.1254	0.0197	0.0012	14.7	18.8	1,519
6	4.92	0.0467	0.0012	0.0204	0.1297	0.3254	0.3254	0.1297	0.0204	0.0012	14.5	19.4	1,558
7	5.74	0.0280	0.0013	0.0208	0.1322	0.3317	0.3317	0.1322	0.0208	0.0013	14.1	19.8	1,581
8	6.56	0.0168	0.0013	0.0210	0.1337	0.3356	0.3356	0.1337	0.0210	0.0013	13.5	20.0	1,594
9	7.38	0.0101	0.0013	0.0212	0.1346	0.3379	0.3379	0.1346	0.0212	0.0013	12.8	20.2	1,602
10	8.20	0.0060	0.0013	0.0213	0.1352	0.3392	0.3392	0.1352	0.0213	0.0013	12.1	20.3	1,607
11	9.02	0.0036	0.0013	0.0213	0.1355	0.3401	0.3401	0.1355	0.0213	0.0013	11.3	20.3	1,610
12	9.84	0.0022	0.0013	0.0214	0.1357	0.3406	0.3406	0.1357	0.0214	0.0013	10.5	20.3	1,612
13	10.66	0.0013	0.0013	0.0214	0.1358	0.3409	0.3409	0.1358	0.0214	0.0013	9.7	20.4	1,613
14	11.48	0.0008	0.0013	0.0214	0.1359	0.3410	0.3410	0.1359	0.0214	0.0013	8.9	20.4	1,614
15	12.30	0.0005	0.0013	0.0214	0.1359	0.3411	0.3411	0.1359	0.0214	0.0013	8.1	20.4	1,614
16	13.12	0.0003	0.0013	0.0214	0.1360	0.3412	0.3412	0.1360	0.0214	0.0013	7.3	20.4	1,614
17	13.94	0.0002	0.0013	0.0214	0.1360	0.3412	0.3412	0.1360	0.0214	0.0013	6.4	20.4	1,614
18	14.76	0.0001	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	5.6	20.4	1,614
19	15.58	0.0001	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	4.8	20.4	1,614
20	16.40	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	4.0	20.4	1,614

Table 1.3

EXPLORATION EFFORT - DISCOVERY SIZE PROBABILITY MATRIX

EXP(U) = 500 S = 20.00% P = 0.6

NO. OF WELLS DRILLED	TOTAL COST	SIZE (BBL/DAY): 0 NPV ($M): 0	6 0.00	22 0.00	77 0.44	269 4.80	931 17	3,226 58	11,180 200	38,748 692	EXPECTED PROFIT OF PROJECT	EXPECTED DISCOVERY VALUE	VARIANCE OF DISCOVERY VALUE
1	0.82	0.4000	0.0008	0.0128	0.0816	0.2048	0.2048	0.0816	0.0128	0.0008	11.4	12.2	1,068
2	1.64	0.1600	0.0011	0.0180	0.1142	0.2867	0.2867	0.1142	0.0180	0.0011	15.5	17.1	1,412
3	2.46	0.0640	0.0012	0.0200	0.1273	0.3195	0.3195	0.1273	0.0200	0.0012	16.6	19.1	1,536
4	3.28	0.0256	0.0013	0.0209	0.1325	0.3326	0.3326	0.1325	0.0209	0.0013	16.6	19.9	1,584
5	4.10	0.0102	0.0013	0.0212	0.1346	0.3378	0.3378	0.1346	0.0212	0.0013	16.1	20.2	1,602
6	4.92	0.0041	0.0013	0.0213	0.1354	0.3399	0.3399	0.1354	0.0213	0.0013	15.4	20.3	1,610
7	5.74	0.0016	0.0013	0.0214	0.1358	0.3407	0.3407	0.1358	0.0214	0.0013	14.6	20.3	1,613
8	6.56	0.0007	0.0013	0.0214	0.1359	0.3411	0.3411	0.1359	0.0214	0.0013	13.8	20.4	1,614
9	7.38	0.0003	0.0013	0.0214	0.1360	0.3412	0.3412	0.1360	0.0214	0.0013	13.0	20.4	1,614
10	8.20	0.0001	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	12.2	20.4	1,614
11	9.02	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	11.4	20.4	1,614
12	9.84	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	10.5	20.4	1,614
13	10.66	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	9.7	20.4	1,614
14	11.48	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	8.9	20.4	1,615
15	12.30	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	8.1	20.4	1,615
16	13.12	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	7.3	20.4	1,615
17	13.94	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	6.4	20.4	1,615
18	14.76	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	5.6	20.4	1,615
19	15.58	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	4.8	20.4	1,615
20	16.40	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	4.0	20.4	1,615

Table 2.0

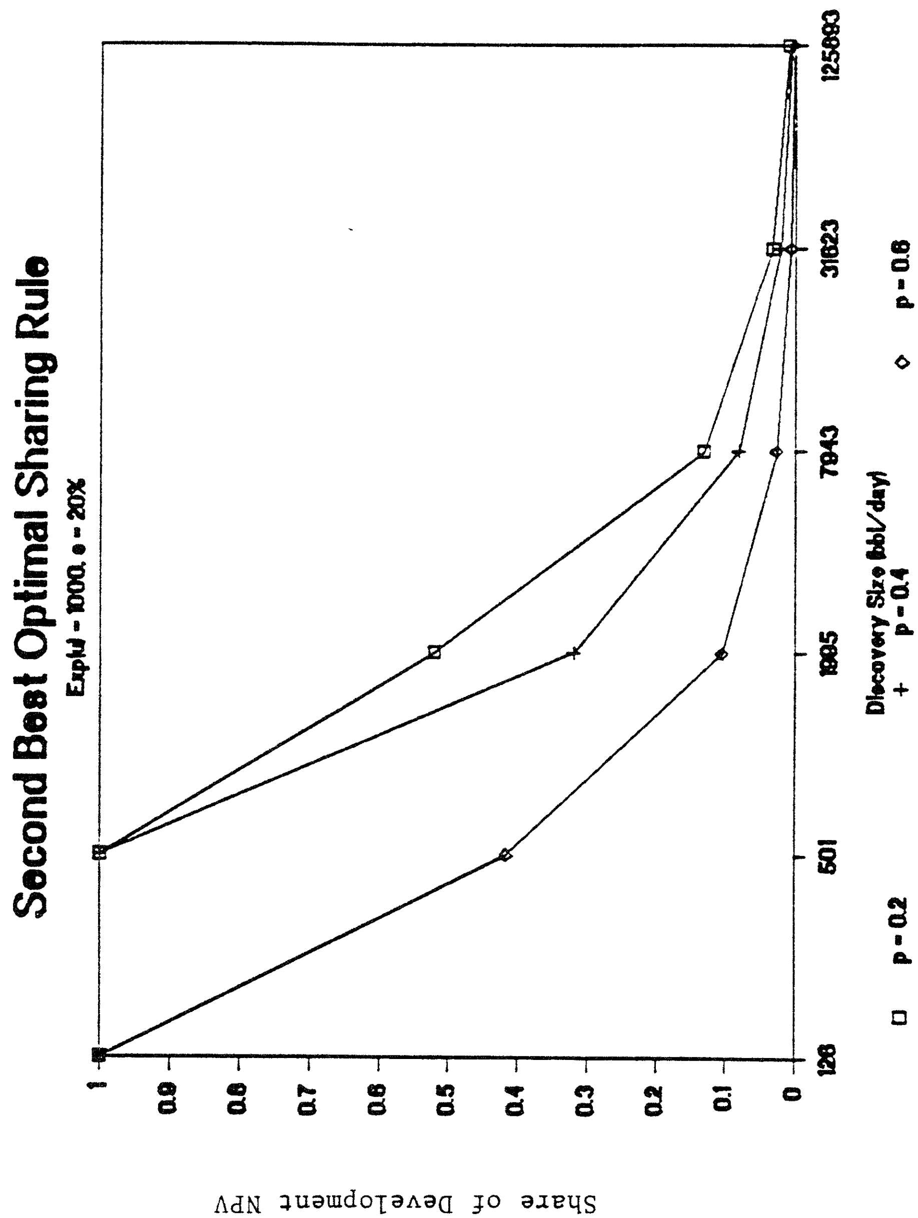
Second Best Optimal Sharing Rule
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
126
501
1995
7943
31623
125893
Discovery Size (bbl/day)
p - 0.2
p - 0.4
p - 0.6
Share of Development NPV

Table 2.1

EXPLORATION EFFORT - DISCOVERY SIZE PROBABILITY MATRIX

EXP(U) = 1000   S = 20.00%   P = 0.2

NO. OF WELLS DRILLED	TOTAL COST	SIZE (BBL/DAY): 0 NPV ($M): 0	8 0.00	32 0.00	126 1.57	501 8.95	1,995 36	7,943 142	31,623 565	125,893 2,249	EXPECTED PROFIT OF PROJECT	EXPECTED DISCOVERY VALUE	VARIANCE OF DISCOVERY VALUE
1	0.82	0.8000	0.0003	0.0043	0.0272	0.0683	0.0683	0.0272	0.0043	0.0003	9.1	9.9	3,221
2	1.64	0.6400	0.0005	0.0077	0.0490	0.1229	0.1229	0.0490	0.0077	0.0005	16.3	17.9	5,655
3	2.46	0.5120	0.0006	0.0104	0.0664	0.1666	0.1666	0.0664	0.0104	0.0006	21.8	24.3	7,511
4	3.28	0.4096	0.0008	0.0126	0.0803	0.2015	0.2015	0.0803	0.0126	0.0008	26.1	29.4	8,938
5	4.10	0.3277	0.0009	0.0144	0.0914	0.2295	0.2295	0.0914	0.0144	0.0009	29.3	33.4	10,042
6	4.92	0.2621	0.0010	0.0158	0.1003	0.2518	0.2518	0.1003	0.0158	0.0010	31.8	36.7	10,901
7	5.74	0.2097	0.0010	0.0169	0.1075	0.2697	0.2697	0.1075	0.0169	0.0010	33.6	39.3	11,573
8	6.56	0.1678	0.0011	0.0178	0.1132	0.2840	0.2840	0.1132	0.0178	0.0011	34.8	41.4	12,101
9	7.38	0.1342	0.0011	0.0185	0.1177	0.2955	0.2955	0.1177	0.0185	0.0011	35.7	43.1	12,517
10	8.20	0.1074	0.0012	0.0191	0.1214	0.3047	0.3047	0.1214	0.0191	0.0012	36.2	44.4	12,846
11	9.02	0.0859	0.0012	0.0196	0.1243	0.3120	0.3120	0.1243	0.0196	0.0012	36.4	45.5	13,106
12	9.84	0.0687	0.0012	0.0199	0.1267	0.3178	0.3178	0.1267	0.0199	0.0012	36.5	46.3	13,313
13	10.66	0.0550	0.0012	0.0202	0.1285	0.3225	0.3225	0.1285	0.0202	0.0012	36.3	47.0	13,478
14	11.48	0.0440	0.0012	0.0205	0.1300	0.3263	0.3263	0.1300	0.0205	0.0012	36.1	47.6	13,608
15	12.30	0.0352	0.0013	0.0206	0.1312	0.3293	0.3293	0.1312	0.0206	0.0013	35.7	48.0	13,713
16	13.12	0.0281	0.0013	0.0208	0.1322	0.3317	0.3317	0.1322	0.0208	0.0013	35.2	48.3	13,796
17	13.94	0.0225	0.0013	0.0209	0.1329	0.3336	0.3336	0.1329	0.0209	0.0013	34.7	48.6	13,862
18	14.76	0.0180	0.0013	0.0210	0.1336	0.3352	0.3352	0.1336	0.0210	0.0013	34.1	48.8	13,915
19	15.58	0.0144	0.0013	0.0211	0.1340	0.3364	0.3364	0.1340	0.0211	0.0013	33.4	49.0	13,957
20	16.40	0.0115	0.0013	0.0212	0.1344	0.3374	0.3374	0.1344	0.0212	0.0013	32.8	49.2	13,991

Table 2.2

EXPLORATION EFFORT - DISCOVERY SIZE PROBABILITY MATRIX

EXP(U) = 1000 S = 20.00% P = 0.4

SIZE (BBL/DAY):		0	8	32	126	501	1,995	7,943	31,623	125,893	EXPECTED	EXPECTED	VARIANCE
NPV ($M):		0	0.00	0.00	1.57	8.95	36	142	565	2,249	PROFIT OF PROJECT	DISCOVERY VALUE	OF DISCOVERY VALUE
NO. OF WELLS DRILLED	TOTAL COST												
1	0.82	0.6000	0.0005	0.0086	0.0544	0.1365	0.1365	0.0544	0.0086	0.0005	19.1	19.9	6,244
2	1.64	0.3600	0.0008	0.0137	0.0870	0.2184	0.2184	0.0870	0.0137	0.0008	30.2	31.8	9,610
3	2.46	0.2160	0.0010	0.0168	0.1066	0.2676	0.2676	0.1066	0.0168	0.0010	36.5	39.0	11,493
4	3.28	0.1296	0.0011	0.0186	0.1184	0.2971	0.2971	0.1184	0.0186	0.0011	40.0	43.3	12,574
5	4.10	0.0778	0.0012	0.0197	0.1254	0.3148	0.3148	0.1254	0.0197	0.0012	41.8	45.9	13,205
6	4.92	0.0467	0.0012	0.0204	0.1297	0.3254	0.3254	0.1297	0.0204	0.0012	42.5	47.4	13,577
7	5.74	0.0280	0.0013	0.0208	0.1322	0.3317	0.3317	0.1322	0.0208	0.0013	42.6	48.3	13,797
8	6.56	0.0168	0.0013	0.0210	0.1337	0.3356	0.3356	0.1337	0.0210	0.0013	42.3	48.9	13,929
9	7.38	0.0101	0.0013	0.0212	0.1346	0.3379	0.3379	0.1346	0.0212	0.0013	41.9	49.2	14,008
10	8.20	0.0060	0.0013	0.0213	0.1352	0.3392	0.3392	0.1352	0.0213	0.0013	41.2	49.4	14,055
11	9.02	0.0036	0.0013	0.0213	0.1355	0.3401	0.3401	0.1355	0.0213	0.0013	40.5	49.6	14,083
12	9.84	0.0022	0.0013	0.0214	0.1357	0.3406	0.3406	0.1357	0.0214	0.0013	39.8	49.6	14,100
13	10.66	0.0013	0.0013	0.0214	0.1358	0.3409	0.3409	0.1358	0.0214	0.0013	39.0	49.7	14,110
14	11.48	0.0008	0.0013	0.0214	0.1359	0.3410	0.3410	0.1359	0.0214	0.0013	38.2	49.7	14,116
15	12.30	0.0005	0.0013	0.0214	0.1359	0.3411	0.3411	0.1359	0.0214	0.0013	37.4	49.7	14,120
16	13.12	0.0003	0.0013	0.0214	0.1360	0.3412	0.3412	0.1360	0.0214	0.0013	36.6	49.7	14,122
17	13.94	0.0002	0.0013	0.0214	0.1360	0.3412	0.3412	0.1360	0.0214	0.0013	35.8	49.7	14,124
18	14.76	0.0001	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	35.0	49.7	14,124
19	15.58	0.0001	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	34.2	49.7	14,125
20	16.40	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	33.3	49.7	14,125

Table 2.3

EXPLORATION EFFORT - DISCOVERY SIZE PROBABILITY MATRIX

EXP(U) = 1000 S = 20.00% P = 0.6

SIZE (BBL/DAY):		0	8	32	126	501	1,995	7,943	31,623	125,893	EXPECTED	EXPECTED	VARIANCE
NPV ($M):		0	0.00	0.00	1.57	8.95	36	142	565	2,249	PROFIT OF PROJECT	DISCOVERY VALUE	OF DISCOVERY VALUE
NO. OF WELLS DRILLED	TOTAL COST												
1	0.82	0.4000	0.0008	0.0128	0.0816	0.2048	0.2048	0.0816	0.0128	0.0008	29.0	29.8	9,069
2	1.64	0.1600	0.0011	0.0180	0.1142	0.2867	0.2867	0.1142	0.0180	0.0011	40.1	41.8	12,198
3	2.46	0.0640	0.0012	0.0200	0.1273	0.3195	0.3195	0.1273	0.0200	0.0012	44.1	46.6	13,370
4	3.28	0.0256	0.0013	0.0209	0.1325	0.3326	0.3326	0.1325	0.0209	0.0013	45.2	48.5	13,826
5	4.10	0.0102	0.0013	0.0212	0.1346	0.3378	0.3378	0.1346	0.0212	0.0013	45.1	49.2	14,006
6	4.92	0.0041	0.0013	0.0213	0.1354	0.3399	0.3399	0.1354	0.0213	0.0013	44.6	49.5	14,078
7	5.74	0.0016	0.0013	0.0214	0.1358	0.3407	0.3407	0.1358	0.0214	0.0013	43.9	49.7	14,106
8	6.56	0.0007	0.0013	0.0214	0.1359	0.3411	0.3411	0.1359	0.0214	0.0013	43.1	49.7	14,118
9	7.38	0.0003	0.0013	0.0214	0.1360	0.3412	0.3412	0.1360	0.0214	0.0013	42.3	49.7	14,123
10	8.20	0.0001	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	41.5	49.7	14,124
11	9.02	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	40.7	49.7	14,125
12	9.84	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	39.9	49.7	14,125
13	10.66	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	39.1	49.7	14,125
14	11.48	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	38.3	49.7	14,126
15	12.30	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	37.4	49.7	14,126
16	13.12	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	36.6	49.7	14,126
17	13.94	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	35.8	49.7	14,126
18	14.76	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	35.0	49.7	14,126
19	15.58	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	34.2	49.7	14,126
20	16.40	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	33.3	49.7	14,126

Table 3.0

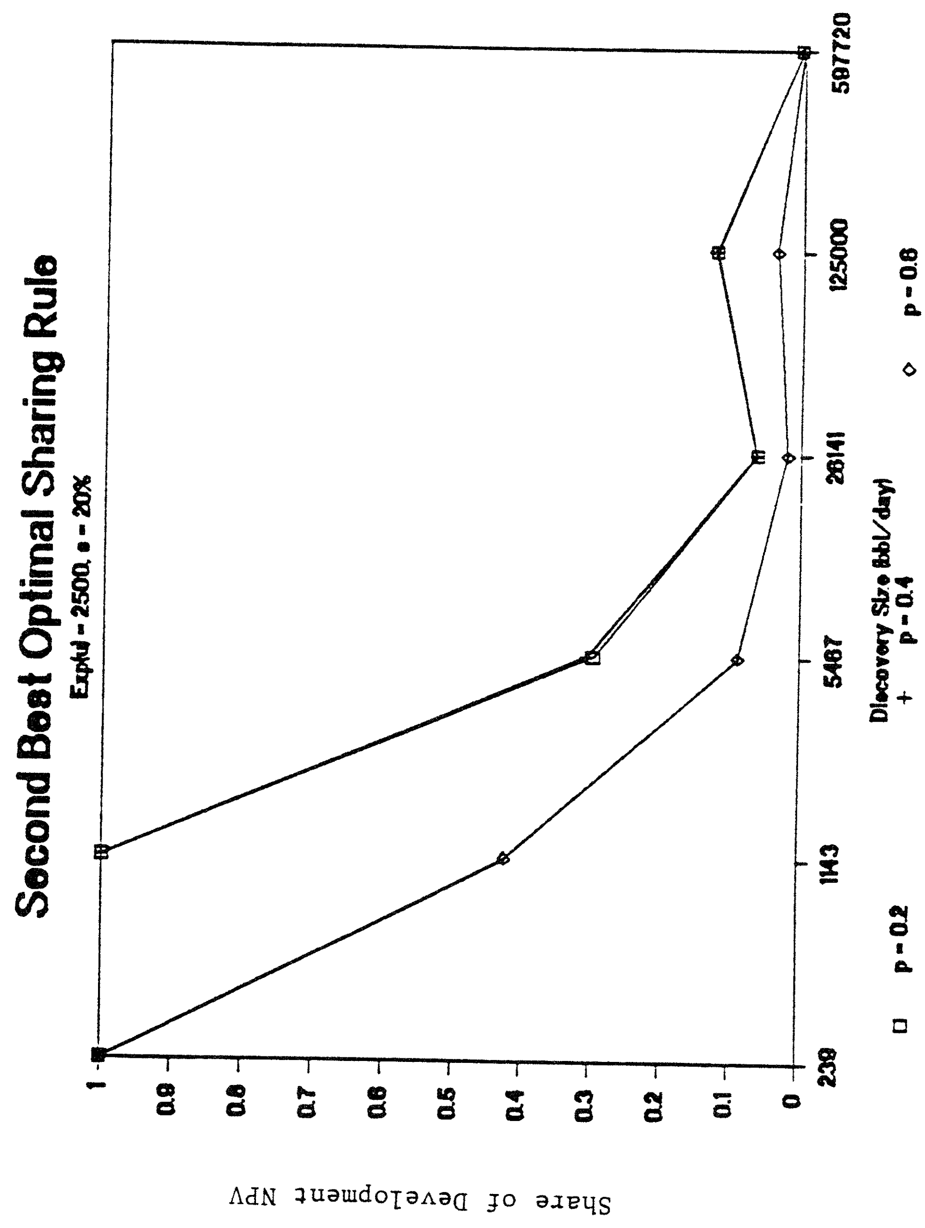
Second Best Optimal Sharing Rule
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
239
1143
5487
26141
125000
597720
Discovery Size (bbl/day)
p = 0.2
p = 0.4
p = 0.6
Share of Development NPV

Table 3.1

EXPLORATION EFFORT - DISCOVERY SIZE PROBABILITY MATRIX

EXP(U) = 2500 S = 20.00% P = 0.2

SIZE (BBL/DAY):		0	10	50	239	1,143	5,467	26,141	125,000	597,720	EXPECTED	EXPECTED	VARIANCE
NPV ($M):		0	0.00	0.00	4.21	20.42	98	467	2,233	10,676	PROFIT	DISCOVERY	OF DISCOVERY
NO. OF WELLS DRILLED	TOTAL COST										OF PROJECT	VALUE	VALUE
1	0.82	0.8000	0.0003	0.0043	0.0272	0.0683	0.0683	0.0272	0.0043	0.0003	32.4	33.2	56,478
2	1.64	0.6400	0.0005	0.0077	0.0490	0.1229	0.1229	0.0490	0.0077	0.0005	58.1	59.8	100,072
3	2.46	0.5120	0.0006	0.0104	0.0664	0.1666	0.1666	0.0664	0.0104	0.0006	78.6	81.0	133,932
4	3.28	0.4096	0.0008	0.0126	0.0803	0.2015	0.2015	0.0803	0.0126	0.0008	94.7	98.0	160,369
5	4.10	0.3277	0.0009	0.0144	0.0914	0.2295	0.2295	0.0914	0.0144	0.0009	107.5	111.6	181,103
6	4.92	0.2621	0.0010	0.0158	0.1003	0.2518	0.2518	0.1003	0.0158	0.0010	117.6	122.5	197,423
7	5.74	0.2097	0.0010	0.0169	0.1075	0.2697	0.2697	0.1075	0.0169	0.0010	125.5	131.2	210,309
8	6.56	0.1678	0.0011	0.0178	0.1132	0.2840	0.2840	0.1132	0.0178	0.0011	131.6	138.2	220,509
9	7.38	0.1342	0.0011	0.0185	0.1177	0.2955	0.2955	0.1177	0.0185	0.0011	136.4	143.7	228,598
10	8.20	0.1074	0.0012	0.0191	0.1214	0.3047	0.3047	0.1214	0.0191	0.0012	140.0	148.2	235,026
11	9.02	0.0859	0.0012	0.0196	0.1243	0.3120	0.3120	0.1243	0.0196	0.0012	142.7	151.8	240,139
12	9.84	0.0687	0.0012	0.0199	0.1267	0.3178	0.3178	0.1267	0.0199	0.0012	144.8	154.6	244,211
13	10.66	0.0550	0.0012	0.0202	0.1285	0.3225	0.3225	0.1285	0.0202	0.0012	146.2	156.9	247,457
14	11.48	0.0440	0.0012	0.0205	0.1300	0.3263	0.3263	0.1300	0.0205	0.0012	147.2	158.7	250,046
15	12.30	0.0352	0.0013	0.0206	0.1312	0.3293	0.3293	0.1312	0.0206	0.0013	147.9	160.2	252,113
16	13.12	0.0281	0.0013	0.0208	0.1322	0.3317	0.3317	0.1322	0.0208	0.0013	148.2	161.4	253,763
17	13.94	0.0225	0.0013	0.0209	0.1329	0.3336	0.3336	0.1329	0.0209	0.0013	148.4	162.3	255,081
18	14.76	0.0180	0.0013	0.0210	0.1336	0.3352	0.3352	0.1336	0.0210	0.0013	148.3	163.0	256,135
19	15.58	0.0144	0.0013	0.0211	0.1340	0.3364	0.3364	0.1340	0.0211	0.0013	148.1	163.6	256,977
20	16.40	0.0115	0.0013	0.0212	0.1344	0.3374	0.3374	0.1344	0.0212	0.0013	147.7	164.1	257,650

Table 3.2

EXPLORATION EFFORT - DISCOVERY SIZE PROBABILITY MATRIX

EXP(U) = 2500 S = 20.00% P = 0.4

SIZE (BBL/DAY):		0	10	50	239	1,143	5,467	26,141	125,000	597,720	EXPECTED	EXPECTED	VARIANCE
NPV ($M):		0	0.00	0.00	4.21	20.42	98	467	2,233	10,676	PROFIT	DISCOVERY	OF DISCOVERY
NO. OF WELLS DRILLED	TOTAL COST										OF PROJECT	VALUE	VALUE
1	0.82	0.6000	0.0005	0.0086	0.0544	0.1365	0.1365	0.0544	0.0086	0.0005	65.6	66.4	110,751
2	1.64	0.3600	0.0008	0.0137	0.0870	0.2184	0.2184	0.0870	0.0137	0.0008	104.6	106.3	172,967
3	2.46	0.2160	0.0010	0.0168	0.1066	0.2676	0.2676	0.1066	0.0168	0.0010	127.7	130.2	208,772
4	3.28	0.1296	0.0011	0.0186	0.1184	0.2971	0.2971	0.1184	0.0186	0.0011	141.2	144.5	229,707
5	4.10	0.0778	0.0012	0.0197	0.1254	0.3148	0.3148	0.1254	0.0197	0.0012	149.0	153.1	242,070
6	4.92	0.0467	0.0012	0.0204	0.1297	0.3254	0.3254	0.1297	0.0204	0.0012	153.4	158.3	249,417
7	5.74	0.0280	0.0013	0.0208	0.1322	0.3317	0.3317	0.1322	0.0208	0.0013	155.6	161.4	253,799
8	6.56	0.0168	0.0013	0.0210	0.1337	0.3356	0.3356	0.1337	0.0210	0.0013	156.7	163.2	256,420
9	7.38	0.0101	0.0013	0.0212	0.1346	0.3379	0.3379	0.1346	0.0212	0.0013	157.0	164.4	257,988
10	8.20	0.0060	0.0013	0.0213	0.1352	0.3392	0.3392	0.1352	0.0213	0.0013	156.8	165.0	258,929
11	9.02	0.0036	0.0013	0.0213	0.1355	0.3401	0.3401	0.1355	0.0213	0.0013	156.4	165.4	259,492
12	9.84	0.0022	0.0013	0.0214	0.1357	0.3406	0.3406	0.1357	0.0214	0.0013	155.8	165.7	259,830
13	10.66	0.0013	0.0013	0.0214	0.1358	0.3409	0.3409	0.1358	0.0214	0.0013	155.2	165.8	260,033
14	11.48	0.0008	0.0013	0.0214	0.1359	0.3410	0.3410	0.1359	0.0214	0.0013	154.4	165.9	260,155
15	12.30	0.0005	0.0013	0.0214	0.1359	0.3411	0.3411	0.1359	0.0214	0.0013	153.7	166.0	260,228
16	13.12	0.0003	0.0013	0.0214	0.1360	0.3412	0.3412	0.1360	0.0214	0.0013	152.9	166.0	260,271
17	13.94	0.0002	0.0013	0.0214	0.1360	0.3412	0.3412	0.1360	0.0214	0.0013	152.1	166.0	260,298
18	14.76	0.0001	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	151.3	166.0	260,313
19	15.58	0.0001	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	150.4	166.0	260,323
20	16.40	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	149.6	166.0	260,329

Table 3.3

EXPLORATION EFFORT - DISCOVERY SIZE PROBABILITY MATRIX

EXP(U) = 2500 S = 20.00% P = 0.6

SIZE (BBL/DAY):		0	10	50	239	1,143	5,467	26,141	125,000	597,720	EXPECTED	EXPECTED	VARIANCE
NPV ($M):		0	0.00	0.00	4.21	20.42	98	467	2,233	10,676	PROFIT	DISCOVERY	OF DISCOVERY
NO. OF WELLS DRILLED	TOTAL COST										OF PROJECT	VALUE	VALUE
1	0.82	0.4000	0.0008	0.0128	0.0816	0.2048	0.2048	0.0816	0.0128	0.0008	98.8	99.6	162,818
2	1.64	0.1600	0.0011	0.0180	0.1142	0.2867	0.2867	0.1142	0.0180	0.0011	137.8	139.5	222,388
3	2.46	0.0640	0.0012	0.0200	0.1273	0.3195	0.3195	0.1273	0.0200	0.0012	152.9	155.4	245,327
4	3.28	0.0256	0.0013	0.0209	0.1325	0.3326	0.3326	0.1325	0.0209	0.0013	158.5	161.8	254,360
5	4.10	0.0102	0.0013	0.0212	0.1346	0.3378	0.3378	0.1346	0.0212	0.0013	160.2	164.3	257,951
6	4.92	0.0041	0.0013	0.0213	0.1354	0.3399	0.3399	0.1354	0.0213	0.0013	160.4	165.3	259,383
7	5.74	0.0016	0.0013	0.0214	0.1358	0.3407	0.3407	0.1358	0.0214	0.0013	160.0	165.8	259,956
8	6.56	0.0007	0.0013	0.0214	0.1359	0.3411	0.3411	0.1359	0.0214	0.0013	159.4	165.9	260,184
9	7.38	0.0003	0.0013	0.0214	0.1360	0.3412	0.3412	0.1360	0.0214	0.0013	158.6	166.0	260,276
10	8.20	0.0001	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	157.8	166.0	260,313
11	9.02	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	157.0	166.0	260,327
12	9.84	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	156.2	166.0	260,333
13	10.66	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	155.4	166.0	260,335
14	11.48	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	154.6	166.0	260,336
15	12.30	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	153.7	166.0	260,337
16	13.12	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	152.9	166.0	260,337
17	13.94	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	152.1	166.0	260,337
18	14.76	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	151.3	166.0	260,337
19	15.58	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	150.5	166.0	260,337
20	16.40	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	149.6	166.0	260,337

<u>Table 4.0</u>

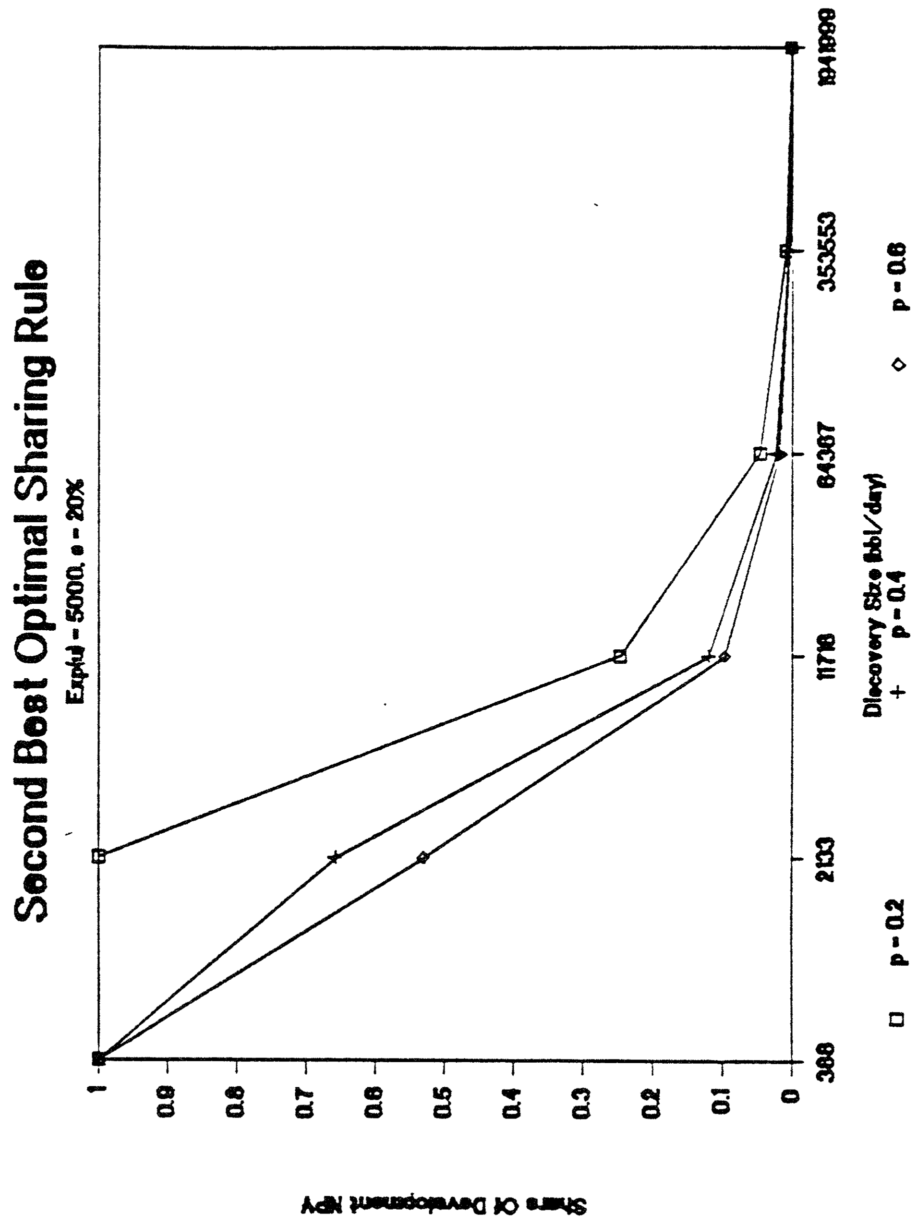
Second Best Optimal Sharing Rule
Exp(u) - 5000, e - 20%
Share Of Development NPV
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
388
2133
11718
64387
353553
1941999
Discovery Size (bbl/day)
p - 0.2
p - 0.4
p - 0.6

Table 4.1

EXPLORATION EFFORT - DISCOVERY SIZE PROBABILITY MATRIX

EXP(U) = 5000 S = 20.00% P = 0.2

SIZE (BBL/DAY):		0	13	71	388	2,133	11,718	64,367	353,553	1,941,999	EXPECTED	EXPECTED	VARIANCE
NPV ($M):		0	0.00	0.28	6.94	38.11	209	1,150	6,315	34,687	PROFIT	DISCOVERY	OF DISCOVERY
NO. OF WELLS DRILLED	TOTAL COST										OF PROJECT	VALUE	VALUE
1	0.82	0.8000	0.0003	0.0043	0.0272	0.0683	0.0683	0.0272	0.0043	0.0003	83.6	84.4	515,436
2	1.64	0.6400	0.0005	0.0077	0.0490	0.1229	0.1229	0.0490	0.0077	0.0005	150.3	151.9	917,528
3	2.46	0.5120	0.0006	0.0104	0.0664	0.1666	0.1666	0.0664	0.0104	0.0006	203.5	205.9	1,232,637
4	3.28	0.4096	0.0008	0.0126	0.0803	0.2015	0.2015	0.0803	0.0126	0.0008	245.9	249.1	1,480,524
5	4.10	0.3277	0.0009	0.0144	0.0914	0.2295	0.2295	0.0914	0.0144	0.0009	279.6	283.7	1,676,144
6	4.92	0.2621	0.0010	0.0158	0.1003	0.2518	0.2518	0.1003	0.0158	0.0010	306.4	311.4	1,830,919
7	5.74	0.2097	0.0010	0.0169	0.1075	0.2697	0.2697	0.1075	0.0169	0.0010	327.7	333.5	1,953,638
8	6.56	0.1678	0.0011	0.0178	0.1132	0.2840	0.2840	0.1132	0.0178	0.0011	344.6	351.2	2,051,108
9	7.38	0.1342	0.0011	0.0185	0.1177	0.2955	0.2955	0.1177	0.0185	0.0011	358.0	365.3	2,128,633
10	8.20	0.1074	0.0012	0.0191	0.1214	0.3047	0.3047	0.1214	0.0191	0.0012	368.5	376.7	2,190,365
11	9.02	0.0859	0.0012	0.0196	0.1243	0.3120	0.3120	0.1243	0.0196	0.0012	376.7	385.7	2,239,565
12	9.84	0.0687	0.0012	0.0199	0.1267	0.3178	0.3178	0.1267	0.0199	0.0012	383.1	393.0	2,278,807
13	10.66	0.0550	0.0012	0.0202	0.1285	0.3225	0.3225	0.1285	0.0202	0.0012	388.1	398.8	2,310,125
14	11.48	0.0440	0.0012	0.0205	0.1300	0.3263	0.3263	0.1300	0.0205	0.0012	391.9	403.4	2,335,131
15	12.30	0.0352	0.0013	0.0206	0.1312	0.3293	0.3293	0.1312	0.0206	0.0013	394.8	407.1	2,355,105
16	13.12	0.0281	0.0013	0.0208	0.1322	0.3317	0.3317	0.1322	0.0208	0.0013	397.0	410.1	2,371,064
17	13.94	0.0225	0.0013	0.0209	0.1329	0.3336	0.3336	0.1329	0.0209	0.0013	398.5	412.5	2,383,818
18	14.76	0.0180	0.0013	0.0210	0.1336	0.3352	0.3352	0.1336	0.0210	0.0013	399.6	414.4	2,394,014
19	15.58	0.0144	0.0013	0.0211	0.1340	0.3364	0.3364	0.1340	0.0211	0.0013	400.3	415.9	2,402,165
20	16.40	0.0115	0.0013	0.0212	0.1344	0.3374	0.3374	0.1344	0.0212	0.0013	400.7	417.1	2,408,683

Table 4.2

EXPLORATION EFFORT - DISCOVERY SIZE PROBABILITY MATRIX

EXP(U) = 5000 S = 20.00% P = 0.4

SIZE (BBL/DAY):		0	13	71	388	2,133	11,718	64,367	353,553	1,941,999	EXPECTED	EXPECTED	VARIANCE
NPV ($M):		0	0.00	0.28	6.94	38.11	209	1,150	6,315	34,687	PROFIT	DISCOVERY	OF DISCOVERY
NO. OF WELLS DRILLED	TOTAL COST										OF PROJECT	VALUE	VALUE
1	0.82	0.6000	0.0005	0.0086	0.0544	0.1365	0.1365	0.0544	0.0086	0.0005	168.0	168.8	1,016,627
2	1.64	0.3600	0.0008	0.0137	0.0870	0.2184	0.2184	0.0870	0.0137	0.0008	268.4	270.1	1,599,251
3	2.46	0.2160	0.0010	0.0168	0.1066	0.2676	0.2676	0.1066	0.0168	0.0010	328.4	330.8	1,938,979
4	3.28	0.1296	0.0011	0.0186	0.1184	0.2971	0.2971	0.1184	0.0186	0.0011	364.0	367.3	2,139,271
5	4.10	0.0778	0.0012	0.0197	0.1254	0.3148	0.3148	0.1254	0.0197	0.0012	385.1	389.2	2,258,170
6	4.92	0.0467	0.0012	0.0204	0.1297	0.3254	0.3254	0.1297	0.0204	0.0012	397.4	402.3	2,329,050
7	5.74	0.0280	0.0013	0.0208	0.1322	0.3317	0.3317	0.1322	0.0208	0.0013	404.4	410.2	2,371,413
8	6.56	0.0168	0.0013	0.0210	0.1337	0.3356	0.3356	0.1337	0.0210	0.0013	408.3	414.9	2,396,771
9	7.38	0.0101	0.0013	0.0212	0.1346	0.3379	0.3379	0.1346	0.0212	0.0013	410.4	417.7	2,411,964
10	8.20	0.0060	0.0013	0.0213	0.1352	0.3392	0.3392	0.1352	0.0213	0.0013	411.2	419.4	2,421,072
11	9.02	0.0036	0.0013	0.0213	0.1355	0.3401	0.3401	0.1355	0.0213	0.0013	411.4	420.5	2,426,535
12	9.84	0.0022	0.0013	0.0214	0.1357	0.3406	0.3406	0.1357	0.0214	0.0013	411.2	421.1	2,429,811
13	10.66	0.0013	0.0013	0.0214	0.1358	0.3409	0.3409	0.1358	0.0214	0.0013	410.8	421.4	2,431,776
14	11.48	0.0008	0.0013	0.0214	0.1359	0.3410	0.3410	0.1359	0.0214	0.0013	410.2	421.7	2,432,955
15	12.30	0.0005	0.0013	0.0214	0.1359	0.3411	0.3411	0.1359	0.0214	0.0013	409.5	421.8	2,433,663
16	13.12	0.0003	0.0013	0.0214	0.1360	0.3412	0.3412	0.1360	0.0214	0.0013	408.7	421.9	2,434,087
17	13.94	0.0002	0.0013	0.0214	0.1360	0.3412	0.3412	0.1360	0.0214	0.0013	408.0	421.9	2,434,342
18	14.76	0.0001	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	407.2	421.9	2,434,495
19	15.58	0.0001	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	406.4	422.0	2,434,586
20	16.40	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	405.6	422.0	2,434,641

Table 4.3

EXPLORATION EFFORT - DISCOVERY SIZE PROBABILITY MATRIX

EXP(U) = 5000 S = 20.00% P = 0.6

SIZE (BBL/DAY):		0	13	71	388	2,133	11,718	64,367	353,553	1,941,999	EXPECTED	EXPECTED	VARIANCE
NPV ($M):		0	0.00	0.28	6.94	38.11	209	1,150	6,315	34,687	PROFIT OF PROJECT	DISCOVERY VALUE	OF DISCOVERY VALUE
NO. OF WELLS DRILLED	TOTAL COST												
1	0.82	0.4000	0.0008	0.0128	0.0816	0.2048	0.2048	0.0816	0.0128	0.0008	252.4	253.2	1,503,571
2	1.64	0.1600	0.0011	0.0180	0.1142	0.2867	0.2867	0.1142	0.0180	0.0011	352.8	354.5	2,069,101
3	2.46	0.0640	0.0012	0.0200	0.1273	0.3195	0.3195	0.1273	0.0200	0.0012	392.5	395.0	2,289,569
4	3.28	0.0256	0.0013	0.0209	0.1325	0.3326	0.3326	0.1325	0.0209	0.0013	407.9	411.2	2,376,837
5	4.10	0.0102	0.0013	0.0212	0.1346	0.3378	0.3378	0.1346	0.0212	0.0013	413.6	417.7	2,411,597
6	4.92	0.0041	0.0013	0.0213	0.1354	0.3399	0.3399	0.1354	0.0213	0.0013	415.3	420.3	2,425,478
7	5.74	0.0016	0.0013	0.0214	0.1358	0.3407	0.3407	0.1358	0.0214	0.0013	415.6	421.3	2,431,026
8	6.56	0.0007	0.0013	0.0214	0.1359	0.3411	0.3411	0.1359	0.0214	0.0013	415.1	421.7	2,433,245
9	7.38	0.0003	0.0013	0.0214	0.1360	0.3412	0.3412	0.1360	0.0214	0.0013	414.5	421.9	2,434,132
10	8.20	0.0001	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	413.7	421.9	2,434,487
11	9.02	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	412.9	422.0	2,434,629
12	9.84	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	412.1	422.0	2,434,686
13	10.66	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	411.3	422.0	2,434,709
14	11.48	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	410.5	422.0	2,434,718
15	12.30	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	409.7	422.0	2,434,722
16	13.12	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	408.9	422.0	2,434,723
17	13.94	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	408.0	422.0	2,434,724
18	14.76	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	407.2	422.0	2,434,724
19	15.58	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	406.4	422.0	2,434,724
20	16.40	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	405.6	422.0	2,434,724

Table 5.0

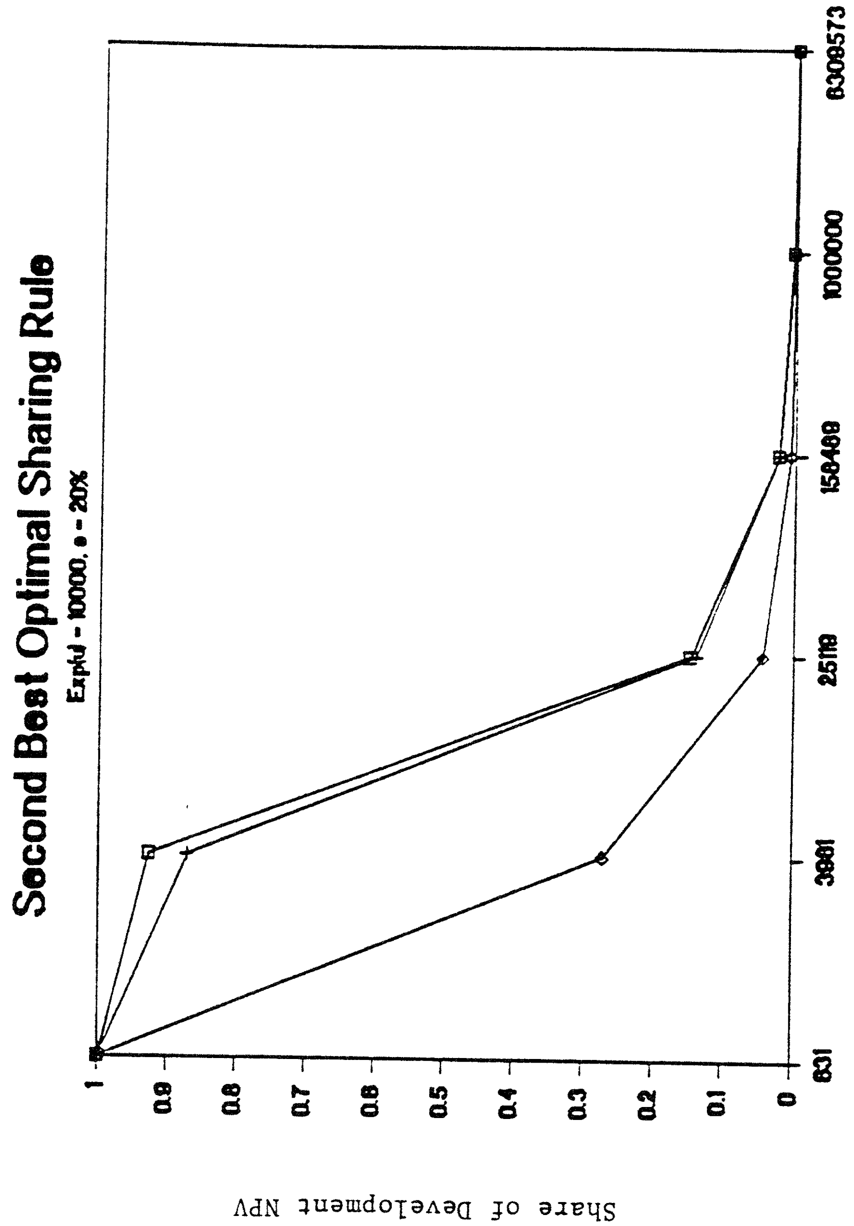
Second Best Optimal Sharing Rule
Explu - 10000, e - 20%
Share of Development NPV
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
631
3981
25119
158489
1000000
6309573
Discovery Size (bbl/day)
p - 0.2
p - 0.4
p - 0.6

Table 5.1

EXPLORATION EFFORT - DISCOVERY SIZE PROBABILITY MATRIX

EXP(U) = 10000 S = 20.00% P = 0.2

SIZE (BBL/DAY):		0	16	100	631	3,981	25,119	158,489	1,000,000	6,309,573	EXPECTED	EXPECTED	VARIANCE
NPV ($M):		0	0.00	0.96	11.27	71.11	449	2,831	17,862	112,699	PROFIT	DISCOVERY	OF DISCOVERY
NO. OF WELLS DRILLED	TOTAL COST										OF PROJECT	VALUE	VALUE
1	0.82	0.8000	0.0003	0.0043	0.0272	0.0683	0.0683	0.0272	0.0043	0.0003	217.7	218.5	4,852,046
2	1.64	0.6400	0.0005	0.0077	0.0490	0.1229	0.1229	0.0490	0.0077	0.0005	391.7	393.4	8,664,910
3	2.46	0.5120	0.0006	0.0104	0.0664	0.1666	0.1666	0.0664	0.0104	0.0006	530.8	533.2	11,671,186
4	3.28	0.4096	0.0008	0.0126	0.0803	0.2015	0.2015	0.0803	0.0126	0.0008	641.8	645.1	14,048,038
5	4.10	0.3277	0.0009	0.0144	0.0914	0.2295	0.2295	0.0914	0.0144	0.0009	730.5	734.6	15,931,490
6	4.92	0.2621	0.0010	0.0158	0.1003	0.2518	0.2518	0.1003	0.0158	0.0010	801.3	806.3	17,426,714
7	5.74	0.2097	0.0010	0.0169	0.1075	0.2697	0.2697	0.1075	0.0169	0.0010	857.8	863.5	18,615,508
8	6.56	0.1678	0.0011	0.0178	0.1132	0.2840	0.2840	0.1132	0.0178	0.0011	902.8	909.4	19,561,818
9	7.38	0.1342	0.0011	0.0185	0.1177	0.2955	0.2955	0.1177	0.0185	0.0011	938.7	946.0	20,315,841
10	8.20	0.1074	0.0012	0.0191	0.1214	0.3047	0.3047	0.1214	0.0191	0.0012	967.2	975.4	20,917,123
11	9.02	0.0859	0.0012	0.0196	0.1243	0.3120	0.3120	0.1243	0.0196	0.0012	989.8	998.8	21,396,911
12	9.84	0.0687	0.0012	0.0199	0.1267	0.3178	0.3178	0.1267	0.0199	0.0012	1,007.8	1,017.6	21,779,947
13	10.66	0.0550	0.0012	0.0202	0.1285	0.3225	0.3225	0.1285	0.0202	0.0012	1,022.0	1,032.6	22,085,869
14	11.48	0.0440	0.0012	0.0205	0.1300	0.3263	0.3263	0.1300	0.0205	0.0012	1,033.2	1,044.6	22,330,282
15	12.30	0.0352	0.0013	0.0206	0.1312	0.3293	0.3293	0.1312	0.0206	0.0013	1,042.0	1,054.2	22,525,605
16	13.12	0.0281	0.0013	0.0208	0.1322	0.3317	0.3317	0.1322	0.0208	0.0013	1,048.8	1,061.9	22,681,729
17	13.94	0.0225	0.0013	0.0209	0.1329	0.3336	0.3336	0.1329	0.0209	0.0013	1,054.2	1,068.1	22,806,544
18	14.76	0.0180	0.0013	0.0210	0.1336	0.3352	0.3352	0.1336	0.0210	0.0013	1,058.3	1,073.0	22,906,342
19	15.58	0.0144	0.0013	0.0211	0.1340	0.3364	0.3364	0.1340	0.0211	0.0013	1,061.4	1,076.9	22,986,145
20	16.40	0.0115	0.0013	0.0212	0.1344	0.3374	0.3374	0.1344	0.0212	0.0013	1,063.7	1,080.1	23,049,965

Table 5.2

EXPLORATION EFFORT - DISCOVERY SIZE PROBABILITY MATRIX

EXP(U) = 10000   S = 20.00%   P = 0.4

SIZE (BBL/DAY):		0	16	100	631	3,981	25,119	158,489	1,000,000	6,309,573	EXPECTED PROFIT OF PROJECT	EXPECTED DISCOVERY VALUE	VARIANCE OF DISCOVERY VALUE
NPV ($M):		0	0.00	0.96	11.27	71.11	449	2,831	17,862	112,699			
NO. OF WELLS DRILLED	TOTAL COST												
1	0.82	0.6000	0.0005	0.0086	0.0544	0.1365	0.1365	0.0544	0.0086	0.0005	436.3	437.1	9,608,574
2	1.64	0.3600	0.0008	0.0137	0.0870	0.2184	0.2184	0.0870	0.0137	0.0008	697.7	699.3	15,190,323
3	2.46	0.2160	0.0010	0.0168	0.1066	0.2676	0.2676	0.1066	0.0168	0.0010	854.2	856.7	18,473,350
4	3.28	0.1296	0.0011	0.0186	0.1184	0.2971	0.2971	0.1184	0.0186	0.0011	947.8	951.1	20,419,398
5	4.10	0.0778	0.0012	0.0197	0.1254	0.3148	0.3148	0.1254	0.0197	0.0012	1,003.6	1,007.7	21,578,471
6	4.92	0.0467	0.0012	0.0204	0.1297	0.3254	0.3254	0.1297	0.0204	0.0012	1,036.8	1,041.7	22,270,834
7	5.74	0.0280	0.0013	0.0208	0.1322	0.3317	0.3317	0.1322	0.0208	0.0013	1,056.4	1,062.1	22,685,143
8	6.56	0.0168	0.0013	0.0210	0.1337	0.3356	0.3356	0.1337	0.0210	0.0013	1,067.8	1,074.3	22,933,329
9	7.38	0.0101	0.0013	0.0212	0.1346	0.3379	0.3379	0.1346	0.0212	0.0013	1,074.3	1,081.7	23,082,097
10	8.20	0.0060	0.0013	0.0213	0.1352	0.3392	0.3392	0.1352	0.0213	0.0013	1,077.9	1,086.1	23,171,306
11	9.02	0.0036	0.0013	0.0213	0.1355	0.3401	0.3401	0.1355	0.0213	0.0013	1,079.7	1,088.7	23,224,813
12	9.84	0.0022	0.0013	0.0214	0.1357	0.3406	0.3406	0.1357	0.0214	0.0013	1,080.5	1,090.3	23,256,910
13	10.66	0.0013	0.0013	0.0214	0.1358	0.3409	0.3409	0.1358	0.0214	0.0013	1,080.6	1,091.3	23,276,166
14	11.48	0.0008	0.0013	0.0214	0.1359	0.3410	0.3410	0.1359	0.0214	0.0013	1,080.4	1,091.8	23,287,719
15	12.30	0.0005	0.0013	0.0214	0.1359	0.3411	0.3411	0.1359	0.0214	0.0013	1,079.9	1,092.2	23,294,650
16	13.12	0.0003	0.0013	0.0214	0.1360	0.3412	0.3412	0.1360	0.0214	0.0013	1,079.3	1,092.4	23,298,809
17	13.94	0.0002	0.0013	0.0214	0.1360	0.3412	0.3412	0.1360	0.0214	0.0013	1,078.6	1,092.5	23,301,304
18	14.76	0.0001	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	1,077.8	1,092.6	23,302,801
19	15.58	0.0001	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	1,077.1	1,092.6	23,303,699
20	16.40	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	1,076.3	1,092.7	23,304,238

Table 5.3

EXPLORATION EFFORT - DISCOVERY SIZE PROBABILITY MATRIX

EXP(U) = 10000 S = 20.00% P = 0.6

SIZE (BBL/DAY):		0	16	100	631	3,981	25,119	158,489	1,000,000	6,309,573	EXPECTED	EXPECTED	VARIANCE
NPV ($M):		0	0.00	0.96	11.27	71.11	449	2,831	17,862	112,699	PROFIT	DISCOVERY	OF DISCOVERY
NO. OF WELLS DRILLED	TOTAL COST										OF PROJECT	VALUE	VALUE
1	0.82	0.4000	0.0008	0.0128	0.0816	0.2048	0.2048	0.0816	0.0128	0.0008	654.8	655.6	14,269,584
2	1.64	0.1600	0.0011	0.0180	0.1142	0.2867	0.2867	0.1142	0.0180	0.0011	916.2	917.9	19,736,710
3	2.46	0.0640	0.0012	0.0200	0.1273	0.3195	0.3195	0.1273	0.0200	0.0012	1,020.3	1,022.8	21,885,048
4	3.28	0.0256	0.0013	0.0209	0.1325	0.3326	0.3326	0.1325	0.0209	0.0013	1,061.4	1,064.7	22,738,221
5	4.10	0.0102	0.0013	0.0212	0.1346	0.3378	0.3378	0.1346	0.0212	0.0013	1,077.4	1,081.5	23,078,504
6	4.92	0.0041	0.0013	0.0213	0.1354	0.3399	0.3399	0.1354	0.0213	0.0013	1,083.3	1,088.2	23,214,460
7	5.74	0.0016	0.0013	0.0214	0.1358	0.3407	0.3407	0.1358	0.0214	0.0013	1,085.2	1,090.9	23,268,817
8	6.56	0.0007	0.0013	0.0214	0.1359	0.3411	0.3411	0.1359	0.0214	0.0013	1,085.4	1,092.0	23,290,555
9	7.38	0.0003	0.0013	0.0214	0.1360	0.3412	0.3412	0.1360	0.0214	0.0013	1,085.0	1,092.4	23,299,250
10	8.20	0.0001	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	1,084.4	1,092.6	23,302,728
11	9.02	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	1,083.6	1,092.6	23,304,119
12	9.84	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	1,082.8	1,092.7	23,304,676
13	10.66	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	1,082.0	1,092.7	23,304,898
14	11.48	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	1,081.2	1,092.7	23,304,987
15	12.30	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	1,080.4	1,092.7	23,305,023
16	13.12	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	1,079.6	1,092.7	23,305,037
17	13.94	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	1,078.8	1,092.7	23,305,043
18	14.76	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	1,077.9	1,092.7	23,305,045
19	15.58	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	1,077.1	1,092.7	23,305,046
20	16.40	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	1,076.3	1,092.7	23,305,046

Table 6.0

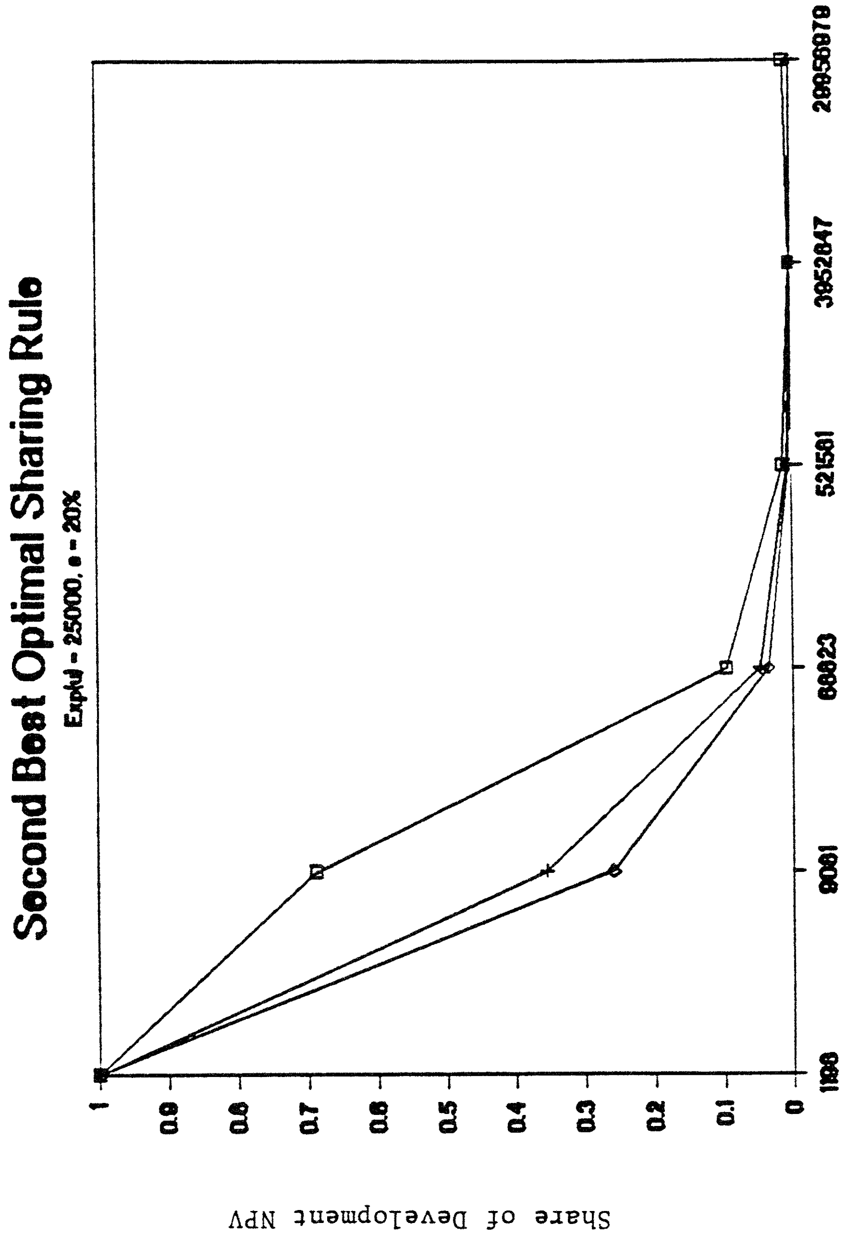
Second Best Optimal Sharing Rule
Exp(u) = 25000, e = 20%
Share of Development NPV
Discovery Size (bbl/day)
9081
68823
521581
3952847
p = 0.2
p = 0.4
p = 0.6

Table 6.1

EXPLORATION EFFORT - DISCOVERY SIZE PROBABILITY MATRIX

EXP(U) = 25000 S = 20.00% P = 0.2

SIZE (BBL/DAY):		0	21	158	1,198	9,081	68,823	521,581	3,952,847	29,956,979	EXPECTED PROFIT OF PROJECT	EXPECTED DISCOVERY VALUE	VARIANCE OF DISCOVERY VALUE
NPV ($M):		0	0.00	2.32	21.40	162.21	1,229	9,316	70,604	535,079			
NO. OF WELLS DRILLED	TOTAL COST												
1	0.82	0.8000	0.0003	0.0043	0.0272	0.0683	0.0683	0.0272	0.0043	0.0003	789.5	790.3	97,617,032
2	1.64	0.6400	0.0005	0.0077	0.0490	0.1229	0.1229	0.0490	0.0077	0.0005	1,420.9	1,422.5	174,811,309
3	2.46	0.5120	0.0006	0.0104	0.0664	0.1666	0.1666	0.0664	0.0104	0.0006	1,925.8	1,928.3	235,991,147
4	3.28	0.4096	0.0008	0.0126	0.0803	0.2015	0.2015	0.0803	0.0126	0.0008	2,329.6	2,332.9	284,566,644
5	4.10	0.3277	0.0009	0.0144	0.0914	0.2295	0.2295	0.0914	0.0144	0.0009	2,652.5	2,656.6	323,191,283
6	4.92	0.2621	0.0010	0.0158	0.1003	0.2518	0.2518	0.1003	0.0158	0.0010	2,910.7	2,915.6	353,940,109
7	5.74	0.2097	0.0010	0.0169	0.1075	0.2697	0.2697	0.1075	0.0169	0.0010	3,117.0	3,122.7	378,442,602
8	6.56	0.1678	0.0011	0.0178	0.1132	0.2840	0.2840	0.1132	0.0178	0.0011	3,281.9	3,288.5	397,982,794
9	7.38	0.1342	0.0011	0.0185	0.1177	0.2955	0.2955	0.1177	0.0185	0.0011	3,413.7	3,421.1	413,575,394
10	8.20	0.1074	0.0012	0.0191	0.1214	0.3047	0.3047	0.1214	0.0191	0.0012	3,518.9	3,527.1	426,024,159
11	9.02	0.0859	0.0012	0.0196	0.1243	0.3120	0.3120	0.1243	0.0196	0.0012	3,603.0	3,612.0	435,966,971
12	9.84	0.0687	0.0012	0.0199	0.1267	0.3178	0.3178	0.1267	0.0199	0.0012	3,670.0	3,679.9	443,910,851
13	10.66	0.0550	0.0012	0.0202	0.1285	0.3225	0.3225	0.1285	0.0202	0.0012	3,723.5	3,734.2	450,259,319
14	11.48	0.0440	0.0012	0.0205	0.1300	0.3263	0.3263	0.1300	0.0205	0.0012	3,766.2	3,777.6	455,333,846
15	12.30	0.0352	0.0013	0.0206	0.1312	0.3293	0.3293	0.1312	0.0206	0.0013	3,800.1	3,812.4	459,390,750
16	13.12	0.0281	0.0013	0.0208	0.1322	0.3317	0.3317	0.1322	0.0208	0.0013	3,827.1	3,840.2	462,634,533
17	13.94	0.0225	0.0013	0.0209	0.1329	0.3336	0.3336	0.1329	0.0209	0.0013	3,848.5	3,862.4	465,228,447
18	14.76	0.0180	0.0013	0.0210	0.1336	0.3352	0.3352	0.1336	0.0210	0.0013	3,865.5	3,880.2	467,302,865
19	15.58	0.0144	0.0013	0.0211	0.1340	0.3364	0.3364	0.1340	0.0211	0.0013	3,878.9	3,894.5	468,961,943
20	16.40	0.0115	0.0013	0.0212	0.1344	0.3374	0.3374	0.1344	0.0212	0.0013	3,889.5	3,905.9	470,288,914

Table 6.2

EXPLORATION EFFORT - DISCOVERY SIZE PROBABILITY MATRIX

EXP(U) = 25000 S = 20.00% P = 0.4

SIZE (BBL/DAY):		0	21	158	1,198	9,081	68,823	521,581	3,952,847	29,956,979	EXPECTED	EXPECTED	VARIANCE
NPV ($M):		0	0.00	2.32	21.40	162.21	1,229	9,316	70,604	535,079	PROFIT	DISCOVERY	OF DISCOVERY
NO. OF WELLS DRILLED	TOTAL COST										OF PROJECT	VALUE	VALUE
1	0.82	0.6000	0.0005	0.0086	0.0544	0.1365	0.1365	0.0544	0.0086	0.0005	1,579.7	1,580.6	193,984,969
2	1.64	0.3600	0.0008	0.0137	0.0870	0.2184	0.2184	0.0870	0.0137	0.0008	2,527.3	2,528.9	307,977,686
3	2.46	0.2160	0.0010	0.0168	0.1066	0.2676	0.2676	0.1066	0.0168	0.0010	3,095.5	3,097.9	375,509,942
4	3.28	0.1296	0.0011	0.0186	0.1184	0.2971	0.2971	0.1184	0.0186	0.0011	3,436.0	3,439.3	415,718,480
5	4.10	0.0778	0.0012	0.0197	0.1254	0.3148	0.3148	0.1254	0.0197	0.0012	3,640.1	3,644.2	439,731,710
6	4.92	0.0467	0.0012	0.0204	0.1297	0.3254	0.3254	0.1297	0.0204	0.0012	3,762.1	3,767.1	454,099,366
7	5.74	0.0280	0.0013	0.0208	0.1322	0.3317	0.3317	0.1322	0.0208	0.0013	3,835.1	3,840.8	462,705,458
8	6.56	0.0168	0.0013	0.0210	0.1337	0.3356	0.3356	0.1337	0.0210	0.0013	3,878.5	3,885.0	467,863,893
9	7.38	0.0101	0.0013	0.0212	0.1346	0.3379	0.3379	0.1346	0.0212	0.0013	3,904.2	3,911.6	470,957,075
10	8.20	0.0060	0.0013	0.0213	0.1352	0.3392	0.3392	0.1352	0.0213	0.0013	3,919.3	3,927.5	472,812,307
11	9.02	0.0036	0.0013	0.0213	0.1355	0.3401	0.3401	0.1355	0.0213	0.0013	3,928.1	3,937.1	473,925,203
12	9.84	0.0022	0.0013	0.0214	0.1357	0.3406	0.3406	0.1357	0.0214	0.0013	3,933.0	3,942.8	474,592,853
13	10.66	0.0013	0.0013	0.0214	0.1358	0.3409	0.3409	0.1358	0.0214	0.0013	3,935.6	3,946.3	474,993,411
14	11.48	0.0008	0.0013	0.0214	0.1359	0.3410	0.3410	0.1359	0.0214	0.0013	3,936.8	3,948.3	475,233,735
15	12.30	0.0005	0.0013	0.0214	0.1359	0.3411	0.3411	0.1359	0.0214	0.0013	3,937.3	3,949.6	475,377,925
16	13.12	0.0003	0.0013	0.0214	0.1360	0.3412	0.3412	0.1360	0.0214	0.0013	3,937.2	3,950.3	475,464,437
17	13.94	0.0002	0.0013	0.0214	0.1360	0.3412	0.3412	0.1360	0.0214	0.0013	3,936.8	3,950.7	475,516,344
18	14.76	0.0001	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	3,936.3	3,951.0	475,547,488
19	15.58	0.0001	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	3,935.6	3,951.2	475,566,175
20	16.40	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	3,934.9	3,951.3	475,577,386

Table 6.3

EXPLORATION EFFORT - DISCOVERY SIZE PROBABILITY MATRIX

EXP(U) = 25000 S = 20.00% P = 0.6

SIZE (BBL/DAY):		0	21	158	1,198	9,081	68,823	521,581	3,952,847	29,956,979	EXPECTED	EXPECTED	VARIANCE
NPV ($M):		0	0.00	2.32	21.40	162.21	1,229	9,316	70,604	535,079	PROFIT	DISCOVERY	OF DISCOVERY
NO. OF WELLS DRILLED	TOTAL COST										OF PROJECT	VALUE	VALUE
1	0.82	0.4000	0.0008	0.0128	0.0816	0.2048	0.2048	0.0816	0.0128	0.0008	2,370.0	2,370.9	289,103,809
2	1.64	0.1600	0.0011	0.0180	0.1142	0.2867	0.2867	0.1142	0.0180	0.0011	3,317.6	3,319.2	401,597,612
3	2.46	0.0640	0.0012	0.0200	0.1273	0.3195	0.3195	0.1273	0.0200	0.0012	3,696.1	3,698.5	446,091,498
4	3.28	0.0256	0.0013	0.0209	0.1325	0.3326	0.3326	0.1325	0.0209	0.0013	3,847.0	3,850.3	463,808,470
5	4.10	0.0102	0.0013	0.0212	0.1346	0.3378	0.3378	0.1346	0.0212	0.0013	3,906.9	3,911.0	470,882,366
6	4.92	0.0041	0.0013	0.0213	0.1354	0.3399	0.3399	0.1354	0.0213	0.0013	3,930.3	3,935.2	473,709,862
7	5.74	0.0016	0.0013	0.0214	0.1358	0.3407	0.3407	0.1358	0.0214	0.0013	3,939.2	3,944.9	474,840,530
8	6.56	0.0007	0.0013	0.0214	0.1359	0.3411	0.3411	0.1359	0.0214	0.0013	3,942.3	3,948.8	475,292,745
9	7.38	0.0003	0.0013	0.0214	0.1360	0.3412	0.3412	0.1360	0.0214	0.0013	3,943.0	3,950.4	475,473,622
10	8.20	0.0001	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	3,942.8	3,951.0	475,545,971
11	9.02	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	3,942.2	3,951.3	475,574,911
12	9.84	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	3,941.5	3,951.4	475,586,487
13	10.66	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	3,940.7	3,951.4	475,591,117
14	11.48	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	3,939.9	3,951.4	475,592,969
15	12.30	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	3,939.1	3,951.4	475,593,710
16	13.12	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	3,938.3	3,951.4	475,594,007
17	13.94	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	3,937.5	3,951.4	475,594,125
18	14.76	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	3,936.7	3,951.4	475,594,172
19	15.58	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	3,935.8	3,951.4	475,594,191
20	16.40	0.0000	0.0013	0.0214	0.1360	0.3413	0.3413	0.1360	0.0214	0.0013	3,935.0	3,951.4	475,594,199