CHINA'S OFFSHORE PETROLEUM DEVELOPMENT - STRATEGY, GOALS, AND CONTRACTUAL POLICIES

by

Dongwei Chen

B.S., Shantung University
(1976)

SUBMITTED TO THE SLOAN SCHOOL OF MANAGEMENT
IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS OF THE
DEGREES OF

MASTER OF SCIENCE

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

June 1982

© Dongwei Chen 1982

The author hereby grants to M.I.T. permission to reproduce and to distribute copies of this thesis document in whole or in part.

Signature of Author _____
Sloan School of Management
May 11, 1982

Certified by _____
Gordon M. Kaufman
Thesis Supervisor

Accepted by _____
Jeffrey A. Barks
Director of Master's Programs

Archives
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
JUN 7 1982
LIBRARIES

CHINA'S OFFSHORE PETROLEUM DEVELOPMENT - STRATEGY, GOALS, AND CONTRACTUAL POLICIES

by

Dongwei Chen

Submitted to the Sloan School of Management in partial Fulfillment of the requirements for the degree of Master of Science in Business Management

ABSTRACT

China's offshore areas have recently been opened for oil and gas exploration and development by the PRC in concert with international oil companies. Effective working relations between the PRC and foreign partners require contractual arrengements which satisfy the principal needs of both parties. To do so requires intensive negotiations over an extended period of time. The outcome will be determined by complex and multifaceted interactions between the negotiating parties.

The purpose of this these is to examine these interactions in the context of exploration and development of China's offshore petroleum resources.

In the first part of this thesis, the history and current status of the PRC's offshore petroleum program are reviewed, an assessment of China's offshore petroleum potential is provided, China's current energy situation is examined and a possible energy planning is described. These constitute a point of departure for determination of the general goals and policies underpinning the PRC's offshore development strategy.

In the second part the consequences for China and foreign

oil companies under alternative contractual formats are examined using a computer based model that simulates key uncertainties in exploration and development. While no one contractual format stands out as the best for both parties in all dimensions, the analysis which affords insights into strengths and weaknesses of each format for a variety of possible outcomes of exploitation activities is a usful device for clarifying implications of choice of contract terms to both the PRC and its negotiating partners. In doing so, it may possibly lead to more stable and longer lasting agreements.

Thesis Supervisor: Dr. Gordon M. Kaufman

Title: Professor of Operation Research
and Management
Alfred P. Sloan School of Management of
Massachusetts Institute of Technology

CHINA'S OFFSHORE PETROLEUM DEVELOPMENT -
STRATEGY, GOALS, CONTRACTUAL POLICIES

TABLE OF CONTENTS

TITLE PAGE 1
ABSTRACT 2
TABLE OF CONTENTS 4
ACKNOWLEDGEMENTS 7
I. INTRODUCTION 8
1. Background - History and Current status of the PRC's Offshore Petroleum Development 8
2. Scope of Thesis 19
References 21
II. CHINA'S OFFSHORE PETROLEUM POTENTIAL, STRATEGIC GOALS, AND NEGOTIATING STANCE 22
1. China's Offshore Petroleum Potential 22
2. Economic Goals 29
3. China's Strategic Objectives and Current Negotiating Strategy and Policies 44
4. The Legal Framework 49
References 53
III. A COMPARISON OF ALTERNATIVE CONTRACTUAL SYSTEMS 56
1. Alternative Offshore Petroleum Contractual Systems 56
2. The Bargaining Framework and Risk Analysis 62
3. The Simulation Model 67
4. Comparison of Alternative Contracts 76
References 92
APPENDIX I. KEY ELEMENTS OF JOINT VENTYRE, PRODUCTION SHARING AND RISK SERVICE CONTRACTS 94

APPENDIX II. BASE CASE - GEOLOGICAL, ENGINEERING AND ECONOMIC PARAMETERS FOR A HYPOTHETICAL OIL FIELD IN THE SOUTH CHINA SEA 99
APPENDIX III. MODEL LISTING 107

EXHIBITS

1. China's Offshore Areas and The Seismic Surveying Areas In The South China Sea 10
2. First Four Oil Exploitation Contracts Concluded With Foreign Companies By The PRC 12
3. Seismic Surveying Rightholders In Yellow Sea 13
4. Seismic Surveying Rightholders In South China Sea and Beibu Gulf 14
5. China's Offshore Petroleum Bearing Basins 25
6. Assessment of China's Offshore Oil Potential 28
7. The PRC's Production of Primary Energy, 1979 - 1981 30
8. The PRC's Economic Growth Rates and Energy Output Growth Rates: 1979 - 1981 33
9. The Forecasts For China's Economic Growth, Domestic Energy Demand and Supply 38
10. Prospects of China's Crude Oil Exports 41
11. Estimateed China's Oil Output and Exports From Offshore Fields 42
12. Countries Using Joint Ventyre, Production Sharing and Risk service contractual Formats 60
13. Host Country - Oil Companies Schematic 64
14. Geological Risks 69
15. Model Structure 74
16. Objectives To An Oil Agreement 78
17. NPV Cumulative Probability Distributions 80
18. IRR Cumulative Probability Distributions 81
19. Risks Associated With Contracts 82

20. NPV As Function of Recoverable Oil 83
21. Relations Between Oil Share and Recoverable Oil 85
22. Payback Periods In the Most Likely Case 86
23. Sensitivity Analysis For Discount Rate 87
24. Sensitivity Analysis For Oil Prices 87
25. Sensitivity Analysis For Interest Rate 89
26. Probabilities Assigned To Value of Geological Attributes 99
27. P - P Plot 101
28. Lognormal Distribution of Recoverable Oil 102
29. Project Time - Line 104
30. Investment Profile 105
31. Production Profile 106

ACKNOWLEDGEMENTS

I especially wish to thank my thesis supervisor, Prof. Gordon M. Kaufman, who appropriated time from his already busy schedules to offer a lot of help in writing this thesis. I am also grateful to Prof. Henry D. Jacoby for his valuable suggestion and comment.

Finally, I wish to express my sincere gratitude to Prof. John D.C. Little, who has been my advisor during the past two years.

I. INTRODUCTION

1. Background - History and Current Status of PRC's Offshore Petroleum Development

China's future oil prospects - and, in fact, general economic prospects of its broad modernization program - during the decade ahead may depend to a significant degree on the results of offshore oil and gas development.

Although offshore geological prospecting for oil in China started in 1957, during last thirty years most of the petroleum development took place on land and the net result in the oil industry was the exploration and exploitation of inland areas closer to China's industrial and population centers. In 1971, the PRC began to operate one home made platform rig 16 km offshore in the Bohai Gulf, 40 km southeast of Daku. Since then, China has shown an increasing interest in exploring the offshore areas and been increasing the size and capabilities of its mobile rig fleet, both imported and domestically constructed. Fields off Tianjin have been producing small amounts of crude since 1973, while Chinese geologists have done part of the geophysical work along the coast of China.

After reassessing the energy situation according to the new economic development planning, the PRC decided to initiate a crash program aimed at accelerating development of offshore oil and gas resources with the foreign cooperation in large scale. In mid-1978, The China National Oil and Gas Exploration and Development Corporation (CNOGC), which was responsible to

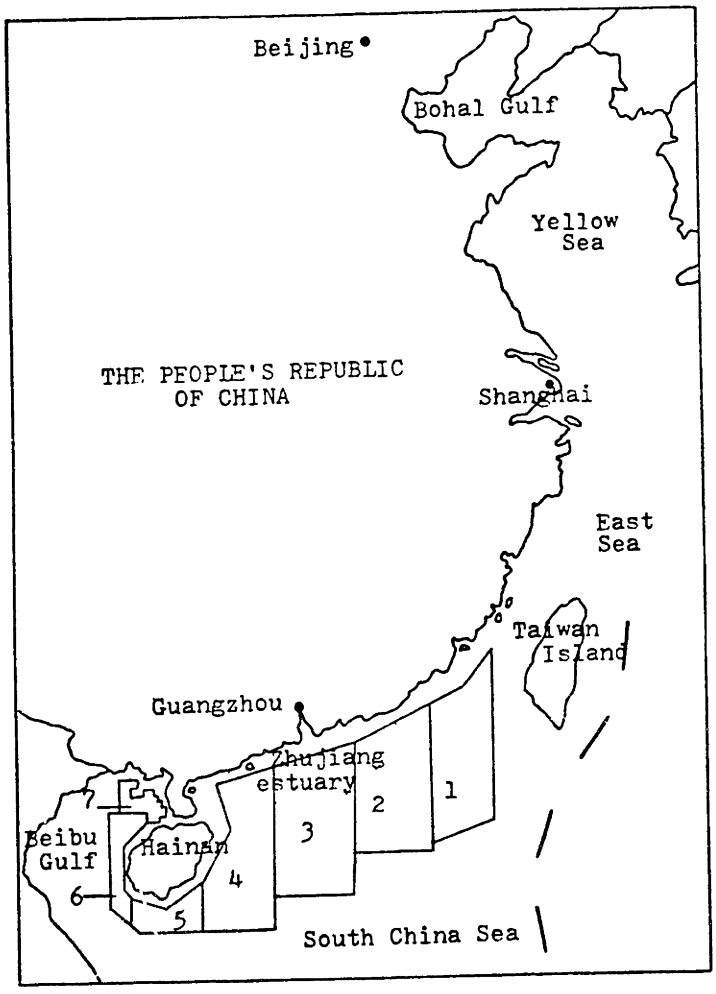
the China Petroleum Corporation which in turn under the Petroleum Ministry, began to invite foreign oil corporations to send representatives to China to begin discussion about conducting detailed seismic surveys of China's offshore areas, and talks continued through the following year. Then in mid-1979, CNOGC signed a series of agreements for seismic surveys in the China Sea with the majors, several large independents and several foreign national companies, altogether forty-six companies from thirteen countries. Several major areas were delineated for surveys and the major companies were designated as the principal "operators" for each area. Many other oil companies were invited to be "participants". The foreign oil companies involved agreed to carry out and interpret offshore surveys, and to submit the analyzed results to CNOGC independently at their own expense prior to bidding for the drilling rights.

Thereafter, intensive seismic surveying was initiated along almost all of the coast of China (see Fig.I.1).

In Bohai Gulf, a Japanese consortium led by a Japanese national company (Japan-China Oil Development Corporation, or JCODC), composed of Japan Arabian Oil Company, Idemitsu Kosan, Japanese Petroleum Exploration Corporation, Mitsubishi, Mitsui and Teikoku, has been surveying and explorating 24,500 sq km in the southern and western portions. In the northern part, two French national companies (ELF Aquitaine Chine and CFP-Total) negotiated agreements for seismic and geological survey

Fig.I1

China's Offshore Areas and the Seismic Surveying Areas In the South China Sea



1. Phillips
2. Chevron/ Texaco
3. Exxon
4. Mobil
5. Arco
6. Amoco
7. Total

Sources: Far East Economic Review (Sept. 18, 1981).

Beijing Review (Feb. 27, 1982).

of two areas of 2,000 and 2,100 sq km, with British Petroleum (BP), Petro Canada, and Japan National Oil Corporation as the participants. After CNOGC thoroughly analyzed the survey results, first two contracts were concluded late in May 1980 for exploration in Bohai Gulf. Exploration drilling has begun since then (see Table I.1).

In the Yellow Sea, surveying has been divided into British and French spheres of responsibility. ELF served as operator for 60,000 sq km stretching out toward Korea from the Shantong peninsula, BP would shoot 30,000 sq km of the Yellow Sea north of Shanghai. Some 30 oil companies jointed ELF and BP as the participants. BP completed 8,140 line-km in June 1980; and ELF completed 8,579 line-km in November 1979. BP subsequently undertook stratigraphic drilling and by March 1981 had drilled two 3,000 meter wells (see Table I.2).

American companies have been the main operators in surveying of most of the South China Sea, just off the China coast, from south of Taiwan island to south of Hainan island. Six major blocks were designated in this region on the basis of agreements signed between March and July 1979. The principal operators for the six major blocks, from north to south, are Phillips Petroleum, Chevron/Texaco, Exxon, Mobil, Arco, and Amoco (also see Fig.I.1). Many oil companies also signed on as participants with access to the seismic data and, like the principal operators, obtained rights to participate in the eventual bidding for exploration and developing rights (see

Table I.1

First Four Petroleum Exploitation Contracts

Concluded with Foreign Oil Companies by the PRC

Contractor	Interest hold	Area
1. Japan-China Oil Development Corp.*	100 %	11,400 sq km in southern Bohai Gulf
2. ELF Aquitaine Chine (operator)	70 %	9,400 sq km in northern Bohai Gulf
Total Chine	30 %	
3. Total Chine (operator)	70 %	10,190 sq km in Beibu Gulf
ELF Aquitaine Chine	30 %	
4. Atlantic Richfield (operator)	80 %	9,000 sq km south of Hainan Island
Santa Fe	20 %	

Source: "Special Report On China", Petroleum Economist (Nov. 1981).

* Subsidiary of Japanese National Oil Company (JNOC).

Table I.2

Seismic Surveying Rightholders

In the Yellow Sea

	Original Participants	Area in sq. km. as of Apr 1980		Original Participants	Area in sq km. as of Apr 1980
BP et al		32,600	SNEA et al		60,000
	BRITISH PETROLEUM (Optr)			SOCIETE NATIONALE ELF AQUITAINE (Optr)	
	AMOCO INTERNATIONAL			TOTAL EXPLORATION	
	BERKELEY EXPLORATION & PRODUCTION LTD			**Early Participants**	
	BROKEN HILL PROPRIETARY CO LTD			AGIP (OVERSEAS) LTD	
	CHEVRON OVERSEAS			AMOCO INTERNATIONAL	
	CITIES SERVICE			AMPOL EXPLORATION	
	DEMINEX			BERKELEY EXPLORATION & PRODUCTION LTD	
	ESSO EXPLORATION INC			BRASPETRO	
	MURPHY ASIA OIL CO			BRITISH PETROLEUM	
	OCCIDENTAL EASTERN INC			BROKEN HILL PROPRIETARY CO LTD	
	PETRO-CANADA EXPLORATION INC			DEMINEX	
	ROYAL DUTCH/SHELL			ESSO EXPLORATION INC	
	SOCIETE NATIONALE ELF AQUITAINE			HISPANOIL	
	TOTAL EXPLORATION			INA-NAFTAPLIN	
	UNION OIL CO OF CALIFORNIA			JAPAN NATIONAL OIL CORPORATION	
	UNION TEXAS ASIA OFFSHORE INC			KERR MCGEE CORP	
	Early Participants			MOBIL OIL CORP	
	CLUFF OIL			MURPHY ASIA OIL CO	
	RANGER OIL (CANADA) LTD			OCCIDENTAL EASTERN INC	
	TEXACO INTERNATIONAL			PETRO-CANADA EXPLORATION INC	
	Late Participants			RANGER OIL (CANADA) LTD	
	AMPOL EXPLORATION			ROYAL DUTCH/SHELL	
	BRASPETRO			TEXAS EASTERN CORP	
	CANADIAN SUPERIOR			UNION OIL CO OF CALIFORNIA	
	CONOCO ORIENT INC			UNION TEXAS ASIA OFFSHORE INC	
	HISPANOIL			**Late Participants**	
	INA-NAFTAPLIN			CLUFF OIL	
	JAPAN NATIONAL OIL CORPORATION			CONOCO ORIENT INC	
	KAISER OIL LTD			KAISER OIL LTD	
	KERR MCGEE CORP			PAN CANADIAN	
	KUWAIT OIL			PECTEN ORIENT CO	
	MOBIL OIL CORP			PHILLIPS PETROLEUM CO	
	PAN CANADIAN			TENNECO OIL CO	
	PHILLIPS PETROLEUM CO			TRICENTROL OIL CORP LTD	
	TEXAS EASTERN CORP				

Source: Petroleum Economist November 1981.

p. 493.

Table I.3

Seismic Surveying Rightholders

In the South China Sea and Beibu Gulf

	Original Participants	Area in sq. km. as of Mar 1980
AMOCO	AMOCO INTERNATIONAL (Optr) AGIP (OVERSEAS) LTD BRITISH PETROLEUM CITIES SERVICE PENNZOIL UNION OIL CO OF CALIFORNIA Early Participants BRASPETRO IDEMITSU OIL TEXAS EASTERN CORP	26,000
ARCO	Original Participants ATLANTIC RICHFIELD (Optr) SANTE FE	22,000
MOBIL	Original Participants MOBIL OIL (Optr) AGIP (OVERSEAS) LTD CHEVRON OVERSEAS ESSO EXPLORATION INC PHILLIPS PETROLEUM CO SOCIETE NATIONALE ELF AQUITAINE TEXACO INTERNATIONAL TOTAL EXPLORATION UNION TEXAS ASIA OFFSHORE INC Early Participants AMOCO INTERNATIONAL AMPOL EXPLORATION BRASPETRO BRITISH PETROLEUM BROKEN HILL PROPRIETARY CITIES SERVICE CONOCO ORIENT INC DEMINEX GETTY OIL HISPANOIL HUNT-SEDCO INA-NAFTAPLIN JAPAN NATIONAL OIL CORP MURPHY OCCIDENTAL EASTERN INC PECTEN ORIENT CO PENNZOIL PETRO-CANADA EXPLORATION INC RANGER OIL (CANADA) LTD ROYAL DUTCH/SHELL SUNMARK TEXAS EASTERN CORP TRICENTROL NORTH SEA LTD UNION OIL CO OF CALIFORNIA	70,000
ESSO	Original Participants ESSO EXPLORATION INC (Optr) AGIP (OVERSEAS) LTD CHEVRON OVERSEAS MOBIL OIL PHILLIPS PETROLEUM CO SOCIETE NATIONALE ELF AQUITAINE TEXACO INTERNATIONAL TOTAL EXPLORATION UNION TEXAS ASIA OFFSHORE INC Early Participants: See MOBIL	71,000
CHEVRON/ TEXACO	Original Participants CHEVRON OVERSEAS/TEXACO INTERNATIONAL (Optr) AGIP (OVERSEAS) LTD ESSO EXPLORATION INC MOBIL OIL PHILLIPS PETROLEUM CO SOCIETE NATIONALE ELF AQUITAINE TOTAL EXPLORATION UNION TEXAS ASIA OFFSHORE INC Early Participants: See MOBIL	65,000
PHILLIPS	Original Participants PHILLIPS PETROLEUM CO AGIP (OVERSEAS) LTD CHEVRON OVERSEAS ESSO EXPLORATION INC MOBIL OIL SOCIETE NATIONAL ELF AQUITAINE TEXACO INTERNATIONAL TOTAL EXPLORATION UNION TEXAS ASIA OFFSHORE INC Early Participants: See MOBIL	65,000

Source: Petroleum Economist November 1981. p.494.

Table I.3). The total area is about 334,600 sq km. By July 1980, total of 134,700 line-km were shot by these companies. During the following year, companies sent delegations to China independently to submit analyzed results and to make detailed presentations.

China has also been cooperating on geophysical research in the South China Sea with the US government. The first stage was completed in August 1980 using a Columbia University's seismic ship, and the data was analyzed in the US. The second stage began in 1981 using a Chinese vessel and will be finished this year.

In June 1981, Arco and Santa Fe signed a preliminary agreement with CNOGC. This is the fourth of a series of agreements signed with foreign oil companies by China for exploration drilling and development, but is the first of its kind between American oil companies and China so far. The covered area is about 9,000 sq km south of Hainan island (see Table I.1).

In a tract at the northeast corner of Beibu Gulf, under a Sino-French agreement (also see Table I.1), exploration drilling is already under way by CNOGC in cooperation with Total Chine.

Meanwhile, China continues pushing ahead its own offshore exploration. The 150,000 sq km surface of the Zhujiang (Pearl) River estuary was first surveyed in 1975. In 1977 exploration drilling began and two years later commercial quantities of oil were found. To date more than seven wells have been

drilled by the PRC's Ministry of Geology. In other areas of the South China Sea and Baibu Gulf, a total 11 wells have been drilled and at least seven discoveries have been made (two in Yinggehai Sea and five in Beibu Gulf). In the East China Sea, which area is 770,000 sq km and not open for bidding this time, geophysical and geochemical surveying has been conducted since 1974. The Longjing No.1 well drilled in February 1981, yields high pressure gas and oil and other two wells have been drilling since February this year.

So far China has shown extraordinary skill in the initial stage of its effort to obtain major assistance from the world's leading oil companies in explorating China's offshore petroleum resources. Beginning in May 1979, by 1981, 46 oil companies involved have conducted one of the most extensive and intensive petroleum surveying operation in history. Between September 1979 and July 1980, surveying blocks covered a total 411,000 sq km in the Yellow Sea, the South China Sea and the Beibu Gulf (Tonkin Gulf), which were shot by the world's biggest-ever seismic exploration group at their own expense in cooperation with China, with the hope of obtaining drilling acreage once bidding was open.

From late 1980 to June 1981, foreign firms paraded to Peking to present seismic reports on each block. China invited only the operators and other selected firms, a total of 16 companies to present the unified reports, which were completed in early July 1981.

In September 1981, China announced that China's offshore geological prospecting covering an area of one million sq km (about one fifth of the China Sea) has been basically completed . Large sedimentary basins totalling 620,000 sq km have been discovered, and geophysical surveys conducted since 1979 indicate excellent prospects for oil and gas exploitation in China's continental shelf.

In early December 1981, the Fourth Session of the Fifth National People's Congress of the PRC examined and adopted the Law Governing Income Taxes for Foreign Enterprises. According to this legislation, income tax will be levied on net earning of all foreign enterprises operating in China at a progressive rate ranging from 20 to 40 percent. A local surtax of 10 percent of the taxable income will also be levied. It is estimated that the effective tax rate on the income of a major oil company will be 48.75 percent, but in ways that should, for example, allow American companies to credit the payments in China against their US taxes. Thus one of the most ticklish problems impacting profitability of foreign oil companies has been solved.

On January 30,1982, the State Council of the PRC promulgated the Regulations on the Exploitation of Offshore Petroleum Resources in Co-operation With Foreign Enterprises. On February 15, China National Offshore Oil Corporation (CNOOC) was established, which will take full charge of co-operating with foreign companies in exploiting oil reserves in China's

continental shelf. On February 16, CNOOC announced the call for the first round of bidding. All of the 46 foreign companies that have participated technically and financially in seismic surveys of China's offshore areas were notified and invited to bid.

The first round of bidding took place in two phases. The first phase concerned the northern part of the south Yellow Sea and the Zhujiang (Pearl) River estuary in the South China Sea; the second phase concerned the southern part of the south Yellow Sea, the Beibu Gulf basin and the Yinggehai basin. The total area is 150,000 sq km.

The deadline for applications is March 30, 1982. So far there are 35 companies which have sent in the applications in this round of bidding, and now a CNOOC-appointed committee of experts is studying the bids. Then CNOOC will select bidders for further negotiations during the second half of this year and finally decide to whom to award the oil exploration and development contracts.

So far China has tried to compress the preliminary study of offshore petroleum resources into three years for such a large scale operation and the results are encouraging. However, the remaining steps in negotiations could be difficult.

2. Scope of Thesis

In this thesis I will examine China's strategic goals and interactions between the PRC and foreign oil companies in the context of exploration and development of China's offshore oil and gas resources. My motivation is that what happen there will be the principal determinants of all future negotiations.

The first part of the thesis will review China's current perception of the role offshore oil and gas will play in development of the country's economy. First, an assessment of the PRC's offshore petroleum potential will be presented. Then based on forecasting of China's economic development during the next 10 years, I will outline one possible current plan for accelerating offshore exploration, development, and production. Third, based on the economic goals set for the PRC energy sector and the analysis of China's policies so far, I will try to describe China's current strategic position for offshore development, a basic element in coming negotiations.

Effective working relations between China and foreign oil companies require contractual arrangements that satisfy the principal needs of both parties. What form should contracts for exploitation take? This is the central question I will address in the second part of this thesis. There will be no unique, definitive answer. However, a study of the consequences for both sides of alternative contractual formats will afford valuable insights. A review of alternative forms of contract is presented. A host government-private oil

companies bargainning schematic will provide a guidline for the further discussion, and which is followed with an analytical model of contractual formats. Based on a hypothetic oil field in the South China Sea, I will use the model as a tool to project possible consequences and provide a comparison of the alternatives. Uncertainty plays a key role in such comparisons and can not be fully resolved even with access to data available to all actors. In view of the extreme sensitivity of key data at this point in time, this study must be based on publically available data. Since one of our principal objectives is to develop a framework for logical analysis of alternative negotiating schemes, rather than to specify which course of action by each party to negotiations is the best given access to all current data, this is not a serious impediment.

REFERENCES

Various publications were used to obtain valuable background information on the history and the current status of China's offshore petroleum activity:

1. Barnett, A. D.: China's Economiy In Global Perspective, the Brookings Institution, Washington (1981).
2. "The PASCO Report: HK and Chinese Oil", Petroleum News (June 1981).
3. Green, S. R.: "The Offshore Oil Race", The China Business Review (July-August, 1981).
4. Fountain, K.: "The Development of China's Offshore Oil", The China Business Review (January-February, 1980).
5. "An Offshore Bonanza", Far Eastern Economic Review (September 18, 1981).
6. "Special Report On China", Petroleum Economist (Nov. 1981).
7. "China's Offshore Resources", Beijing Review (September 1981, No.40).
8. "Tax Law", Beijing Review (December 1981).
9. "Bidding for Offshore Petroleum Exploitation", Beijing Review (February 1982).

II. CHINA'S OFFSHORE PETROLEUM POTENTIAL, STRATEGIC GOALS, AND NEGOTIATING STANCE

1. China's Offshore Oil and Gas Potential

To evaluate alternative options for oil and gas development in China's offshore areas, and explain China's current strategic position, estimates of amounts and characteristics of potential recoverable hydrocarbons contained in the relevant areas must be made.

Although knowledge of China's offshore reserves increased rapidly during last few years, neither China nor foreign oil companies have publically revealed this knowledge.

Nevertheless, there have been various attempts by others to make rough estimates. A UN-sponsored survey made in late 1960s in areas off the China coast stimulated serious interest in the possibility that large reserves might be located in this region. The report resulting from that survey stated that there is a "high probability" that the continental sheff between Taiwan of China and Japan might be "one of the most prolific oil and gas reservoirs in the world".[1]

One of the first outside comprehensive evaluations of China's offshore reserves was made by A. A. Meyerhoff, who had access to Soviet data. In 1975, he estimated that the most likely offshore potential might as great as 30 billion barrels (or 4.1 billion tons) of recoverable reserves at then current world oil price.[2]

In the same year, Jan-Olaf Willums, using a different approach, came to a conclusion similar to Meyerhoff's. He gave a pessimistic estimate (0.25 fractile) of 8.7 billion barrels, an optimistic estimate (0.75 fractile) of 283.6 billion barrels and a most likely amount of recoverable reserves of 29 billion barrels.[3] Both authors at 1976 had revised their forecasts and given the similar results.[4]

In 1977, the CIA conservatively estimated that China's offshore potential reserves might total a quarter-billion to a half- billion tons, while they correctly asserted that the data necessary for a reliable estimate was not available. However, the CIA analysts gave considerable credence to a study estimating offshore reserves of China as totaling between 5.6 billion to 9.3 billion tons. This suggests that they thought that their assessment should be above the minimum figure but not necessarily as large as the maximum.[5]

One study by an American oil company executive[6] estimated, on the basis of all exploration and studies done up to 1978, that there could be 0.4 billion to 0.8 billion tons in Bohai Gulf, 2.6 to 4.9 billion tons in the South China Sea, and between 2 billion to 3.3 billion tons in the Yellow Sea, the East Sea and Taiwan basins.

A revised assessment made by Jan-Olaf Willium in 1980 provided comparative figures.[7] His mean estimates were: the East Sea, 6.8 billion tons; the South China Sea, including

Beibu Gulf, 2.7 billion tons; the Yellow Sea, 2.3; Bohai Gulf, 1.9; and Taiwan basin, 1.9 billion tons. These estimates are close to those he made in 1975, except for an increase in his estimate for the South China Sea. Five years ago, these estimates were considered too optimistic. They are not now so considered.

The results of large scale surveying and exploration in 1979-1981 have undoubtedly rendered it possible to make more precise estimates. Although the data is not yet available, the information known so far supports reserve assessments beyond the most optimistic estimates made earlier.

In September 1981, China announced discoveries of six large offshore oil and gas bearing basins: the Bohai Sea, the South China Sea, East Sea, Zhujiang (Pearl) River estuary(1), Beibu Gulf(2), and Yinggehai(3). The earlist discovered basins are in the Bohai Gulf, which coveres an area of 80,000 sq km, and are a natural extension of the Shengli(4), Dagang(5), and Liaohe(6) oil fields in the North China basin (see Fig. II.1). Altogether the coast and offshore oil and gas bearing areas occupy a total area of 180,000 sq km. The most promising oil field is the East Sea basin covering an area of 460,000 sq km. The long strip of area off the east coast of Zhejiang in this basin has the largest oil and gas bearing structures ever discovered in China.[8]

In the same month the Chinese press disclosed that the South China Sea Geological Investigation Bureau of the PRC's Ministry

Fig.II.1

China's Offshore Oil And Gas Bearing Basins

Source: Beijing Review (Oct. 7, 1981).

of Geology had submited a report "The Pearl River Basin: Oil Prospects and Assessment" based on four years of exploration work done by the Bureau independently, with no assistance by foreign firms. The conclusion is that the Pearl River basin's hydrocarbon deposits exceed any other known (proved) reserves in China.[9]

Although the quantitive assessment has still not officially disclosed, it is apparent that foreign oil companies who had finished their seismic survey around this area share similar view. According to the record of a interview in September 1981 conducted by Stephanie R. Green, director of the Programs and Government Relations Department of the National Council for US-China Trade, with Zhang Wenbin, vice-minister of the PRC's Ministry of Petroleum, Zhang responded as follows:

> Q: How do the seismic reports look for the four blocks of the Pearl River basin? Can you quantify the potenially recoverable reserves?
>
> Zhang: The (foreign) companies have provided different figures. Some are high, some are low. For example, Mobil has said 13.8 billion tons, Occidental has said 9 billion, and Exxon 3 billion.[10]

Meanwhile, according to the Far East Economic Review,[11] the official Chinese estimates of the country's offshore oil reserves - circulated within relevant government ministries but never before published - are conservatively put at about

10 billion tons, or about 73 billion barrels. Because only a fraction of the 5 million sq km of the China Sea is surveyed, this estimate may indeed be conservative.

Combinning new information available with Willums' work, which is still among the best publically available, my personal assessment of China's offshore oil potential is shown in Table II.1.

Very little information about offshore natural gas potential is available. The best outside estimate was made by Myerhoff and Willums,[4] who stated that the total - admittedly very tenuous - of China's offshore ultimate natural gas recovery is not less than 100 TCF. This appears to be very conservative. According to a recent report, the offshore gas reserve could be 2.9 trillion cu ms, and may have to be revised upward.[12]

According to the latest authoritative assessment of the world's energy resources (Survey of Energy Resources 1980. Prepared by Federal Institute for Geosciences and Natural Resources, Hanover, Germany, for 11th World Energy Conference, Munich, September 1980),[13] the proved recoverable conventional oil reserve of the world is 89.14 billion tons. China's offshore estimated recoverable oil reserve, 11.5 billion tons, will have significant influence upon the future of the world's oil supply.

Table II.1

Assessment Of China's Offshore Oil Potential*

Area	Recoverable Oil Reserve (10^9 tons)			In Place Potential (10^9 tons)		
	Low	Most Likely	High	Low	Most Likely	High**
Bohai Gulf	0.2	0.5	1.8	0.6	1.9	7.2
Yellow Sea	0.2	0.6	2.0	0.9	2.3	8.7
East Sea	1.5	5.0	26.3	6.0	20.0	105.2
Taiwan basin	0.1	0.5	1.0	0.4	1.9	2.5
South China Sea	1.3	4.7	10.6	5.2	18.8	42.4
Beibu Gulf	0.05	0.2	0.5	0.2	0.8	2.0
Total	3.6	11.5	42.2	13.2	45.6	160.0

* The assessments of the East Sea and the South China Sea are based on new information, others are the same as Willums'.[3]

** They are 0.25 fractile, 0.5 fractile, and 0.75 fractile respectively.

2. Economic Goals of Offshore Development

The Current Energy Situation of the PRC

The rate of growth of energy supply during the past three years has not kept pace with the needs for domestic demand and export in China. According to official statistics[14], coal and crude oil output growth rates in 1979 were only 2.8 and 2 percent respectively, both dramatically lower than average growth rates during last 30 years. In 1980, in real term coal output decreased 2.4 percent, and crude oil and natural gas output decreased 0.2 and 1.7 percent respectively. According to information disclosed by the Chinese press[15], energy output in 1981 continued to decline. Table II.2 shows the production of primary energy of the PRC during the past three years.

China is rich in energy resources. The publications of the US government currently estimate China's total coal resources to be about 1.5 trillion tons, puting China roughly on a par with the Soviet Union and the United States, and the proved reserves are at least 80 billion tons[16]. A more conservative official estimate of China in 1980 put coal resources at 600 billion tons.[17] China also has the greatest potential in the world for future development of hydroelectricity. One outside study[18] estimated China could develop a capacity of about 540 gigawatts. The official estimate of China is of the order of 600 gigawatts[17].China's offshore oil potential could reach 10 billion tons, as we talked earlier, and the onshore reserve

Table II.2

The PRC's Production of Primary Energy: 1979 - 1981

	1979	1980	1981
Crude Oil (million tons)	106.15	105.95	101.11*
Coal (million tons)	635.00	620.00	600.00*
gas (billion cu meters)	14.51	14.27	14.00**
Hydroelectricity (billion KWH)	48.60	56.00	59.40***
Total (million tons of coal equivalent, MTCE)****	654.53	643.73	615.06

For data of 1979 and 1980, see SSB Communique 1981.

* According to Chinese press[15], China had produced a total of 100 million tons of crude oil up to December 27, 1981. Meanwhile, during the first nine months of 1981, oil production averaged 2.0203 million barrels per day[18]. Combined with this information, it leads to a rough estimate of total oil output of 101.11 million tons. The coal output data is from the same source.

** Supposing that the percentage change in output per year is the same as that from 1979 to 1980.

*** See The China Business Review May-June 1981, p.48.

**** Here it supposes that 1 ton of crude oil = 1.5 TCE; 1 ton of coal = 0.74 TCE; 1000 cu meters of gas = 1.332 TCE; and 1000 KWH = 0.125 TCE.

could be half of that amount[18]. Current shortages of domestic energy supply are mainly due to the slow rates of exploration and development of new energy resources relative to demand, not to absence of economic resources potential.

For coal production, although total capacity of mines under construction was reported as 76 million tons, most of which could only come into production by 1985. But if new tunnelling reverses the trend of declining output from existing mines, the coal output could turn upwards sharply very soon[19].

However, the onshore oil production, which produces almost all of oil output of China so far, is very hard to increase the output in large scale during 1980s. Most exploration work will be concentrated in the northwest fields because the good prospects, but transport and logistics are very difficult. According to Zhang Wenbin[20], China will continue to concentrate on the big eastern fields of Daqing, Shengli, and Dagang with enhanced recovery methods to raise output, meanwhile try to find new pools within old large oil fields to balance off other declining areas. The finding of new fields in the east is still possible, but even in that case it would not have too much help during this decade because the long period of exploration and development. The most likely case is during 1980s the onshore oil output would be stable, although the next decade could be again a fast increasing period of onshore production before the end of this centuary.

On the other hand, China has shown an almost total disregard

for energy efficiency in the past. That, coupled with the fact that much of the countries obsolete equipment consumes fuel at a high rate, means energy efficiency figures are appallingly low. In 1979, China consumed approximately 2.5 kilograms of coal equivalent for every US dollar of gross national product-about two times more than other developing countries. Not only is this rate far behind some developed countries, it is also below the high level once achieved in the PRC. According to a World Bank report on China's economy released in June 1981[19], China's erengy growth outpaced GDP over the past two decades by a factor of 1.8; middle-income countries scored 1.2 over the same period; and the current figure for Japan is below 1. Only about 30 percent of the commercial energy that China consumed was actually converted to useful energy. In the industrial sector, which accounts for 72 percent of the nation's primary commercial energy consumption, about 40 percent was converted to useful energy. That figure in the developed countries would be about 70 percent[21].

This implies that China's potential energy saving from the conservation is so enormous that it can make a very substantial contribution to energy demand and supply balance over the coming years. In fact, China has begun a major program to increase the efficiency of energy use since 1979. This program has had significant contribution to the economic growth in the past three years, under condition of enery output declining, as shown in Table II.3.

Table II.3

The PRC's Economic Growth Rates And Energy Output Growth Rates For The Past Three Years

	1979	1980	1981
Total Industrial and Agricultural Output Growth Rates (%)*	8.5	7.2	3.0
Total Energy Growth Rates (%)**	3.1	-1.7	-4.5

* See The China Business Review (November-December 1981).

** Based on data in Table II.2.

China is currently the world's eighth largest oil producer[22] and in 1979 its exports earning of oil as percentage of total imports is 13.3. The main constraint on China's oil exports is rapidly rising domestic demand. The current energy saving program for increasing the utilisation of coal and hydropower relative to that of oil may be helpful in short run; it requests transformation all of oil burning boilers to use coal by 1985, which could save about 10 million tons oil after that year. But the ever-growing demand for petroleum products would run off all the export oil to the end of this decade, if China relies upon the faltering onshore oil production mainly. In fact, China's exports earning of oil as percentage of total imports decreased to 12.5 in 1980, and in 1981 this figure is about 11.5[23].

Under this situation, the government is hoping for early

success in launching a offshore petroleum exploitation program that will bring on stream oil for internal consumption, and for oil export in order to generate income financing other areas of China's modernization plan. Because of this, the China's offshore petroleum development has become the most promising area for China-U.S. business cooperation.

Economic Goals and Offshore Planning

The offshore petroleum development should be determined by entire energy planning, and which in turn should depend on the whole economic development. So much unpredictable factors are in the future, and it could be a very speculative exercise to attempt a quantitative analysis of the prospects for China's economy at this time. But a rough outline should be done anyway, because the economic goals set for the PRC's energy sector constitute a point of departure for description of China's offshore petroleum development strategy.

A recent comprehensive outside study of China's economy was done by the World Bank. Its report was released for official distribution in June last year. This report was based on the research of the World Bank team who visited China in late - 1980. It gives a lot of attention to energy - a major potential bottleneck, and basing on two economic growth scenarios for China in the current decade, the bank gave four energy balance projections with two different policies: high energy saving and repid switching to coal; or moderate energy saving and

moderate switching to coal, under high economic growth scenario and low economic growth scenario respectively[19]. While this report indeed gave a lot of information and understanding of China's economy, it at least has two weaknesses. First, it underestimated the important meaning of current economic "readjustment" policy in China. The readjustment of unreasonable industrial structure means cutting off the undesireable output of heavy industry and improving its efficiency and the quality of products, meantime shifting the investment to light industry to increase consumer goods and exports. Because the light industry uses about 80 percent less energy than that of heavy industry for the same output value in China, this policy itself is a very significant factor for energy saving. The figures in Table II.3 could be explained partly by this fact.

Second, the World Bank report ignored the role of offshore petroleum development in energy sector for this decade. But accelerating the offshore petroleum exploitation is one of the economic strategic goals of China during 1980s, realization of this goal would have great influence upon China's economy.

For prospect of China's offshore development goals, following factors should be considered respectively.

- Growth Rates of Whole Economy -

According to Premier Zhao Ziyang's report on the work of the government delivered at December last year, which concerned China's Sixth Five-Year Plan (1981 - 1985) and the country's economic prospects[24], the total output values of industry and

agriculture in 1981 was around 3 percent (so was the national income). The 1982 plan calls for an increase of 4 percent and efforts will be made to exceed this figure. A fundamental change for the better in China's finance and economic structure will be the main target of the Six Five-Year Plan. During this period there will be a certain rate of economic growth although the pace can not be very fast. The speed could be increased during Seventh Five-Year Plan if a good foundation is laid during current period. The last 10 years of this century will likely be a period of vigorous economic development, and the total goal is to increase the gross output values of industry and agriculture three fold within 20 years. Using these information and the SSB statistics, combining with other considerations, I give a personal estimate of the PRC's GNP growth forecasts for next 20 years, as shown in Table II.4.

- The Domestic Energy Demand-Supply Prospect -

At present, the great stress is placed on the priority of energy conservation, mainly by improvement and innovation for economic and technical efficiency. In 1981, the energy consumption a US dollar of GDP was about 2.06 kilogrames of coal equivalent, a improved level than before. But this figure is still very high. According to the World Bank data[25], in 1978, the same indicator for Japan was 0.7, and that for East Germany was 1.5. It would be reasonable to assume that China's goal for next 10 years is to reduce this ratio to be as the same as that of East Germany (here I choice the indicator of

East Germany as a benchmark because its statistics follow the same Soviet practices).

Meanwhile, although the total output of onshore oil fields probabily maintain stable during next four years and the domestic demand for petroleum products will continue to increase, but by 1986, the petroleum industry will get about 10 million tons of more feedstaff each year from oil saving from direct burnning (using coal instead). This would make the total domestic demand for crude oil basicly stable too. After that time, however, the domestic demand for crude oil will increase about 5 percent each year.

According to current investment, the natural gas and hydropower could be increasing rapidly. Here I assume during the Sixth Five-Year Plan period, their growth rates would be 5 percent each year, and they will be 10 percent each year for the last five years of this decade.

The coal production will have considerable growth, and by the late of 1980s, China's coal industry would have a production capability of about 730 million tons output each year.

Onshore oil production in the period of next four years will still concentrate on . oil fields in the Northeast, but exploration and development will be strengthened in other areas. After 1985, the total onshore oil output would again increase with a growth rate about 5 percent each year.

Putting all of these considerations together, we can get a rough forecast about the domestic energy demand and supply,

and the oil exports from onshore production for this decade (also see Table II.4).

Table II.4*

The Forecasts of China's Economic Growth, Domestic Energy Demand and Supply, and Crude Oil Exports

Year	GDP**	R***	Domestic Supply(MTCE)	Domestic Demand(MTCE)	Oil Exports (million tons)
1981	291.2	2.06	615.06	599.87	12.0
1982	302.8	2.00	627.30	605.60	12.0
1983	318.0	1.94	637.51	616.92	12.0
1984	337.0	1.88	652.67	633.56	12.0
1985	360.6	1.82	674.68	655.20	12.0
1986	385.8	1.76	708.15	679.01	14.7
1987	412.9	1.70	729.92	701.93	15.5
1988	441.8	1.64	752.79	724.55	16.2
1989	472.7	1.58	777.84	746.87	17.0
1990	505.8	1.50	789.62	758.70	17.9

* Only considering onshore production.

** Using data in 1980 as the basis, and the unit is billion US dollars (1980 US dollar).

China's "total output value of industry and agriculture" and "national income" statistics, following Soviet practices, differ from western calculations of GNP and GDP. According to usual practice, I assume the GDP is 64 percent of the total output value of industry and

agriculture, which in 1980 is 661.9 billion yuan. In that year the exchange rate is 1 US dollar 1.5 yuan, so China's GDP in 1980 should be about 282.7 billion US dollars. For more discussions about this problem, see reference 26, p.625, note 288.

In 1981, the growth rate is 3%. I assume the growth rates in 1982, 1983 and 1984 would be 4%, 5% and 6% respectively, after that, the GDP would increase at 7% annually through 1990.

*** R is the energy (kilograms of coal equivalent) consumed for every US dollar of GDP.

- The Oil Exports and Offshore Exploitation -

The degree of success that China achieves increasing exports of oil in the 1980s will be one of the key determinants of its ability to increase overall foreign trade for importing needed capital goods and advanced technology from the major developed countries, which would play a very important role in China's modernization program. As the data shown in Table II.4, the onshore oil production could support the domestic demand for petroleum products, but the oil exports would increase too slowly to meet needs for increasing exports. According to Barnett and other experts[26], although China is not likely to be able to sustain the 30 to 40 percent of annual growth rate during last few years, its imports should be increased by about 13 percent each year during the years ahead in this

decade (about 40 percent of imports is for capital goods and technology) for supporting its economic construction. Meanwhile it is appeared that China will try its best to keep on maintaining the balance between its imports and its exports to avoid big trade deficit and heavy depending on foreign loan. Because the constraints on other export items, for realizing this goal China should increase the oil export revenue to be about 25 percent of its total export revenue at the end of 1980s. But China's oil exports from onshore production could only pay off about 12 percent of its imports each year at that time. So increasing the oil exports could be seen as the major economic motive of China for offshore petroleum development, and the expected offshore oil output will represent a substantial, and probably critical, contribution to China's modernization program.

Considering all factors discussed above, I give a possible China's oil exports prospect and a offshore development plan, as shown in Table II.5 and Fig. II.3.

The projected China's offshore oil production will concentrate on Bohai Gulf, South Yellow Sea and the South China Sea during this decade. By 1990, the oil output from the South China Sea alone would be about 50 million tons each year, because of big potential and the works to be done. In 1980s the East Sea probably will not enter this scenario, although it will play a more important role during next decade.

Year	Exports From Onshore Fields (million tons)	Exports From Offshore Fields* (million tons)	Total Oil Exports (million tons)	Oil Exports Revenue** (billion $)	Total*** Imports (billion $)	Oil Exports Revenue As % of Imports
1981	12.0	-	12.0	3.1	21.9	14
1982	12.0	-	12.0	3.2	24.7	13
1983	12.0	-	12.0	3.3	28.0	12
1984	12.0	-	12.0	3.4	31.6	11
1985	12.0	3.1	15.1	4.3	35.7	12
1986	14.7	7.2	21.9	6.5	40.4	16
1987	15.5	12.4	27.9	8.4	45.6	18
1988	16.2	18.6	34.8	10.7	51.6	21
1989	17.0	25.8	42.8	13.6	58.3	23
1990	17.9	34.0	51.9	16.8	65.4	25

Table II.5 China's Crude Oil Exports Prospects

* Based on Fountain's forecasts[23].

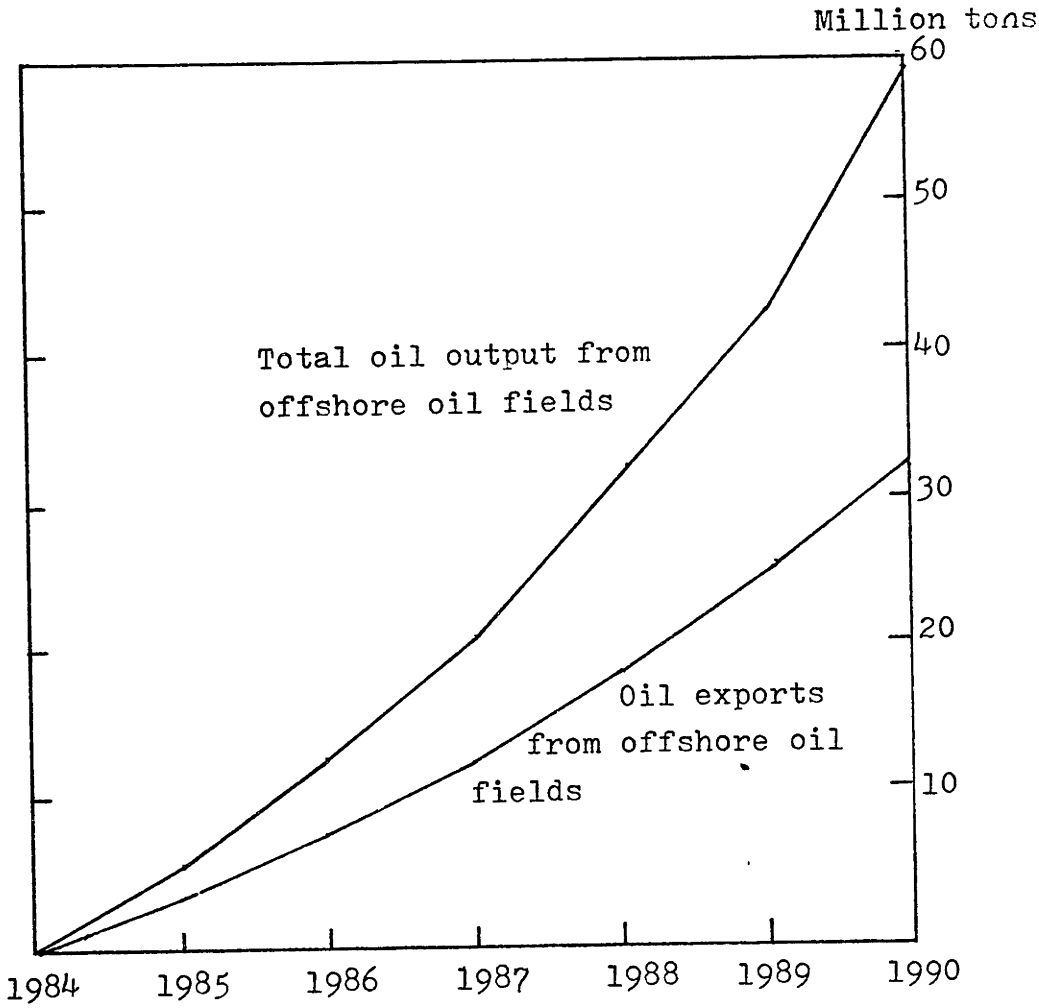
** Here I use the World Bank's forecast about oil price (2.4% real annual growth rate through 1990), and assume the price is 35 US dollars per barrel (see reference 27).

*** In 1980 US dollar.

Fig. II.3

Estimated China's Oil Output and

Oil Exports From Offshore Fields*



* This scenario assumes that offshore oil output are divided 57.5 : 42.5 between China and its contractors. This is the current practices of Sino - Japan agreement, and not necessary to be the same case for others.

This prospect is consistent with several independent views. One research made in 1980 by Fountain[23] based on the economic and technical analysis of China's offshore potential, suggested that if China carries on its offshore program, its oil export revenue could approach 16 billion US dollars each year by 1990, a sum equivalent to 23 percent of China's projected imports in that year. According to two independent research reports submited in 1981 respectively by Michael Sandberg, chairman of the Hong Kong and Shanghai Bank, and William Lear of the First National Bank of Chicago[27], not only both of them used the 50 million tons prospect in the South China Sea as the basis, there was remarkable agreement as to the probable financing costs of China's offshore program too. Both of them estimated that it would cost 20 billion US dollars or 11 billion US dollars at current prices.

Another report gave a outline for China's offshore developing plan to realize its goal[28]. During next four years China should drill about 110 wildcat wells and about 100 evaluation and confirmation wells; by 1985, there would be up to 10 small to medium oil fields to start producing and by 1990, about 40 complexes of production facilities should be operating. The total exploration cost alone (excluding development costs) could reach about 3.6 billion US dollars.

3. China's Strategic Goals and Current Negotiating Strategy and Policies

China's strategic decision for accelerating offshore oil and gas exploration and development cooperated with international oil companies is based on its whole economic goals of the modernization program, and China's practices of last three years make it possible to draw a outline of its strategic goals for offshore development. These goals constitute the basis of China's current strategy and policies which aim at strengthening its stance in the coming negotiation.

China's Strategic Goals For Its Offshore Program

(1). Increasing total offshore oil output to about 60 million tons per year by 1990, which would increase the export revenue of oil to about 25 percent of China's total import costs, so it could support the planned imports of capital goods and advanced technology from developed countries on the basis of balance between exports and imports.

Meanwhile, the offshore petroleum producing capacity formed during this decade would meet the requirements of the ever-growing domestic demand in the long run.

(2). The principal in involving foreign oil companies in petroleum exploration and development within China's offshore areas is to secure investments of risk capital and the necessary technical experience and managerial skills of outside to carry out as thorough and as rapid the exploitation of the

offshore petroleum resources as is reasonably possible, in a manner which will ensure maximum ultimate recovery of reserves and yield maximum benefits to the national economy according to the planning. Meanwhile, China will protect its sovereignty over its own natural resources and minimize the interference by the foreign oil companies in developing national economy.

(3). China will work toward full use of domestic resources, developing technology and industry of offshore equipments. This will have dual roles: first, these resources could be used as China's share of investment, without spending the lacked foreign currency directly; second, China could achieve its independent offshore petroleum development ability eventually.

The Strategy and Policies For Realizing Offshore Strategic Goals

(1). Because the world oil supply generally faces a more uncertain future, and the huge China Sea was the last sizable offshore surface untouched by international oil corporations in the world, China can attract a lot of foreign oil companies to take part in its offshore exploration by promising that would be a preliminary to get the rights to bid for development and production in the future. In fact, in the past three years foreign oil companies have finished seismic surveying for 1 million sq km of China's offshore areas at their own expense and in cooperation with China. This work would take much more time if China carrys out the surveying by itself.

Meanwhile, the encouraging results obtained from this process make it possible for China and its partners to share the basic same prospects of China's offshore petroleum potential, this is a good basis for a further mutual beneficial relationship of cooperation.

(2). China has tried its best to invite as many foreign oil companies to take part in its offshore program as possible for diversifying the types of the foreign partners. Among current 46 oil companies who have the rights to bid, there are not only so-called "seven sisters" of major international oil corporations and many small majors, there are also many state-owned and independent oil companies, with different background and interests. Thus China gets a large space for negotiation and avoids the possible monopoly power of any single foreign oil company in developing its offshore resources. China has announced that everyone who took part in the seismic surveying has the equal right for bidding and only one part of the oil companies can get development contracts. It is apparent that China will achieve better negotiating position in full using this competitive situation.

(3). China continues to accelerate its own offshore exploration and development, mainly in the East Sea and the South China Sea (the East Sea is not opened for bidding). Meanwhile it has set up a considerable production capacity of offshore petroleum equipments, for example, jackup rigs, semisubmersibles and platforms[29].

The strategic considerations for this policy are mainly as follows: in the worst case of failures in negotiation (for example, because some unpredictable changes in international political situation), China can continue its offshore program; in the joint exploration phases, China can use these prior exploration drilling as China's share to reduce the supply price of foreign investment, as in the case of negotiation with Japanese companies in Bohai Bay[30]; using Chinese equipment in offshore oil development and production, China can pay for its share of investment of joint venture and save its valuable foreign currencies; and more important, China can eventually develop its offshore resources independently in the long run.

(4). In the past three years, China has been trying its best to construct a stable investment environment by meeting the basic prerequisite of legislation.

China's tax law passed last year will apply equally to all foreign firms concerned, including oil companies, and will form a legal basis for agreements between China and other governments to avoid double taxation. For example, by prior negotiating with American government, the tax structure allows American oil companies to credit what they pay in China against their tax liabilities at home. Thus while China could increase its revenues, the foreign companies also could get enough incentives to go ahead.

China also promulgated a legal framework to secure its

strategic objectives and the lawful rights and interests of the foreign oil companies, which I will discuss in next section.

The final contracts which will be signed in forthcoming negotiations will play the key role for realizing China's strategic objectives eventually. The CNOOC (former CNOGC) has exerted a great deal of effort in developing a contractual concept for exploration and development operations which will retain most of the benefits for the PRC while being sufficiently lucrative to attract foreign investment and the technology. They have sought the advice of many countries, which include Norway, Brazil and U.K. as well as the United Nations. The Norwegians have been their principal advisor [22]. Although there is very little information available at this time, it is appeared that China will sign different contracts with different partners on the case-by -case basis. A logical analysis and comparison of alternative contractual formats will be the theme of last part of this thesis (Ch.3).

4. The Legal Framework

Having formulated its broad strategy, government has to establish a legal framework to secure its strategic objectives. Different countries use different approaches, but generally these approaches may be classified into three categories:[31]

(1). General Legislation System

Under this system, legislation fixed in advance conditions under which rights to explore for and exploit petroleum resources may be granted under standard form licences or leases; royalty taxes and other payment to be made are also determined by legislation. The countries in this category include the United States, Canada, Australia and most of the EEC countries.

(2). Individually Negotiated (ad hoc) System

In this case, there is no general system of legislation, or the legislation is of a very general nature, and the government grants rights on the basis of individually negotiated agreements. This was the case with the early concessions granted in most of the traditional oil producing countries, such as Iran, Iraq and Saudi Arabia, more recent examples are provided by Indonesia and Bangladesh.

(3). Hybrid System (General Legislation Supplemented With Individually Negotiated Agreement)

Under this system, general legislation lays down certain fundamental provisons and stipulates certain minimum standards

and conditions which must be satisfied by applicants for the grant of the right to explore for and exploit petroleum resources but provides for certain important terms and conditions to be settled by negotiation. Among the countries which fall into this category are Britain, India, Malaysia, the Netherlands, New Zealand, Norway and Trinidad and Tobago.

On January 30 this year, the State Council of the PRC promulgated Regulations On the Exploitation of Offshore Petroleum Resources In Co-operation With Foreign Enterprises[32]. This is a example of the hybrid system.

Among matters fixed by legislation is the basic pattern of cooperation between the PRC and foreign enterprises: foreign enterprises shall provide exploration investment, undertake exploration operations, and bear all exploration risk. If a commercial oil and/or gas field is discovered, both the foreign contractor and CNOOC shall make investment in the co-operative development. The foreign contractor shall be responsible for development and production operations until CNOOC takes over the production operations when conditions permit under the petroleum contract. The foreign contractor may recover its investment and expenses and receive remuneration out of the petroleum produced according to the provisons of the petroleum contract (Article 7). A number of conditions are prescribed which must be accepted by applicant: foreign company and its employees shall pay enterprise and individual income taxes according to the tax law of the PRC

(Article 9); the delivery and transmission of all original data to sources outside the PRC shall be conducted in accordance with the Rules on Control of Data and Information formulated by the Ministry of Petroleum Industry (Article 23); in order to achieve the highest practicable ultimate oil recovery, the operator shall work out an overall development plan for each field and conduct production operations in accordance with regulations and relevant rules promulgated by the Ministry of Petroleum Industry on exploitation of petroleum resources (Article 16); operation bases must be established within the territory of the PRC (Article 17); CNOOC has the right to send personnel to join the foreign operator in making master designs and engineering designs and the foreign operator must give preference to manufacturers and engineering companies within China for all facilities to be built in implementing the contract, including artificial island, platforms, building and structures provided that they are competitive in quality and price, term of delivery and services; the same fashion priority shall be given to use of Chinese design corporations and service firms for engineering design, geophysical prospecting, well drilling, diving, helicopter services, vessels, and onshore bases (Article 18,19,20,21). In case an operator or a subcontractor violates the regulations in operations, it will be fined, even to the extent of suspending its right to conduct the operations, all economic losses so incurred shall be borne by the party responsible (Article 28).

While all of these matters are laid down in the general legislation, a number of critical issues are deliberately left open for bidding and negotiation. China may possibly use different types of negotiating agreements on a case-by-case basis. Important issues which to be negotiated include, for example, the size of blocks, the extent of state participation, oil payback, and respective percentage of interests to be held by each party, as well as management structure and control of operations.

Hybrid system is increasingly being adopted by the host governments because first, it strengthens the government's negotiating position; second, it introduces flexibility and leaves room for negotiation on matters where variation from a standard format should be reasonably expected[33].

In sum, the PRC's petroleum regulation provides a suitable legal mechanism to secure its strategic objectives as well as tactical flexibility in cooperation with foreign oil companies for offshore petroleum exploration and development.

REFERENCES

1. Harrison, S. S.: China, Oil and Asia: Conflict Ahead? Columbia University Press (1977).
2. Meyerhoff, A. A.: China's Petroleum Potential; World Petroleum Report 1975.
3. Willums, J-O.: China's Oil and Gas Potential and Estimates On Output - Report submitted To M.I.T. Energy Group, Unpublished paper (September 1975).
4. Meyerhoff, A. A. and Willums, J-O.: Petroleum Geology and Industry of the People's Republic of China, United Nations ESCAP, CCOP Technical Bulletin Vol. 10, 1976, pp. 103-212.
5. Goodman, H. I.: Energy - A Major Determinant of the Asian Power Balance, paper prepared for Ditchley Foundation Conference (Feb. 1978).
6. CIA: "China, Oil Production Prospects", ER 77-10030U (June, 1977).
7. Segal, J.: "Need For More Oil Exploration" Petroleum Economist (November 1981).
8. Beijing Review, (Oct. 1981).
9. 南方日报 (September 15, 1981).
10. The China Business Review, (Nov.-Dec. 1981).
11. Far East Economic Review, p57, (Oct.2, 1981)

12. Far East Economic Review (Oct.2, 1981), p51.
13. Rahmer, B. A.: "The World's Energy Potential", Petroleum Economist (Nov. 1980).
14. SSB Communique 1981, Beijing (1981).
15. FBIS-CHI-81-248, Vol.1, No.248 (Dec. 1981).
16. CIA: "China, The Coal Industry", ER 76-1069I (Nov. 1976).
17. "Report of Trip To the People's Republic of China", Congressional Record (July 23, 1980), p. s9579.
18. "Special Report On China", Petroleum Economist (Nov. 1981)
19. Defls, R.: "A New Kind of Planning", Far East Economic Review (August 14, 1981).
20. The China Business Review (Nov. - Dec. 1981).
21. Taylor, R. P.: "Enery Conservation", The China Business Review (Jan. - Feb. 1982).
22. O'dell, T. C.: Petroleum Exploration - The Trend Toward Service Contracts In Selected Non-OPEC Developing Countries, Master Thesis at MIT (June 1981).
23. Fountain, K.: "The Development of China's Offshore Oil", The China Business Review (Jan. - Feb. 1980).
24. 人民日报 (Dec. 1981).
25. The World Bank: World Development Report, 1980, Oxford University Press, (1981).
26. Barnett, A. D.: China's Economy In Global Perspective,

The Brookings Institution, 1981.

27. Far East Economic Review (December 4, 1981).

28. Far East Economic Review (October 2, 1981).

29. Far East Economic Review (September 18, 1981).

30. Burke, R. G.: "Bohai Opens China's Future", Offshore, (June 20, 1981).

31. Hossain, K.: Law and Policy In Petroleum Development, N. Y., Nichols Publishing Company, 1979.

32. Beijing Review (Feb. 22, 1982). pp 14-18.

33. Waelde, T. W.: "Lifting the Veil From Transnal Mineral Contracts: A Review of Recent Literature", Natural Resources Forum (1977). Vol.I.

III. A COMPARISON OF ALTERNATIVE CONTRACTUAL SYSTEMS

1. Alternative Offshore Petroleum Contractual Systems

Having formulated its broad strategy, the government has to choose a type of petroleum development arrangement to secure its strategic objectives which are to be settled by negotiation and embodied in contractual documents. In this section I will review four different types of contractual formats which are in use today throughout the world.

The Petroleum Concession Agreement

The petroleum concession was the original format used in world petroleum development arrangements. It typically provides the private international oil companies with the rights to explore for, produce, transport and sell hydrocarbons produced within the concession areas for a fixed period of time. Thus this kind of contractual format gives the greatest amount of control over operations to foreign oil companies. The host government's role in the concession is basically of a regulatory nature and the economic benefits depend on tax and royalty requirements imposed on the companies. Even though many "modernized" concession agreements give a host government additional control and decision-making power, this control of its resource development is only indirect, and on average concession contracts are the most economically attractive of the various types of petroleum arrangements from private oil

companies' point of view. Today some third world lesser developed countries who are most anxious to obtain exploration activity in their countries still utilize the concession format because it provides more attractive terms to the international oil companies and encourages their investment in areas of high geological and political risk[1].

Considering the economic and political situation in China, it is apparent that a concession contract is out of the question.

The Joint Venture Agreement

Joint venture contractual format is an arrangement under which the host government and an international petroleum company jointly explore for, develop and operate a petroleum property. The cost and risk in the exploration phase are usually borne exclusively by the company, but in some cases, this cost may be shared by the government and the company proportionally on other basis negotiated (for example in China offshore areas, Chinese petroleum companies have done some geological exploration works in many blocks, so if Chinese government uses a joint venture format, these prior works could be negotiated as the share of the exploration costs). The international company, again depending on the contract negotiated, may receive reimbursement out of the oil produced later for its share of investment in exploration, development and production, although many joint venture agreements do not

always provide payments for covering the exploration costs.

The joint venture agreement generally contains the proviso that it will terminate if a commercial deposit of petroleum is not discovered by the end of the exploration phase. Also imposed are drilling obligations, including firm well commitments and expenditure requirements. The company is also required to relinquish areas from time to time.

Although the joint venture agreements may impose royalties and tax obligations similar to the concession arrangements, the basic pattern is different since the joint venture involves varying degree of the government participation. The state can decide whether or not to share the costs of exploration and development, and typically it will pay its share of operation costs in the production phase.

With regard to the organization of the joint venture, the most common form is that the operations are controlled by a management committee consisting of representives of both parties, and each party has a direct undivided working interest in the exploitation areas (e.g., in Norway and U.K.). Thus the host government can have the direct control in its resource development.

The production Sharing Agreement

The production sharing concept is originated in Indonesia. Under this concept the exclusive right to explore for, develop, produce, transport and market petroleum is granted by the host

government to a state oil company. The state company then retains title to these "petroleum rights" and enters into a contract with the private international oil company which carries out the exploration, development and production operations at its sole cost and risk. The management of the venture usually goes to the risk taking private partner. In the event of commercial discovery, the international oil company is compensated for its "service" with petroleum. The basic elements of the typical production sharing agreement include costs recovery for private company out of a specified percentage of production, a production split between the state and private company of the remainder of the output, and an income tax payment to the government by the company.

The production sharing ensures that the state will receive a negotiated minimum share of production irrespective of the cost of the exploration and development.

The Risk Service Contract

The risk service contract generally places all risk and investment obligations on the international companies. If no discovery is made, within the exploration term of the contract, the contract terminates and all costs involved will simplily written off by contractors themselves. If a discovery is made, in most cases the contractors develop this field and bring the production on stream. Thereafter, the field is either operated by the state, or continued by the contractors, depending on

Table III.1

Countries Using Joint Venture, Production Sharing, And Risk Service Contractual Formats

Contractual Formats	Countries
Joint venture	Netherlands, Norway, United Kingdom.
Production sharing	Indonesia, Peru, Malaysia, Guatemala, Libya, Egypt, Syria, Yemen, Jordan, Bangladesh, Philippines.
Risk service	Venezuela, Brazil, Peru, Argentina, Iraq, Nigeria, Saudi Arabia, Kuwait, Oman, Abu Dhabi, Qatar, Sharja.

Source: Carlton O'Dell.

the specific contract negotiated. In either case, the capital investment of contractors is reimbursed over time with interest and a remuneration or "risk fee". The contractor is paid in cash and has no equity right to any portion of the petroleum produced, although the contract may include provision permitting the foreign company to buy back a certain percentage of the output based on world oil price.

Under service type contracts, contractors are usually subject to taxation only at the general corporate rate in that country.

Countries which have utilized the joint venture, production sharing, and risk service agreements are shown in Table III.1.

In Appendix I, there are lists of the key elements (main economic determinants) of joint venture, production sharing, and risk service agreements, used in Norway, Indonesia and Brazil respectively. They are utilized in following comparative analysis of various contractual formats.

2. The Bargaining Framework and Risk Analysis

The perspective of all private sector oil companies - majors, small majors, and independents, is principally commercial. This orientation is expressed in the words of an executive of One American major: "We couldn't be playing the game unless we thought there was something to play with." The impact on ROI, profitability and other measures of economic performance, tax regimes, and the particular character of the agreements negotiated is of principal concern to all[1,2]. For the majors and some small majors access to exportable oil is another primary goal. Physical control of oil for feedstocks to their refining systems is deemed important. In addition, increasing non-OPEC oil sources of supply is another important objective. Exploitation of China's substantial offshore potential is seen by them as a major steps towards achieving this goal. Companies strongly wish physical control of operations to remain in their hands, prefer to use equipment and service components that they have selected, etc. Naturally they tend to view economic benefits acquiring from production as more important to them than a host country's needs.

Consequently there are divergences in objectives between the PRC and foreign companies that bear on a whole range of issues. The impact of different contractual systems on these divergent sets of objectives must be considered in the course

of negotiating viable contractual terms. Contractual terms play an essential role in determining the degree to which the government attains its goals. Although the government may specify the general format of the contract to be negotiated, the final form of a contractual agreement between the government and oil companies emerges from intensive negotiations.

According to research done by Professor G.M. Kaufman and B. Ball Jr. of MIT[3], relationships and interactions between the state and companies, and factors which determine each party's negotiating stance can expressed in the form of a general host-country and companies bargaining schematic shown in Fig.III.1. These negotiations are viewed by some experts as "obsolescing bargains"[4] with many potential barriers to effective agreement. The recent record shows that while consuming countries grow alarmed by potential scarcity and high price of petroleum products, physical exploration activity in developing countries was no greater in 1979 then in 1970[5].

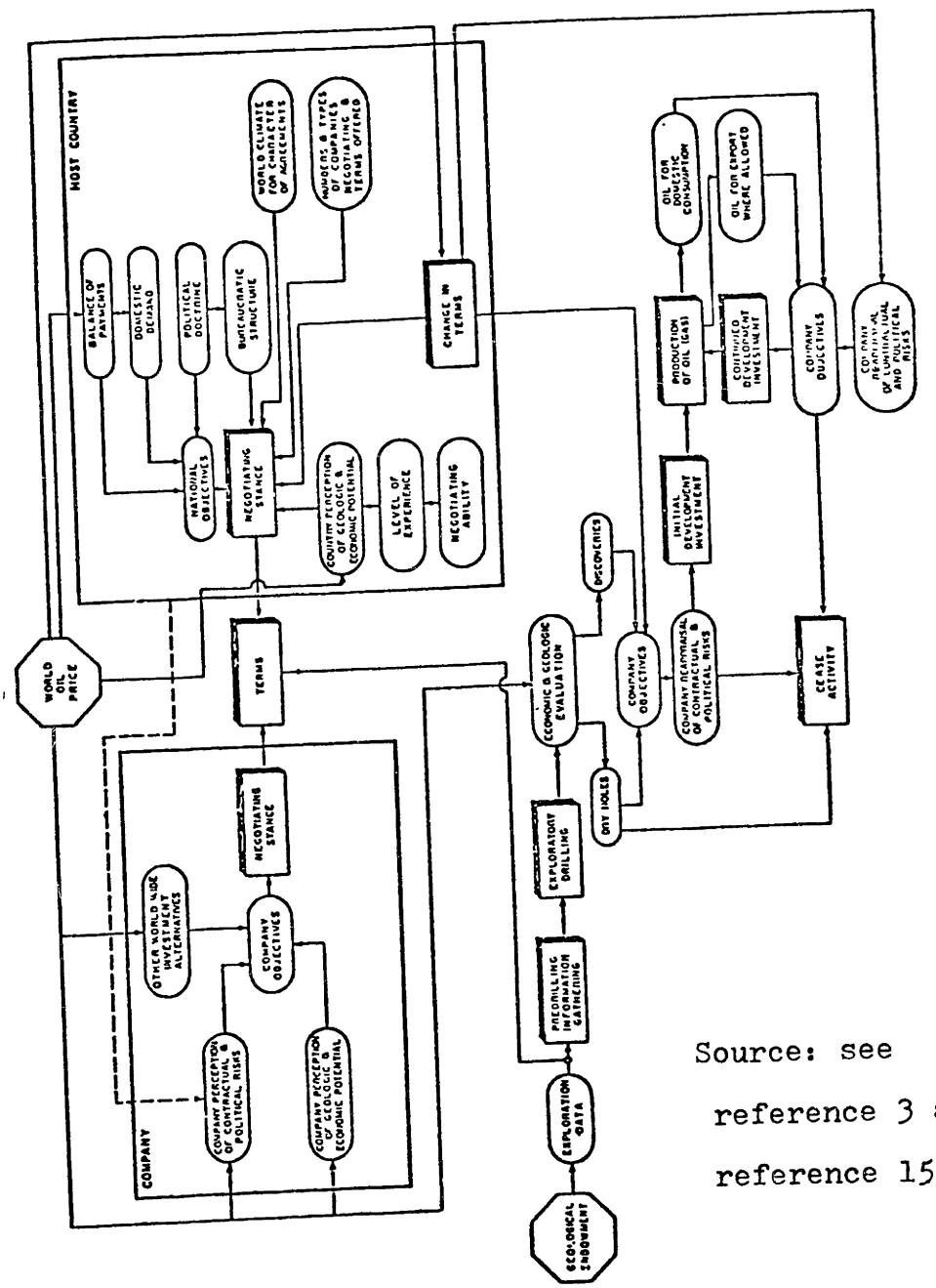
A partial explanation is that companies perceived exploration in LDC's as saddled with very large risks. There are political risk, geological risk, and commercial risk.

Political Risk

In recent years LDCs have increasingly asserted their national sovereignty over their resources. They ask for changes of old concession agreements to suit modern political and economic conditions. This is resonable and there is little

Fig.III.1

Host Country - Oil Companies Schematic



Source: see reference 3 and reference 15.

private companies can do except to acquiesce, but some of them may think these changing conditions increasing risk for their investment.

In general any potential unstable social factors which threaten a host country's political stability will influence the investment environment and increase political risk.

Differential Perceptions of Geological Uncertainties

A large difference between a host country's and a foreign company's perception of geological potential creates tension in negotiations and may lead to contract terms untenable over the long run.

Before exploration, the amounts of recoverable reserves that may obtain are never known with certainty. Contractual terms based on a fixed share of output or profits may prove ex post to be either too small or too large. If the terms are too severe, the investor will seek revised terms (or will not proceed). If they are too generous, the government will ask for renegotiation. An unreasonable or inflexible contractual agreement negotiated before the true value of the oil reserve has been determined enhances one form of political risk induced by geological risk.[6]

Commercial Risk

The large scale of offshore oil and gas ventures increase commercial risks common to all investment. The large minimum economic scale of operation, the fixed single purpose nature

of the investment, long time lags to production (offen four or five years), and the large uncertainties about the future path of world oil prices[7,8], restrict the flexibility of response to changing market conditions.

If we use the term "supply price of the investment" to refer the minimum expected return on investment of oil companies consistent with their decisions to invest, then in general it will increase as the risks increase.

For the government, the central problem of petroleum contractual policy is to establish a stable fiscal framework that, under conditions of uncertainties, obtain a high share of revenues and petroleum output according to its strategic objectives, while at the same time ensuring for the private oil companies the fair supply price of investment or the prospect of a reasonable return on their investment commensurate with their risk. A stable legislation framework, and a clear understanding about the contractual performance in an uncertain environment, will in turn reduce the risks form oil companies and their supply price of investment, thus it will strengthen the government's negotiating position and smooth the way for a satisfactory contract.

3. The Simulation Model

In comparing alternative contractual systems, important concerns are the relative effects of different contractual structures under uncertainty for both private oil companies and the host government. To this end, a simple computer simulation model is constructed. Geological, engineering and economic considerations relevant to both parties' decision making are included so that the model may be useful for quantitatively testing the effects of a wide range of contractual policy alternatives. While used here for comparison of different contractual systems, it can also be used as a negotiating decision support system.

The Methodology

The model simulates the process of implementation of a petroleum contract as a function of a offshore oil field exploitation. Geological, engineering and economic parameters are assumed known, and exploitation is assumed to proceed as follows:

Exploratory drilling will begin as soon as sufficient seismic data is gathered and analyzed to provide an initial well location. A principal risk is that dry holes are still possible. If reserves are discovered, then the single most important decision is whether or not to develop the field. Full suites of well logs, core analyses and other data collected in this phase

are run to assist in evaluation of the prospect. In the development phase, platform(s) will be designed, fabricated and installated; production wells will be drilled and completed along with installation of well head equipment; and an petroleum transport system (pipeline or mooring system) will be built. The principal risk in the development phase is that the actual size of the prospect will be known with approximate certainty only when the production begins and a major investment in development already committed. Development planning is based on estimates of recoverable reserves, which in turn are based on data gathered during the exploration phase. With currently available technology, the best that can be done prior to committing resources and money to development is to judgementally assess probabilities for amounts of recoverable reserves. These judgements are based in part on similarly uncertain judgements about hydrocarbons in place.

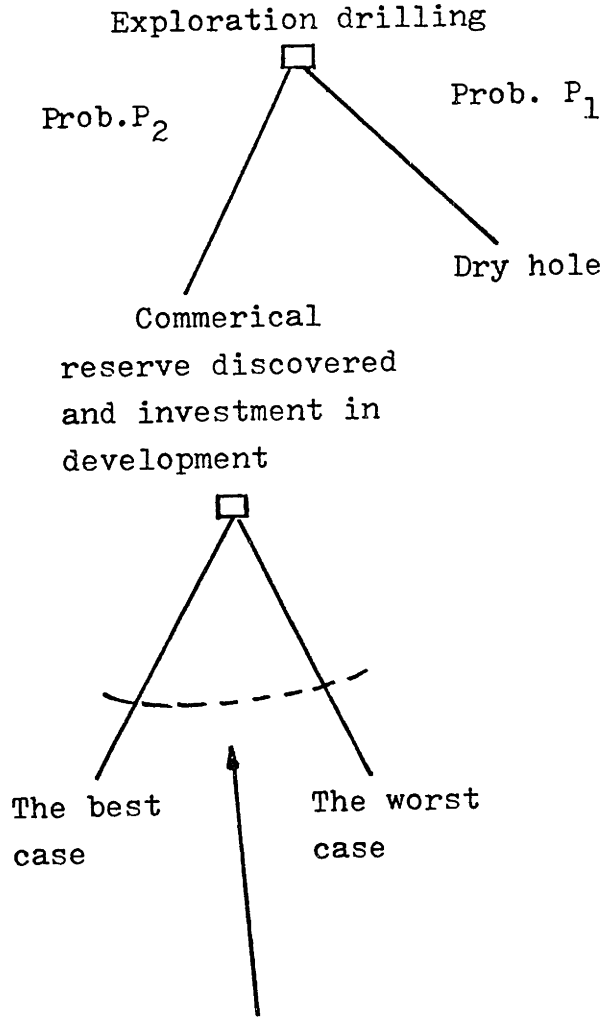
In decision tree format, geological and engineering risks in exploration and development phases can be expresses in Fig. III.2.

In the production phase, after a build-up period during which the rate of output increases each year, output will reach a peak, maintain it for several years, and then decline until the output becomes so low that production becomes uneconomic.

On a scale of time investment and revenue profiles unfold; these profiles will vary with contractual frameworks and

Fig.III.2

Geological and Engineering Risks



different fiscal terms, both the government and the contractors (private oil companies) will experience investment and revenue profiles dictated by the form of their contractual agreements. Risks and rewards may differ substantially between two parties. The model is run here asscessing a hypothetical South China Sea oil field case for which geological, engineering and economic parameters are defined in Appendix II. Economic and risk measures are generated for both parties and compared.

This is ex ante economic analysis under uncertainty. Economic measures - net present value (NPV), internal rate of return (IRR), payback period and oil share - are represented, not as single numbers, but as probability distributions which depend on geological and commerical uncertainties.

In principle comparative analysis of this kind could be supplemented by characterizing each party's attitude towards risk in the form of a probabilistic utility function. The difficulties are manifold, it is not evident whether or not oil companies are risk averse ; some of them surely are, but some are probably not. Consequently , it is necessary to use a summary measure of risk that best captures the sense of what oil men are observed to mean when they speak risk. Domar and Musgrave[9] and Fishburn [11] noted that, in practice, decision makers associate risk with failure to attain a target return. In this model I will follow this approach and, for example, measure risk in terms of the expected value of outcomes with

negative present value of discounting at the supply price of investment.

If $Q_1, Q_2, \cdots, Q_k, Q_{k+1}, \cdots, Q_n$ are expected present values discounted at the investor's supply price of investment with respective probability $P_1, P_2, \cdots, P_k, P_{k+1}, \cdots, P_n$ such that $Q_1, \cdots, Q_k \; 0 \; Q_{k+1}, \cdots, Q_n$; and $\sum_{i=1}^{n} P_i = 1$, then risk as measureed by the expected value of losses is[6]

$$L = - \sum_{i=1}^{k} Q_i P_i \ .$$

From this model we also get the distributions of economic measures vs the range of the possible reserve sizes. The reason to do this can be explained by follows. Suppose a oil contract was negotiated before development and its terms were based on a assumption about the size of reserve. During the developing process the real oil reserve turns out much bigger then the ex ante estimate, and according to those contractual terms the private contractor received such high return that the government would find itself too hard to cope with the internal pressure for renegotiating the contract. This possibility of course will increase the risk and make the whole investment environment unstable. So to see problems from this angle can provid for us some knowledge about the performance of contracts under uncertainty, and it will be very helpful when we compare the different contractual systems.

I use the payback period as a criterion in this model besides

NPV, IRR and oil share. The payback period is usually defined as the length of time required for the stream of cash inflows received by the investor from a project to extinguish the original cash outlays required by the investment.

Mathematically, the payback period PT, is defined by the relationship[11]

$$\sum_{t=0}^{PT} Y_t = 0 \ , \qquad \text{where } Y_t \text{ net cash flows to or from the project, at time } t=0,1,\ldots,PT.$$

One of the defects of this criterion is that it appears not to consider the time value of money. Here I use another definetion for PT:

$$\sum_{t=0}^{PT} NY_t = 0, \qquad \text{where } NY_t \text{ NPVs of net cash inflows or outflows, at time } t=0,1,\ldots,PT.$$

Another well known defect of payback period as a criterion of investment is that it ignores the cash flows that occur after payback. While this is true when we use it as an isolated selection standard, the payback period indeed reflects the investor's desire to preserve an attitude of cash liquidity towards an uncertain future (which will improve the investor's ability to take advantage of unknown but attractive project in the future), and a short payback period could reduce the uncertain future as quickly as possible to a known and certain position[12]. In fact, almost all of private oil companies and governments still use this criterion in their decision making.

The Model Description

This model is basically a standard discounted cash flow algorithm designed to handle uncertainty among key variables and driven by investment, revenues and oil streams associated with a selected production system, given special block conditions (the base case in South China Sea for using in this model is shown in Appendix II).

Principal input variables for the model are:

(1). the probability distribution of amounts of recoverable reserves estimated from exploration data,

(2). contractual terms,

(3). the investment profile over time: exploration cost, operation cost, tangible investment cost, intangible drilling cost; these costs depend on reservoir size, and environment factors such as water depth, reservoir target depth, distance to shore, and transportation options,

(4). world oil price,

(5). discount rates, reflecting the supply price of investment.

Principal output variables for both the government and private oil companies from this model are:

(1). net present value (NPV), given a discount rate,

(2). internal rate of return (IRR),

(3). oil share, which is the ratio of oil received by one

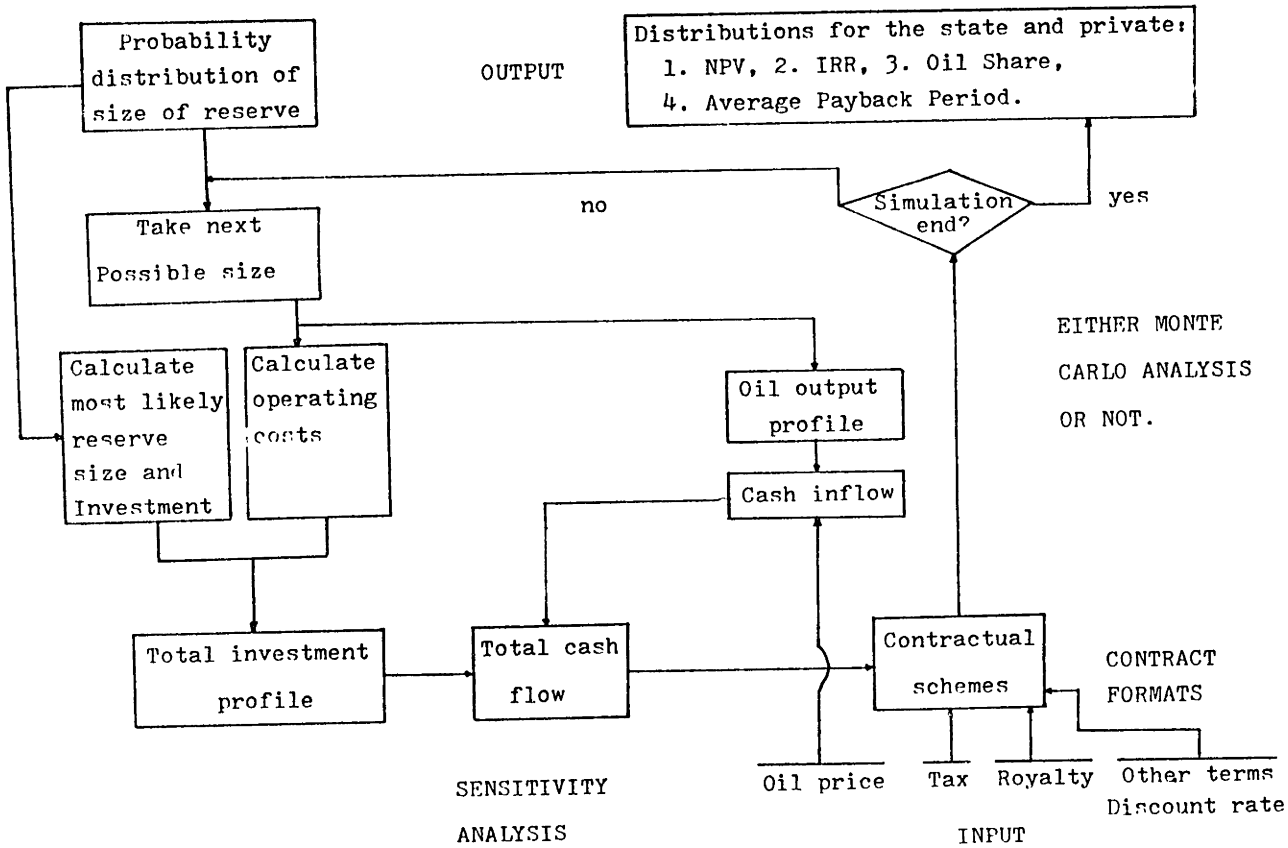


Fig.III.3 Model Structure

party to total oil output, and

(4). payback period.

Fig.III.3 shows the structure of the model. It is programmed using the IFPS (Interactive Financial Planning System)# softwere package in two stages: first, fixing other input variables and using the recoverable reserve probability distribution simulate the model to obtain distributions of criteria; second, using the most likely estimate of recoverable reserves perform a sensitivity analysis on other variables, oil price and discount rate, for example.

This approach allows an explicit examination of the differential effects of critical components of alternative contractual systems on decision making criteria and provides a useful tool for evaluation of various negotiating policies.

The model lists are in Appendix III.

For more information of IFPS, see, for example, "An Introduction To Computer-Assisted Planning Using IFPS", Tutorial. Execucom. June 1980.

4. Comparison of Alternative Contractual Systems

This section affords a comparison of three contracts labelled "Norway joint venture agreement", "Indonesia production sharing agreement" and "Brazil risk service agreement". While each is representative of the type of contract negotiated by the country named, the contract terms assigned here are not necessarily those currently in force. For example, the standard Indonesia production sharing format has undergone periodic changes since the early seventies and become more an amalgam of joint venture and risk service contracts.[1]

Fiscal terms are selected to lie in realistic ranges. They are not adjusted to make the expected value of a criterion (such as rate of return) from each contract equal, as is done by many authors, because first, these three contractual systems are so different in character that it is almost impossible to identify individual components of each that can be adjusted comparably; second, the analysis of results should illustrate each contract's performance relative to a given prospect located in a particular country.

The relative performance of these contracts is strongly influenced by assumptions made about discount rates and world oil prices. While the choice of discount rate varies greatly from company to company, its meaning is clear to private sector companies. What the meaning of "discount rate" for China is, however, is not clear. Here I shall simply assume that

discount rates are the same for private oil companies and the state, and that in the base case they are 20 percent. Uncertainties about the future path of world oil prices are large and attempts to forecast it are speculative. Consequently I will not forecast prices, but will use the World Bank's forecasts mentioned in Ch.2: oil prices will be 37.58 US dollars per barrel in 1983, and will grow at an annual real growth rate of 2.4 percent through 2000.[13] A recently recommended set of forecasts for use in investment analysis is that of J.L. Paddock of MIT[8]. The primary forecast of this set shows real oil prices increasing at 2 % annually through 1990, and at 3.0 % and 4.0 % for 1991 -1995 and 1996 - 2000 respectively. This result is not far from earlier World Bank's estimates.

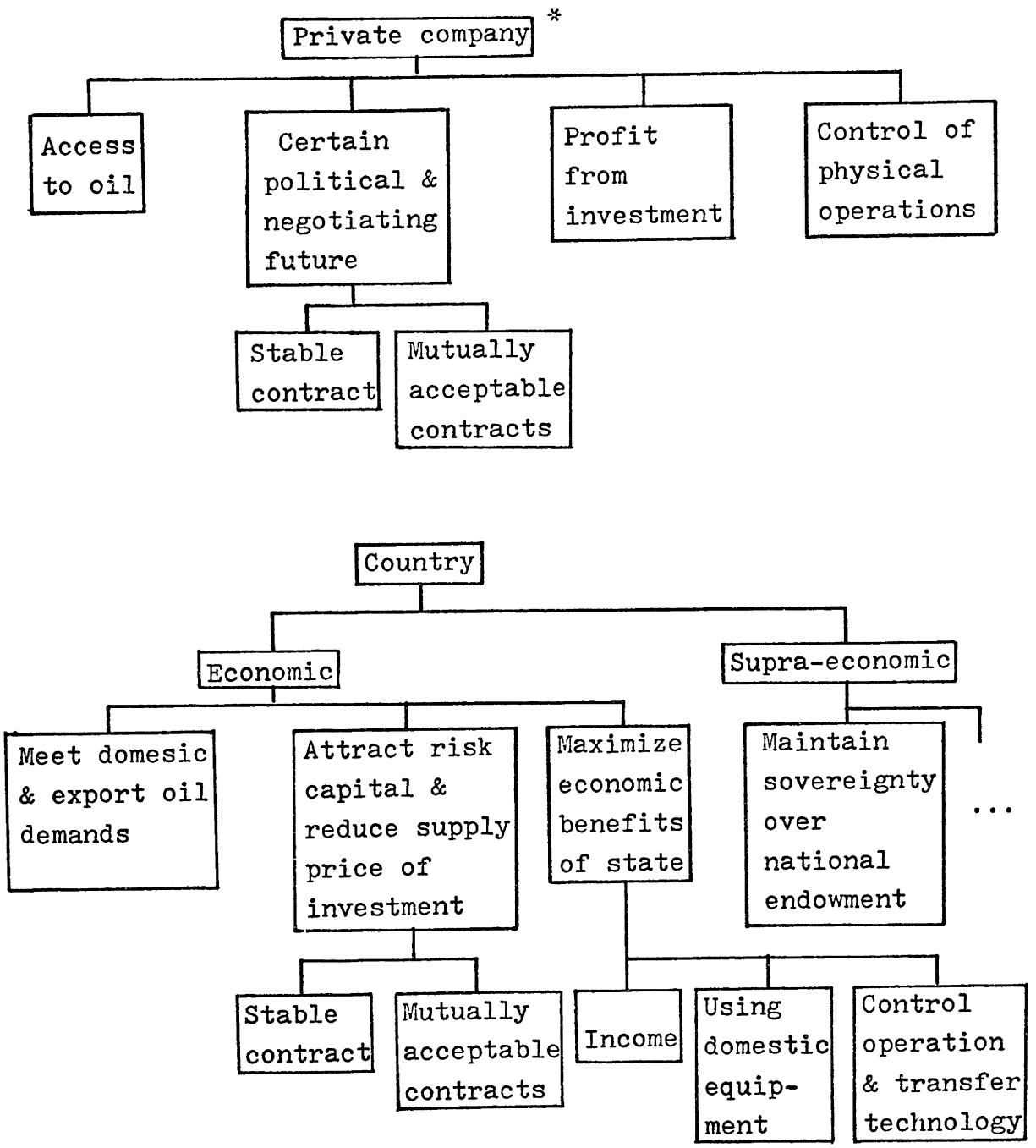
The objectives of both parties to an agreement are shown in Fig.III.4. Computer simulation enables us to judgementally evaluate the degree to which, given a contractual format, achieves each sub-objective that can be measured quantitatively.

The approach adopted for comparison of contracts may be divided into four major steps.

First, using the probability distribution for amount of recoverable oil as input, the model generates probability distributions of NPVs and IRRs for both the state and a generic private oil company for each contractual format. Based on these output it is possible to compare risks to the host government

Fig.III.4

Objectives To An Oil Agreement



* See reference 3.

and private oil companies associated with each type of contract.

Second, NPV and oil share of government and private company are described as functions of amount of recoverable oil under each contract.

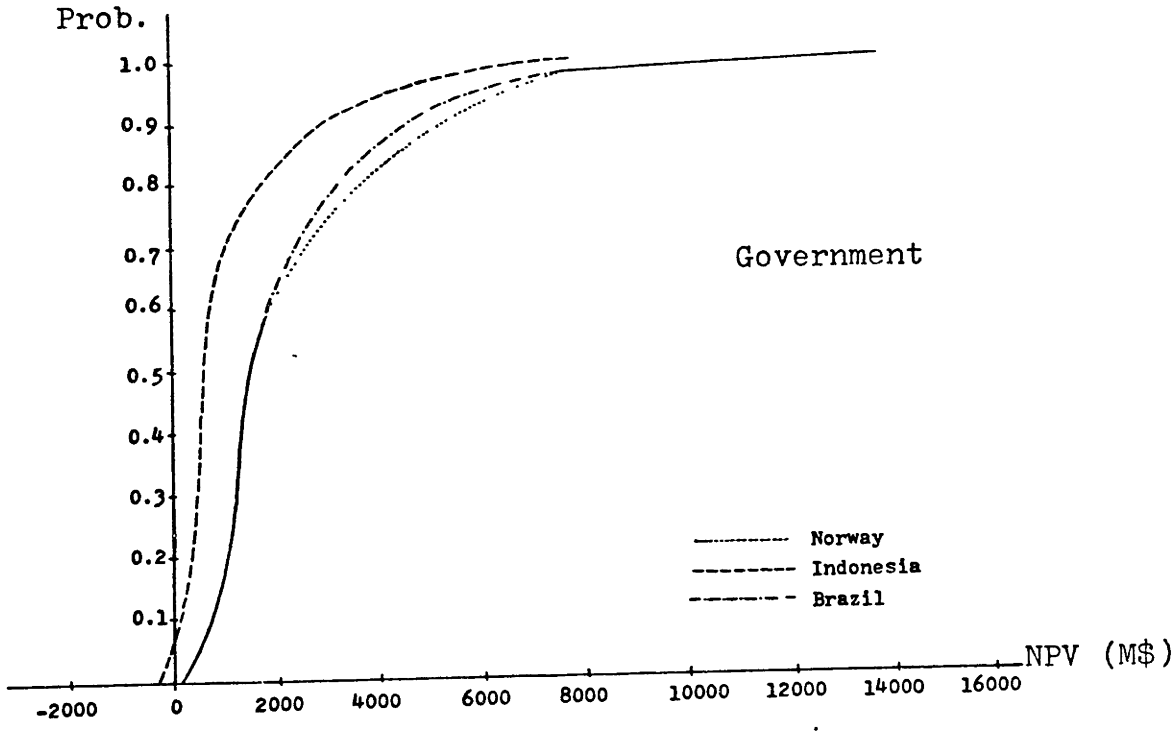
Third, expected payback periods for both government and private contractors are compared for each contract type.

Finally, fixing recoverable oil at the most likely value 584 million barrels, given the assessments shown in Appendix II, the sensitivity of each contract to other uncertain quantities (e.g. discount rate, oil prices, and interest rate) is examined and the implications for the government's negotiating strategy are discussed.

Cumulative Probability Distributions and Contractual Risks

Fig.III.5 and Fig.III.6 show cumulative probability distributions of NPVs and IRRs for both host government and private oil companies. In Fig.III.5, contractual risk - the probability of NPV 0 - is represented by the point at which the cumulative probability distribution crosses the vertical axis. In Fig.III.6, contractual risk is the probability that IRR is less than a specified threshold rate of return, in the base case it is 20 percent.

Another way to view contractual risk is to compute the expected value of a loss, e.g. the expectation of $\min\{NPV, 0\}$ (cf. section 3).



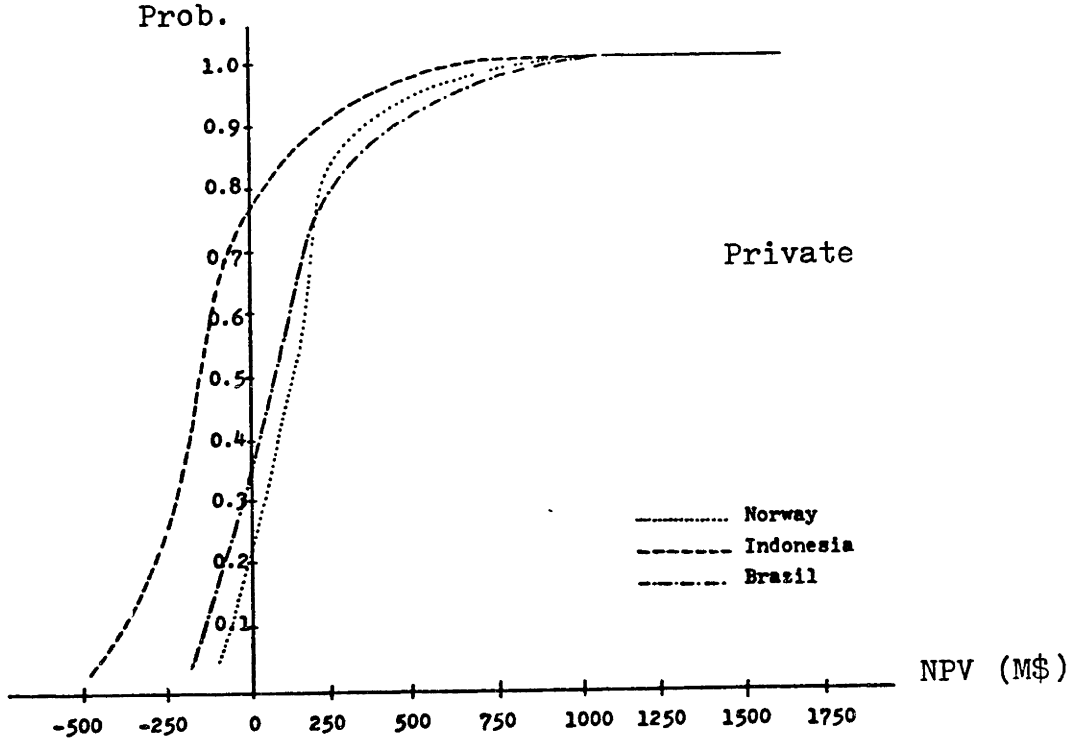
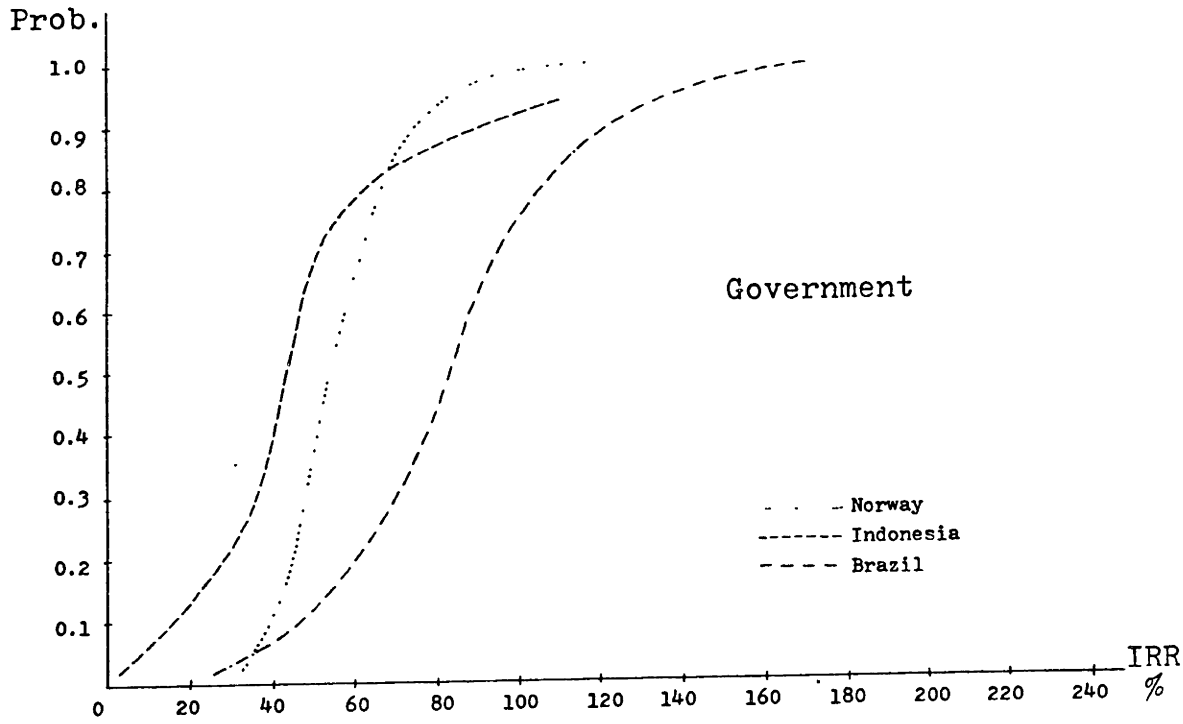


Fig.III.5 NPV Cumulative Probability Distributions



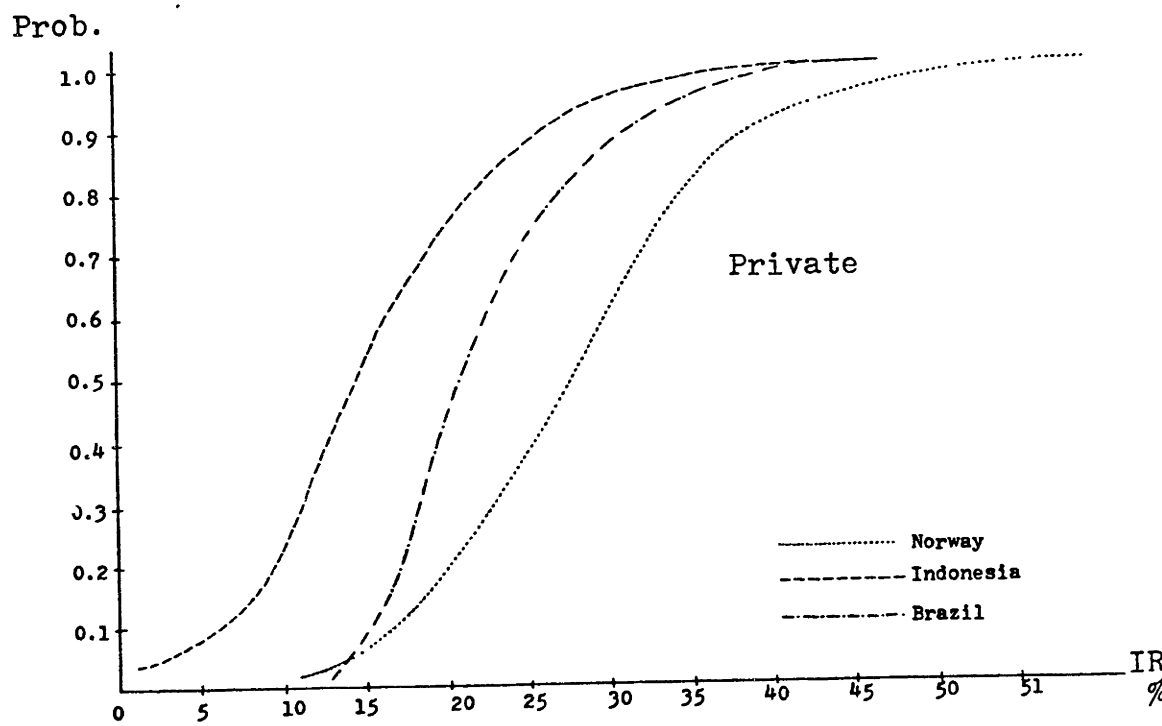


Fig.III.6 IRR Cumulative Probability Distributions

Using the computer model, we obtain:

Table III.2

The Risks Associated With Contracts

Contract format	Prob. of NPV < 0		Expected value of loss*	
	State	Private	State	Private
Joint venture	0	0.21	0	12.3
Risk service	0	0.35	0	33.3
Production sharing	0.07	0.77	21.5	174.6

* Million US dollars.

Risks progressively decrease from production sharing contract to risk service contract to joint venture contract, for both private oil companies and the state.

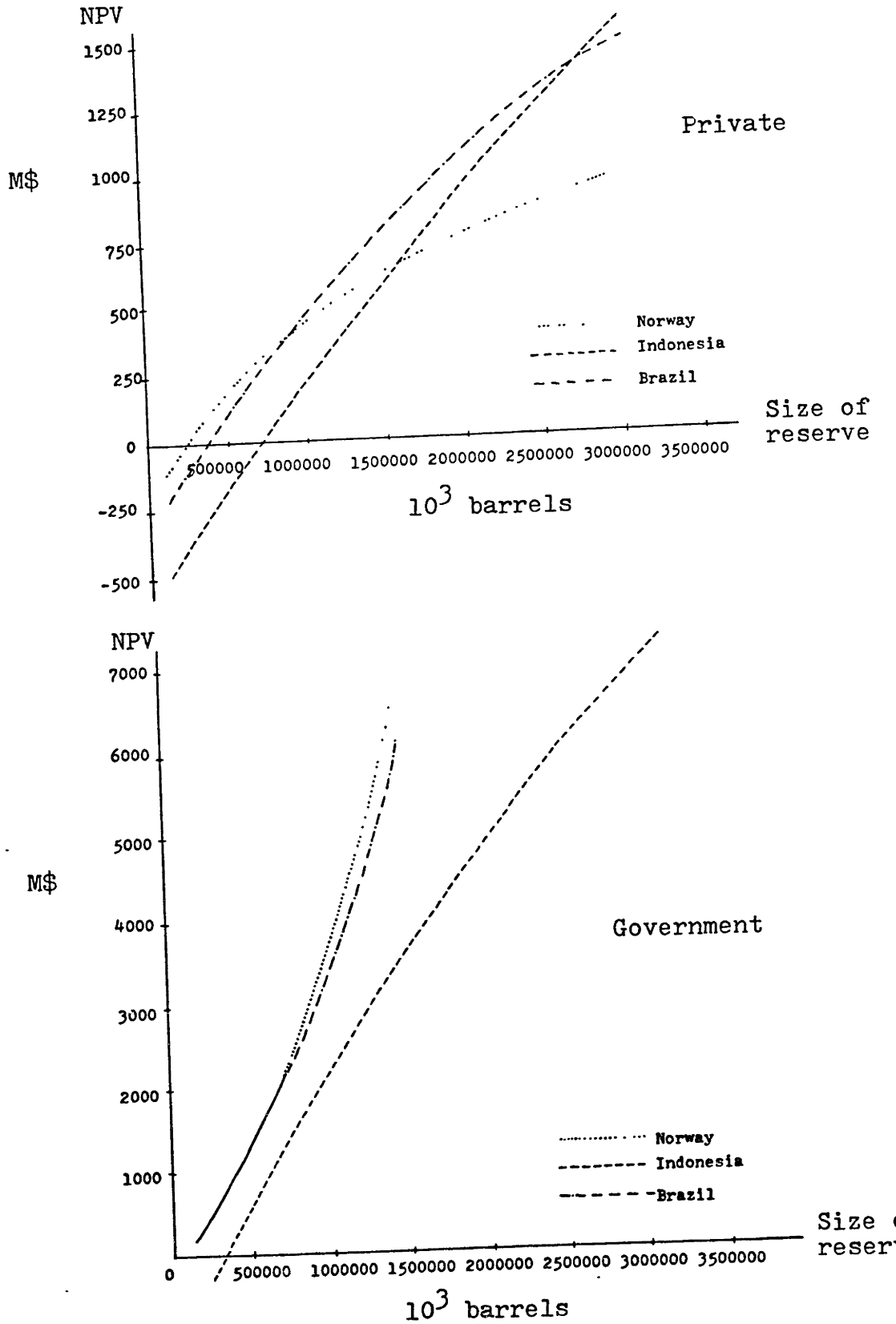
Revenue and Oil share As Function of Recoverable Reserves

Fig.III.7 shows NPV distributions vs. amount of recoverable oil for both private company and host government for each type of contract. Two important characteristics of these contracts can be seen:

(1). Although under all three contracts the state's NPV increases with increasing recoverable oil, the increase in NPV under joint venture and risk service contracts is much larger than that under the production sharing contract.

(2). For private oil companies, the rate at which NPV increases

Fig. III.7 NPVs As Functions Of Recoverable Oil



with increasing amount of recoverable oil for production sharing and risk service contracts is much greater than for a joint venture contract. This implies greater political risks from both private contractor and government's viewpoints for production sharing and risk service contracts than for a joint venture contract in which the private revenues still increase but less rapidly. If a major discovery is made, much larger than originally estimated, under production sharing and risk service contracts private oil companies' revenues may be so large that the host government would be pressured by political circumstances to renegotiate contract terms.

Fig.III.8 shows oil shares for private oil companies and the state as functions of amount of recoverable oil. Under joint venture and risk service contracts the state controls more oil output than that under the production sharing contract.

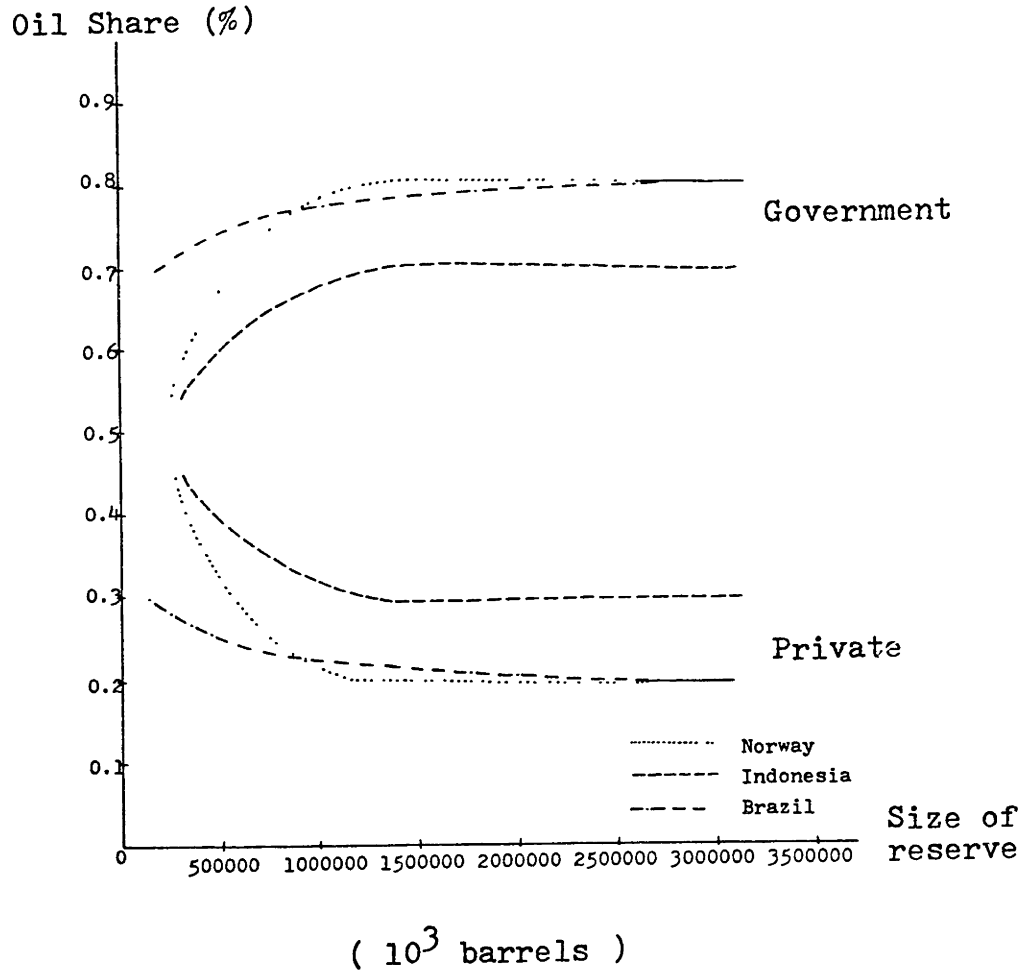
When recoverable reserves are small, a joint venture contract grants the private sector a larger share of oil than a risk service contract and so provides an incentive to attract investment in smaller, more risky prospects. On the other hand, when a prospect is potentially large, the joint venture contract studied here allocates a larger share of oil to the state than either of the other contracts.

The Payback Period

In base case (recoverable oil = 584 million barrels), the

Fig.III.8

Relations Between Oil Shares and Recoverable Oil



payback periods for both the host government and private oil companies under three contracts are shown in Table III.3.

Table III.3

Payback Periods In Most likely Case

Contractual Systems	Private payback period	The state's payback period
joint venture	9	7
Risk service	10	7
Production sharing	-	9

Generally, the output of computer simulation shows that payback periods under joint venture and risk service contracts are shorter than that under a production sharing contract for all possible amounts of recoverable oil.

Sensitivity Analysis of Discount Rate and Oil Price

While joint venture and risk service contracts analyzed here appear superior to the original Indonesia production sharing contract, subsequent changes in Indonesian (and other countries') may possibly modify this conclusion. Here sensitivity analysis is performed for joint venture and risk service contracts only.

NPV shares for private oil companies and the host government as functions of discount rate are shown in Table III.4.

While for the state NPV as a function of discount rate

Table III.4

Sensitivity Analysis For Discount Rate

(recoverable oil=584 million barrels)

Contract	Joint venture				Risk service			
Discount rate	10%	15%	20%	25%	10%	15%	20%	25%
State's NPV*	4949	3242	2142	1420	4720	3119	2094	1425
Private NPV*	564	316	160	60	694	327	95	-53

* Million US dollars

Table III.5

Sensitivity Analysis For Oil Price*

(recoverable oil=584 million barrels)

Contract	Joint venture					Risk service				
Price change rate%	-20	-10	0	10	20	-20	-10	0	10	20
Private NPV change rate%	-45	-22	0	22	45	-82	-41	0	41	82
State NPV change rate%	-25	-12	0	12	25	-25	-12	0	12	25

* Base case, 1983 oil price 37.58 US dollars /barrel.

behaves similarly for both contracts, it dose not for a private company. Private NPV decreases much more quickly with increasing discount rate under risk service than under joint venture contract. Consequently, risk service contract is sensitive to the supply price of investment for private oil companies; it may be acceptable by private contractors only when project uncertainties are small.

Probably the single biggest commercial uncertainty is in the future world oil prices. The results of a sensitivity analysis of oil prices, perhaps the most important source of uncertainty, are shown in Table III.5.

Again, for the state the NPV of both contracts responds similarly, but private revenues vary more dramatically under a risk service contract: changes in NPV are almost twice as large as those under a joint venture contract, over the range ± 20 % of prices examined.

From the host government's viewpoint, these sensitivities of private contractors to uncertainties and contractual terms may strengthen the government's negotiating position. To illustrate, a sensitivity analysis of interest rates in risk service contract is shown in Table III.6.

An increase of as much as 100 % in the interest rate paid by the government to private oil companies decreases the NPV received by the government only about 5 %, while the private oil companies' NPV increases substantially about 68 %. This

constitutes an effective bargaining tool for the government, for by giving up little it can give a private company much more benefits.

Table III.6

Sensitivity Analysis For Interest Rate*

(Risk service contract)

Interest rate change rate %	0	20	40	60	80	100
Private NPV change rate %	0	15.72	30.24	43.70	56.23	67.93
State NPV change rate %	0	-0.98	-1.89	-2.73	-3.51	-4.24

* In base case, interest rate 10%.

Summary

Computer simulation models like that presented here are very useful supports to decision makers who must choose a contract format and specify the parameters of the contract. They allow a speedy analysis of the impact of a variety of uncertainties on both parties to the contract.

Among three contractual systems considered here, the standard Indonesia production sharing contract appears least desirable. Fixed sharing rate can not provide enough flexibility to provide a large share for the state and simultaneously ensure a private contractor the prospect of a reasonable return on his

investment commensurate with his risk. Joint venture and risk service contractual structures appear to be superior. It is important to emphasise, however, that most recent production sharing contracts have improved by introduction of sharing rates that vary with the magnitude of recoverable reserves.[1]

In a joint venture contract, the state is a participatory investor. With no changes in either posted prices, nominal tax rate, or in other terms, the state's share of revenues increases with increasing amounts of recoverable reserves. Hence, both ex ante and ex post the state is ensured a high take of any large discovery; i.e. a large ex post return accrues to the state. To the degree that the state's share is viewed as acceptable both economically and politically, this component of the contract enhances stability of the contract over its life.

Rate of return and oil share under a joint venture contract discussed here are less sensitive to economic uncertainties than a risk service contract.

All of these features of a joint venture contractual system provide a relatively stable environment of investment and could reduce the supply price of investment for private oil companies.

In many respects, a risk service contract compares favorably with a joint venture. However, it is relatively more sensitive to economic uncertainties and changes in contract terms. This sensitivity may or may not make some private oil companies

regard a risk service contract as less desirable than a joint venture, depending on different business environment. When this occurs, the host government must bargain skillfully in order to ensure that its strategic objectives are attained in a more dubious situation. But unlike a joint venture in which the state should invest directly, under a risk service contract the private contractors supply the investment in the form of loans, which is then repaid with the private share of oil outcomes. This is especially attractive to the country who has not enough capital reserved.

Considering the large scale of projects and limited capital reserved by China for offshore petroleum development, the state's strategy might reasonably be to implement a mix of joint venture and risk service contracts together with a modified production sharing agreement on a field by field basis.

REFERENCES

1. Hossain, K.: Law And Policy In Petroleum Development, New York: Nichols Publishing Company, 1979.
2. Hatley, A. G.: Basic Prerequisites For Petroleum Exploration And Development Programs, Unpublished paper, distributed by the East-West Center's Environment And Policy Institute for the use of participants in the workshop on the geology and hydrocarbon potential of the South China Sea and possibilities of joint research and development. August 1980.
3. Kaufman,G. M. and Ball Jr., B.: Alternatives For Accelerating Oil And Gas Discovery And Production In Oil Importing LDCs, Unpublished paper, MIT, October 1981.
4. Raymond, V.: Sovereignty At Bay: The Multinational Spread Of U.S. Enterprises, Basic Books, N. Y., 1971.
5. Kaufman, G. M., Ball Jr., B. and Lingamneni, J.: Oil And Gas Exploration In Developing Countries, MIT working paper, Jan. 1982.
6. Falmer, K. F.: Mineral Taxation Policies In LDC: An Application Of Resource Rent Tax, Unpublished paper for IMF, December 1979.
7. Jacoby, H. D. and Paddock, J.: World Oil Prices And Economic Growth In The 1980s,

working paper No. MIT-EC 81-060wp, MIT, Dec. 1981.

8. Paddock, J.: Oil Price Forecasts Through 2000, Memorandum, Feb. 2, 1982.

9. Domar, E. D. and Musgrave, R. A.:"Proportional Income Taxation And Risk-Taking", Quarterly Journal of Economics, Vol. 58 (May 1944).

10. Fishburn, P. C.: "Mean-Risk Analysis Associated With Below-Target Returns", American Economic Review, Vol. 67 (March 1977).

11. Bussey, L. E.: The Economic Analysis Of Industrial Projects, Prentice-Hall Inc., 1978.

12. Weingartner, H. M.: "Some New View On The Payback Period And Capital Budgeting Decision", Management Science, (August 1969).

13. Far East Economic Review (December 4, 1981).

14. Kaufman, G. M., Runggaldier, W. and Livne, Z.: "A Play Approach To Hydrocarbon Resource Assessment And Evaluation", The Economics Of Exploration For Energy Resources, JAL Press Inc. 1981. pp 69 - 102.

15. O'Dell, T. C.: Petroleum Exploration - The Trend Toward Service Contracts In Selected Non-OPEC Developing Countries, Master thesis, Sloan School of MIT, June 1981.

APPENDIX I

1. Joint Venture Agreement (Norway)

Key elements

Participation: Exploration phase - 100% by private sector.

Development and production phases -

The participation of Statoil is based on a sliding scale related to expected peak production.

Peak production (thous. Barr/Day)	Statoil participation %
0 - 50	51
50 - 100	55
100 - 150	60
150 - 200	65
200 - 250	70
250 - 300	75
300 - 350	77
above 350	80

Royalty:

Peak production (thous. Barr/Day)	Royalty rate %
below 40	8
40 - 100	10
100 - 225	12
225 - 350	14

	above 350	16
Tax:	Standard Norwegian corporate taxes plus a 25% special tax, total about 55% of taxable income.	
Depreciation:	Straight line over 6 years beginning when asset is put in use.	

2. Production Sharing Agreement (Indonesia)

Key elements

Production sharing:	The international oil company is appointed by the state as the contractor of the state oil company. The contractor bears the risks of exploration. In the event of a commercial discovery the contractor takes the future operations and it is entitled to be reimbursed out of a percentage of the oil output (cost oil) and further, to share in the remainder of the production (profit oil).
Cost Recovery:	Operating costs and intangible costs (85% of development drilling costs) are expensed as incurred. Tangibles such as development facilities are depreciated over 7 years,

	using double declining balance method for the first 4 years and straight line method for last 3 years. The percentage reserved for reimbursement of cost is 40 percent each year till all costs are covered.#
Oil split ratio:	65 percent to the state, 35 percent to private company.
Domestic market obligation:	The contractor has obligation to supply the host market with 25% of its oil share. During the first five years of production it could use world oil price, but after that the supply price should be $ 0.2 per barrel.
Tax:	56 percent of taxable income.

A example of this depreciation method:

Suppose investment is 100 dollars, then we have

Year:	1	2	3	4	5	6	7
Depreciation:	28.57	20.41	14.58	10.40	8.68	8.68	8.68

3. Risk Service Agreement (Brazil)

Key elements

Contractor: The international oil company supplies investment in the form of loans for risk service.If no commercial discovery, the exploration costs are bored by the oil company. In the event of a commercial discovery, the investment for exploration and development will be repaid with interest, and the company will be compensated for its services by receiving a share of cash generated by the oil. This payment is called as remuneration. All output of oil belongs to the state but private company has a right to purchase crude oil at world oil price with the remuneration received.

Investment repaid: The investments are repaid once production begins. A 5 years of repayment period in equal annual installment is assumed here.

Interest: Interest is calculated on the development loans only. Interest begins when the investment occurs and is repaid out of

production. In this case the interest is assumed to be 10 percent.

Operation cost: Once on stream, the state takes over operations and pay all operating costs.

Remuneration: Contractor's remuneration is a percentage of the gross production revenues and is based on three X factors corresponding production rates.

Contractor's Remuneration X factors	Production (thous. barrels/D)
X 30 %	0 - 41.4
X 25 %	41.4 - 82.7
X 20 %	above 82.7

This remuneration formula is stairstep (incremental). For example, if actual production is 90 thous. barrels/Day, the contractor will get 30 % of the first 41.4 TBD, 25 % of the next 41.3 TBD, and 20 % of the remaining 7.3 TBD.

Tax: The effective overall tax rate is 46 %.

Source: Kamal Hossain[1] and Thomas Carlton O'Dell[15].

APPENDIX II

Base Case - Geological, Engineering And Economic Parameters For A Hypothetical South China Sea Oil Field

1. Reserve Assignment

This block is located in the South China Sea deep water area at an average water depth of 120 meters. The anticipated productive area extent assigned is about 20 sq km. A potential of 100 meters of oil pay is assigned throughout a prospective interval of a clastic sand-shale sequence expected to be between 1400 and 3200 meters. Considering sand properties in this area recoverable oil is expected to be 40 kilogrames per cubic meter. Multiplying this number by the reservoir volume yields a total of 80 million tons of recoverable oil for the propect underlying this block.

A point estimate of recoverable oil based on the combination of such assumptions has low probability of occurring. Uncertainties must be rendered explicitly. To this end, the following probabilities are assigned to values of geological attributes:

Table AII.1

Area	Prob.	Net Meters Of Pay	Prob.	Rec.Oil	Prob.
9	0.3	60	0.2	35	0.3
20	0.5	100	0.7	40	0.4
42	0.2	227	0.1	44	0.3

Defining for this prospect,

A = productive area (sq km),

H = net meters of pay (meter),

R = volumetric recovery factor (tons/cubic meter);

the amount of recoverable oil reserve Q is

$$Q = R \times H \times A,$$

or equivalently $\log Q = \log R + \log H + \log A$.

According to the assessments in Table AII.1, the expectation of logQ is $\mu = 13.15$ and the variance $\sigma^2 = 0.42$.

A probability - probability plot (P - P plot) of left tail probabilities for $\tilde{Q}$ imputed by Table AII.1 assessments assuming independence of $\tilde{R}$, $\tilde{H}$, and $\tilde{A}$ against left tail probabilities for a lognormal distribution with parameters $\mu = 13.15$ and $\sigma^2 = 0.42$ is displayed in Fig. AII.1.

If the distribution of $\tilde{Q}$ is close to lognormal, the P - P plot should appear as a straight line with slope at 45°.

Fig. AII.1 shows that while not a perfect fit to the distribution of $\tilde{Q}$, a lognormal distribution with $\mu = 13.15$ and $\sigma^2 = 0.42$ is an adequate approximation within the acceptable tolerance of this analysis.

The cumulative probability distribution and the density probability distribution of $\tilde{Q}$ are shown in Fig. AII.2.

Fig. AII.1

P - P Plot (For reference).

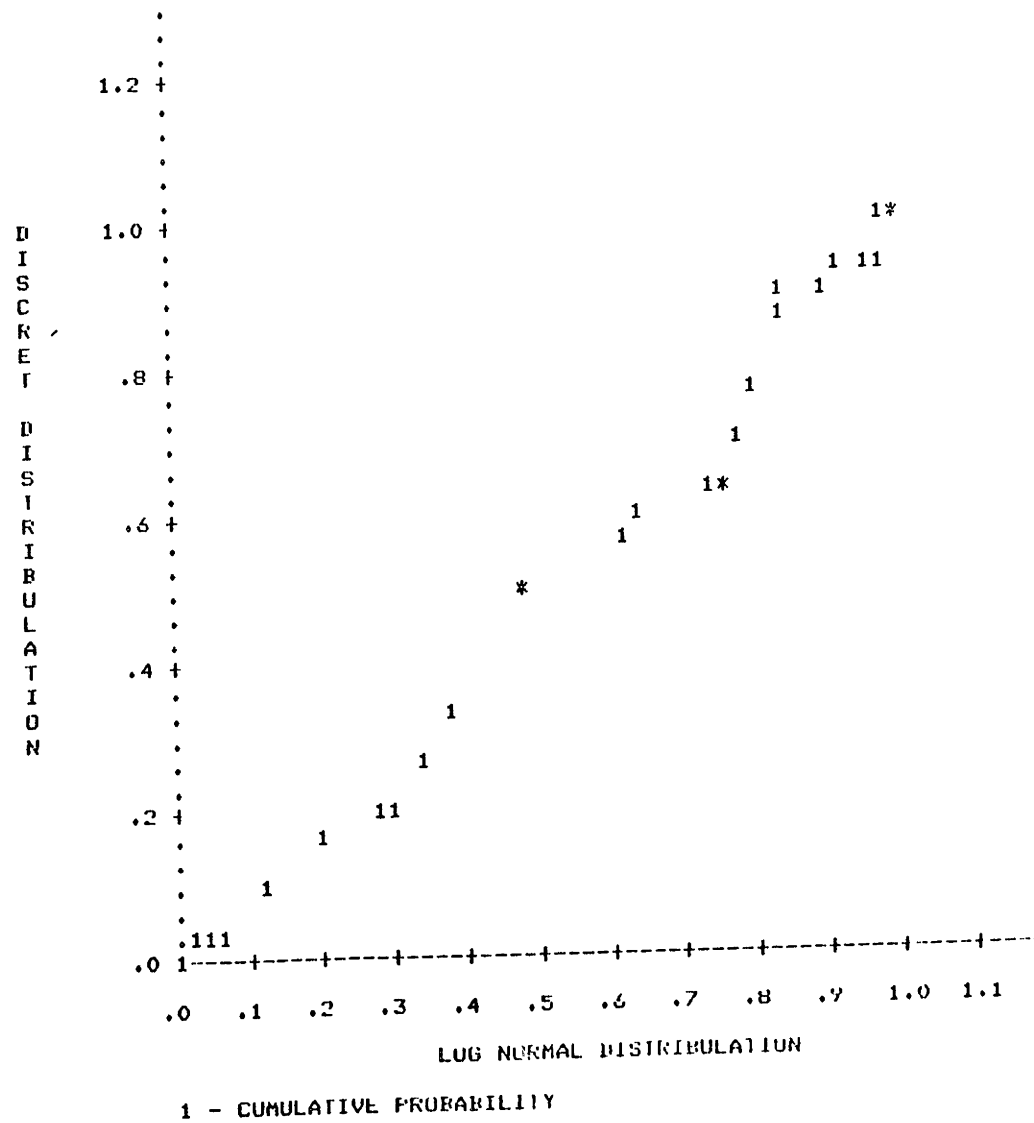
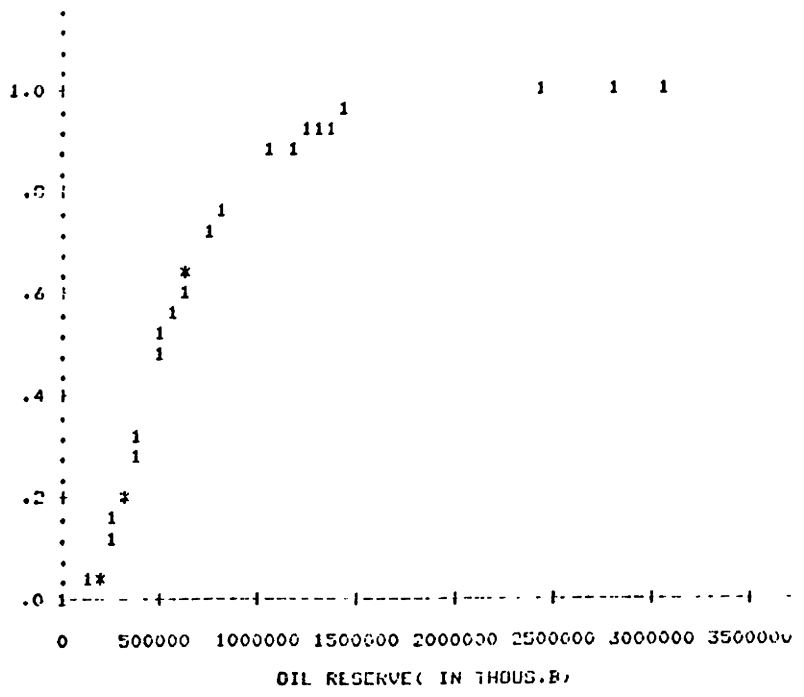
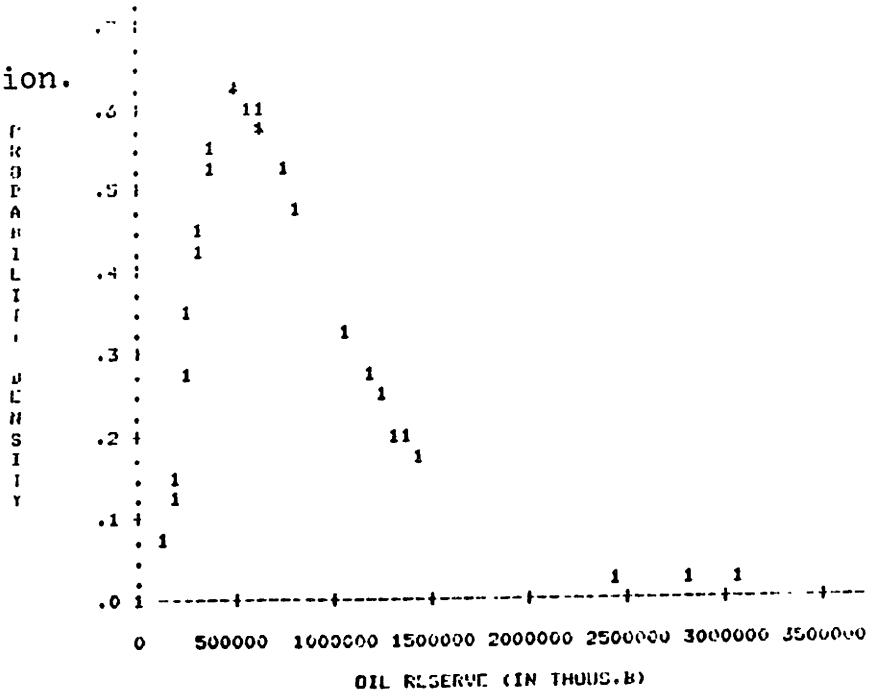


Fig. AII.2

A. Cumulative distribution.



B. Density distribution.



2. Project Planning

This prospect is expected to require three explorating wells. A field with recoverable oil of 80 million tons (or 584 million barrels) in this case will require four 8-pile platforms and a total 88 development wells. Processed crude oil will be transported using tankers, at least in the early life of offshore production. I assume that only one single point mooring system (SPM) is needed for this project. The project's time-line is shown in Fig. AII.3.

3. Costs Estimates (all in 1980 US dollar)

(1). The average cost of an exploratory well is 15 million dollars.

(2). The cost of a platform depends on type of platform and the water depth. A 8-pile platform in 120 meters water costs about 54 million dollars.

(3). The development wells cost about 3 million dollars each.

(4). Total production equipment costs 500 million dollars.

(5). The single point mooring system costs 24 million dollars.

(6). I assume that operating cost is about 2.5 percent of revenue each year.

Combination with the project time-line and other considerations, the investment profile is shown in Table AII.2.

4. Production Prediction

A typical oil and/or gas production profile overtime begins

Fig. AII.3

Project Time-Line

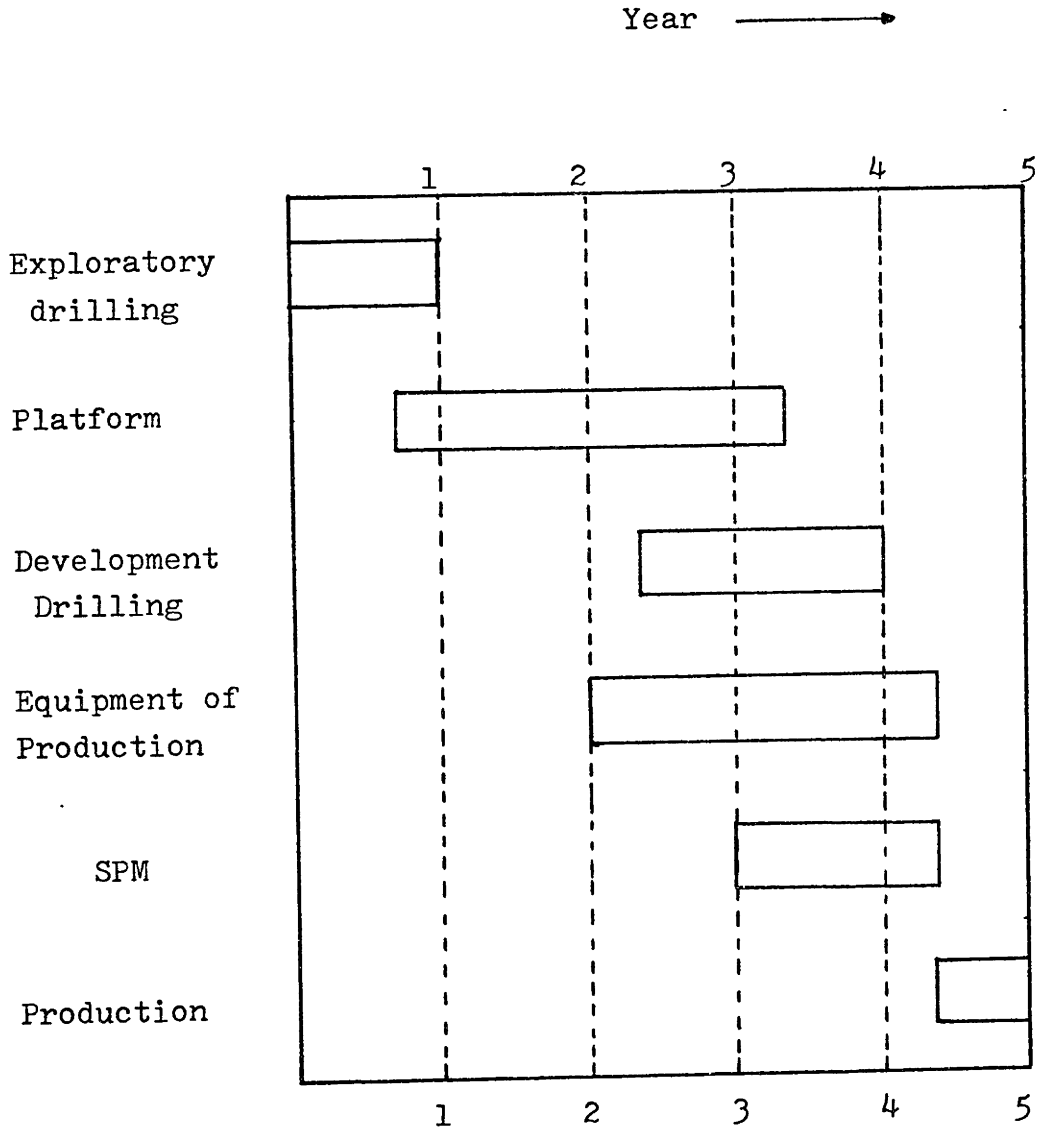


Table AII.2

Investment Profile

Year	Exploration Drilling	Platform	Developing Drilling	Production Equipment	SPM	Operation*
1	45.0	25.0				
2		83.0				
3		80.0	105.6	214.3		
4		28.0	158.4	214.3	18	
5				71.4	6	X_1
⋮						⋮
20						X_{16}

* Operating costs change over production profile.

with a build-up period during which the rate of output is increasing each year as installed capacity is coming on stream, followed by a flat production period, which in turn is followed by a decline in the rate of production over time. Here I assume that the build-up period is three years and that output increases exponentially to peak production, at which point annual output is one eighth of recoverable reserves. Peak production continues for three years, then output declines exponentially for ten years. I assume the fifth year output is 1 million tons, and production will terminate at the end of

20th year, at that point the annual output will decline to 1 million tons again.

Assuming P(t) is the oil production at year t, and S is the recoverable oil reserve, then the production profile over time can be shown as follows:

$$P(t)= \begin{cases} \exp(A(t-5)), & \text{if } 5 \leq t \leq 7; \\ 0.125S, & \text{if } 7 < t \leq 10; \\ 0.125S \exp(-B(t-10)), & \text{if } 10 < t \leq 20, \end{cases}$$

$$(t = 1,2,\ldots, 20.)$$

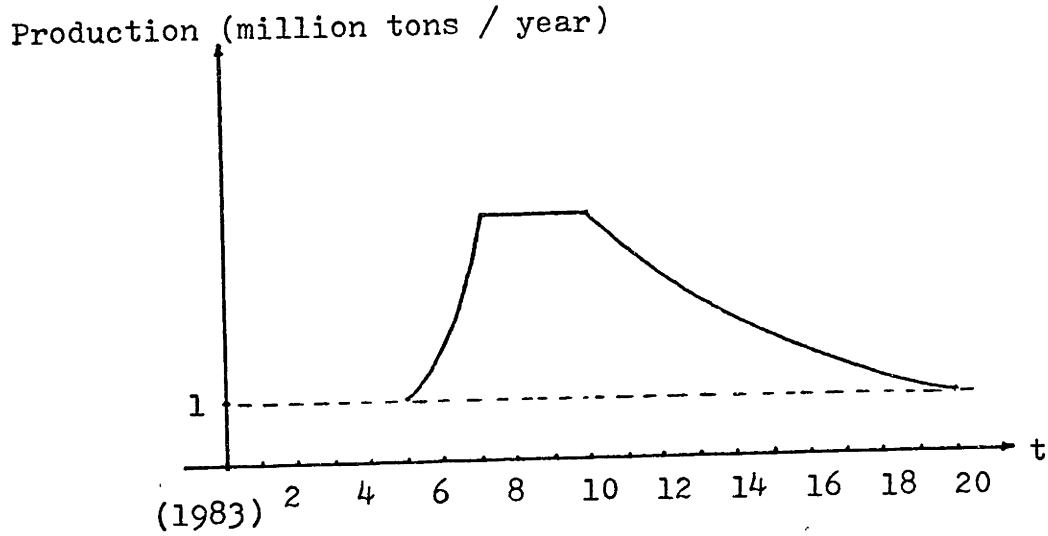
Where A and B are defined as

$$A = (\ln 0.125 + \ln S)/2;$$

$$B = -\ln(1/(0.125S))/11.$$

Fig. AII.4

Production Profile Over Time



APPENDIX III

Following pages are the computer simulation model listing. This model is written with IFPS language. This language and command structure allow the user to describle the problem with no interruption of normal thought processes with a nonprocedural modeling approach.

For example, in this model we can present the oil reserve as a lognormal distribution, then the MONTE CARLO command is used to perform the simulation, and then combined with the WHAT IF capability to examine the sensitivity to uncertainty in the oil prices and discount rate.

CONTRACTUAL SYSTEMS SIMULATION MODEL - DONGWEI CHEN (2/82)

Geological, Engineering And Economic Parameters

```
1.  COLUMNS 1983-2002
2.  OIL RESERVE=AREA*DEPTH*RECOVER RATE
3.  PEAK PRODUCTION=0.125*OIL RESERVE
4.  OIL OUTPUT=0,0,0,0,1,NATEXP(A),NATEXT(2*A),'
5.  PEAK PRODUCTION,PEAK PRODUCTION,PEAK PRODUCTION,'
6.  PEAK PRODUCTION*NATEXP(B),PEAK PRODUCTION*NATEXP(2*B),'
7.  PEAK PRODUCTION*NATEXP(3*B),PEAK PRODUCTION*NATEXP(4*B),'
8.  PEAK PRODUCTION*NATEXP(5*B),PEAK PRODUCTION*NATEXP(6*B),'
9.  PEAK PRODUCTION*NATEXP(7*B),PEAK PRODUCTION*NATEXP(8*B),'
10. PEAK PRODUCTION*NATEXP(9*B),PEAK PRODUCTION*NATEXP(10*B)
11. OIL PRICE=OIL PRICE ESTIMATE,PREVIOUS*1.024
12. OIL REVENUE=OIL PRICE*OIL OUTPUT
13. OPERATING COST=0.025*OIL REVENUE
14. EXPLORATION COST=45,PREVIOUS*0
15. DEVELOPMENT COST=25,83,300,0,418,7,7,4,PREVIOUS*0
16. A=(NATLOG(0.125)+NATLOG(OIL RESERVE))/2
17. B=NATLOG(1/(0.125*OIL RESERVE))/11
18. OIL PRICE ESTIMATE=0.03758
19. DISCOUNT RATE=0.20
```

NORWAY JOINT VENTURE AGREEMENT

```
1.  PRIVATE SHARE OIL = OIL OUTPUT * (1 - STATE PARTICIPATION)
2.  STATE SHARE OIL = OIL OUTPUT * STATE PARTICIPATION
3.  PRIVATE SHARE REVENUE = OIL REVENUE * (1 - STATE PARTICIPATION)
4.  STATE SHARE REVENUE = OIL REVENUE * STATE PARTICIPATION
5.  PRIVATE REVENUE = PRIVATE SHARE REVENUE * (1 - ROYALTY RATE)
6.  STATE REVENUE AFTER ROYALTY = STATE SHARE REVENUE +'
        PRIVATE SHARE REVENUE * ROYALTY RATE
7.  PRIVATE INVESTMENT = TOTAL INVESTMENT * (1 - STATE PARTICIPATION)
8.  STATE INVESTMENT = TOTAL INVESTMENT * STATE PARTICIPATION
9.  PRIVATE OPERATING COST = TOTAL OPERATING COST *
        (1 - STATE PARTICIPATION)
10. STATE OPERATING COST = TOTAL OPERATING COST * STATE PARTICIPATION
11  TOTAL DEPRECIATION = 0, 0, 0, 0, 0, 270.2, 270.2, 270.2,'
        270.2, 270.2, 270.2, 0, 0, 0, 0, 0, 0, 0, 0, 0
12. PRIVATE DEPRECIATION = TOTAL DEPRECIATION *'
        (1 - STATE PARTICIPATION)
13. PRIVATE TOTAL INVESTMENT = PRIVATE INVESTMENT + EXPLORATION COST
14. PRIVATE GROSS MARGIN = PRIVATE REVENUE - PRIVATE OPERATING COST'
        - PRIVATE DEPRECIATION
15. TAX = IF PRIVATE GROSS MARGIN .GT. 0 THEN '
        PRIVATE GROSS MARGIN * TAX RATE ELSE 0
16. PRIVATE NET INCOME AFTER TAX = PRIVATE GROSS MARGIN - TAX
17. STATE TOTAL INCOME = STATE REVENUE AFTER ROYALTY'
        + TAX - STATE OPERATING COST
18. ROYALTY RATE = STEP(PEAK PRODUCTION PER DAY, 0, 0.08,'
        40, 0.1, 100, 0.12, 225, 0.14, 350, 0.16)
19. STATE PARTICIPATION = STEP(PEAK PRODUCTION PER DAY, 0, 0.51,'
        50, 0.55, 100, 0.60, 150, 0.65, 200, 0.70, 250, 0.75,'
        300, 0.77, 350, 0.80 )
20. TAX RATE = 0.55
21. RATE OF RETURN FOR PRIVATE COMPANY = '
        IRR(PRIVATE NET INCOME AFTER TAX'
        + PRIVATE DEPRECIATION, PRIVATE TOTAL INVESTMENT)
22. RATE OF RETURN FOR STATE = '
        IRR(STATE TOTAL INCOME, STATE INVESTMENT)
23. PRESENT VALUE FOR PRIVATE COMPANY = '
        NPVC(PRIVATE NET INCOME AFTER TAX + PRIVATE DEPRECIATION,'
        DISCOUNT RATE, PRIVATE TOTAL INVESTMENT)
24. PRESENT VALUE FOR STATE = '
        NPVC(STATE TOTAL INCOME , DISCOUNT RATE, '
        STATE INVESTMENT)
25. TOTAL STATE OIL SHARE = '
        BCRATIO(STATE SHARE OIL, 0, OIL OUTPUT)
```

INDONESIAN PRODUCTION SHARING AGREEMENT

```
1.  C = OIL REVENUE
2.  DEPRECIATION = 0,0,0,0,302,88,216.37,154.57,110.25,92.02,'
        92.02,92.02,PREVIOUS*0
3.  TOTAL INVESTMENT = INVESTMENT + OPERATING COST
4.  D = 0,0,0,0.4*C,0.4*C,0.4*C,0.4*C,0.4*C,0.4*C,0.4*C,'
        0.4*C,0.4*C,0.4*C,0.4*C,0.4*C,0.4*C,0.4*C,0.4*C,0.4*C,0.4*C
5.  NPV OF TOTAL INVESTMENT = '
        NPVC(TOTAL INVESTMENT,DISCOUNT RATE,0)
6.  NPVD = NPVC(D,DISCOUNT RATE,0)
7.  NEXT=IF NPVD.LE.NPV OF TOTAL INVESTMENT THEN CURRENT+1'
        ELSE PREVIOUS NEXT*1
8.  COST PAYMENT=IF CURRENT.GT.NEXT THEN 0 ELSE D
9.  PRIVATE REVENUE= 0.35*OIL REVENUE=0.35*COST PAYMENT
10. COST OIL=COST PAYMENT/OIL PRICE
11. PRIVATE OIL= 0.35*OIL OUTPUT+0.65*COST OIL
12. STATE OIL = OIL OUTPUT-PRIVATE OIL
13. PRIVATE OIL OBLIGATION = PRIVATE OIL * OBLIGATION RATE
14. STATE SPENDING FROM OBLIGATION='
        DOMESTIC PRICE*PRIVATE OIL OBLIGATION
15. DOMESTIC PRICE= 0,0,0,0,OIL PRICE,OIL PRICE,'
        OIL PRICE,OIL PRICE,OIL PRICE,0.0002,'
        PREVIOUS * 1
16. TOTAL PRIVATE REVENUE = PRIVATE REVENUE-'
        PRIVATE OIL OBLIGATION*(OIL PRICE-DOMESTIC PRICE)
17. PRIVATE GROSS MARGIN=TOTAL PRIVATE REVENUE-'
        OPERATING COST-DEPRECIATION+COST PAYMENT
18. TAX= IF PRIVATE GROSS MARGIN .GT. 0 THEN '
        PRIVATE GROSS MARGIN*TAX RATE ELSE 0
19. PRIVATE NET INCOME= PRIVATE GROSS MARGIN-TAX
20. STATE TOTAL INCOME= STATE REVENUE-DOMESTIC PRICE*'
        PRIVATE OIL OBLIGATION+TAX
21. PRIVATE TOTAL OIL= PRIVATE OIL-PRIVATE OIL OBLIGATION
22. STATE TOTAL OIL= STATE OIL+ PRIVATE OIL OBLIGATION
23. NPV OF PRIVATE COMPANY='
        NPVC(PRIVATE NET INCOME+DEPRECIATION,DISCOUNT RATE,'
        EXPLORATION COST+TOTAL INVESTMENT)
24. NPV OF STATE=NPVC(STATE TOTAL INCOME,DISCOUNT RATE, COST)
25. IRR OF PRIVATE COMPANY=IRR(PRIVATE NET INCOME+DEPRECIATON,'
        EXPLORATION COST+TOTAL INVESTMENT)
26. IRR OF STATE = IRR(STATE TOTAL INCOME,COST)
27. PRIVATE OIL SHARE= BCRATIO(PRIVATE TOTAL OIL,0,OIL OUTPUT)
28. STATE OIL SHARE= BCRATIO(STATE TOTAL OIL ,0,OIL OUTPUT)
29. OBLIGATION RATE = 0.25
30. TAX RATE = 0.56
31. COST=COST PAYMENT+STATE SPENDING FROM OBLIGATION
32. CURRENT=1,PREVIOUS+1
```

BRAZILIAN RISK SERVICE AGREEMENT

```
1.  LOAN REPAYED=0,0,0,0,209.8,209.8,209.8,209.8,209.8,PREVIOUS*0
2.  CURRENT=1, PREVIOUS + 1
3.  INTEREST=L*R,IF CURRENT.LE.9 THEN (PREVIOUS+L)*R ELSE 0
4.  L= NPVC(DEVELOPMENT COST,R,0)
5.  PRIVATE REVENUE=IF OIL OUTPUT.LT.15111 THEN OIL REVENUE* XA ELSE'
        IF OIL OUTPUT.LT.30185.5 THEN'
        15111*XA*OIL PRICE+(OIL OUTPUT-15111)*XB*OIL PRICE ELSE'
        15111*XA*OIL PRICE+15074.5*XB*OIL PRICE+'
        (OIL OUTPUT-30185.5)*XC*OIL PRICE
6.  PRIVATE INFLOW=PRIVATE REVENUE+INTEREST-TAX+LOAN REPAYED
7.  PRIVATE OUTFLOW=EXPLORATION COST+DEVELOPMENT COST
8.  STATE INFLOW=OIL REVENUE-PRIVATE REVENUE+TAX
9.  STATE OUTFLOW=INTEREST+LOAN REPAYED+OPERATING COST
10. TAX=(PRIVATE REVENUE+INTEREST)*TAX RATE
11. PRIVATE NPV=NPVC(PRIVATE INFLOW,DISCOUNT RATE,PRIVATE OUTFLOW)
12. STATE NPV=NPVC(STATE INFLOW,DISCOUNT RATE,STATE OUTFLOW)
13. PRIVATE IRR=IRR(PRIVATE INFLOW,PRIVATE OUTFLOW)
14. STATE IRR=IRR(STATE INFLOW,STATE OUTFLOW)
15. PRIVATE MAX OIL=BCRATIO(PRIVATE REVENUE/OIL PRICE,0,OIL OUTPUT)
16. STATE MIN OIL = '
        BCRATIO(OIL OUTPUT-PRIVATE REVENUE/OIL PRICE,0,OIL OUTPUT)
17. TAX RATE=0.46
18. R=0.1
19. XA=0.3
20. XB=0.25
21. XC=0.2
```