

**POLITICAL RISK MANAGEMENT
AND ITS IMPLICATIONS
IN THE PRESENCE OF A BUYOUT OPTION**

by

NALIK ATIBHAG SANGSNIT

B.Sc. (First Class Honors) in Statistics
Chulalongkorn University, Bangkok, 1986

M.S. in Operations Research
Stanford University, California, 1987

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Signature of Author

MIT Sloan School of Management
December 17, 1993

Certified by

Gordon M. Kaufman, Professor of Operations Research and Management
Dissertation Supervisor

Accepted by

Birger Wernerfelt, Professor of Marketing
Chairman, Doctoral Program Committee

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OF TECHNOLOGY

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ABSTRACT

The main concern of this dissertation is with the implications of political risk for the design of petroleum investment contracts. Political risk is an inherent feature of petroleum investment projects in that the investment and project payoff are separated by time, and events occurring during the lapse of time may alter the project payoff. In general, contracts seek to constitute rules by which the most prominent contingencies are addressed and the accompanying risks reduced. Conventionally, these contingencies are geological or economic in nature; however, where political risk is the concern, it is sensible for contracts to address political contingencies. This research classifies political risk into fiscal risk and non-fiscal risk. The fiscal risk of a petroleum investment project is defined as the risk associated with all host government actions that result in a unilateral departure from the agreed-upon terms and conditions of a contract. Non-fiscal risk is designated as the risk intrinsic to the host country but unrelated to host government actions.

The existence of fiscal risk in general, or expropriation risk in particular, results in either less-than-optimum petroleum exploration for given contract terms or less-favorable contract terms for given geological prospects. This thesis introduces a buyout option into a traditional production-sharing contract as a novel form of contract that can work in conjunction with other means of political risk management to ameliorate this circumstance. A buyout option gives the host government the right to take over the project at the beginning of any period during the project's life. Buyout risk, nonetheless, differs from expropriation risk in that the host government pays compensation, called a buyout value, which is determined by a prespecified mediator mechanism, to the transnational oil company in order

to exercise its right to buy out the investment project. The buyout option, therefore, modifies expropriation risk perceived by transnational oil companies, and seems promising as a device to facilitate mutually advantageous petroleum exploration deals.

The principal findings of this dissertation are theoretical, experimental, and practical. Mutual gains to both the host government and transnational oil company can be achieved and are shown by formal analysis of properties of a production-sharing contract with a buyout option. Whether a production-sharing contract with a buyout option strictly dominates a traditional production-sharing contract depends on several factors: the perceived probabilities of expropriation in the absence of and in the presence of a buyout option, each party's assessment of the project payoff, and the mediator's function for determining the buyout value. Still, a tax range under which expected payoffs from a production-sharing contract with a buyout option are Pareto optimal from the perspectives of both the host government and transnational oil company is identifiable. Moreover, the buyout option expands the domain of agreement between both parties.

This research provides a host government with an optimal policy regarding when to exercise the buyout option and the conditions under which this buyout policy is unique. A binomial lattice price path example illustrates how the host government can construct such an optimal policy. It is shown that, in general, the buyout option has higher value to the host government at a low tax bracket than at higher tax rates and that it supplies the transnational oil company with a cut-off tax rate such that any tax rate greater than the cut-off will prevent the host government from exercising the buyout option in the future. Nevertheless, because its primary objective is to maximize its expected payoff from the project, it is rational for a transnational oil company to negotiate a tax rate lower than the cut-off. In addition, results from an experiment conducted to simulate process of negotiation between host governments and transnational oil companies reveal that their negotiating behavior and outcomes in the presence of a buyout option comply with the theories.

Dissertation Supervisor : Dr. Gordon M. Kaufman

Professor of Operations Research and Management

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CHAPTER 1

INTRODUCTION

1.1 THE SCOPE OF THE DISSERTATION

The main concern of this dissertation is with the implications of political risk for the design of petroleum investment contracts. This research classifies political risk into fiscal risk and non-fiscal risk.¹ The fiscal risk of a petroleum investment project is defined as the risk associated with all host governmental actions that result in a unilateral departure from the agreed-upon terms and conditions of a contract. Non-fiscal risk is designated as the risk intrinsic to the host country but unrelated to host governmental actions. Political risk is an inherent feature of petroleum investment projects in that the investment and project payoff are separated by time, and events occurring during the lapse of time may alter the project payoff. In general, contracts seek to constitute rules by which the most prominent contingencies are addressed and the accompanying risk reduced. Conventionally, these contingencies are geological or economic in nature; however, where political risk is the concern, it is sensible and encouraging for contracts to address political contingencies.

This dissertation begins with a descriptive analysis of the political risk intrinsic in petroleum investment projects in developing countries.

¹ This is the author's definition of political risk. Other definitions and sources of political risk will be discussed in detail in Chapter 2.

Since there is no single accepted definition, the nature of political risk in oil and gas exploration is described in detail. Political risk management issues in an international environment are examined. In particular, political-risk-assessment processes employed by transnational oil companies are explicated. This critical review sets the stage for a formal analysis of new contractual forms that mitigate political risk.

The work in political risk assessment has tended increasingly to make a distinction between fiscal risk and non-fiscal risk. This distinction has resulted from an escalating recognition that non-fiscal risk may not affect project conditions and cash flows and that the magnitude and distribution of the latter is what matters from a transnational oil company's standpoint. The import of this observation is that the focus of political risk assessment has been turned away from the evaluation of political environments in the host country to the terms and conditions under which the project operates. Valuation of fiscal risk is thus an important issue in petroleum investment activity. Fiscal risk is probably the most significant reason for the suppression of petroleum investment activities in developing countries. Both developing countries and transnational oil companies share an interest in minimizing the inefficiencies introduced by fiscal risk.

The fiscal risk that comes to mind most easily in petroleum exploration and production is expropriation, which is an extreme form of fiscal risk. Mahajan (1990) defines expropriation risk as the risk associated with all host government actions that result in the involuntary divestiture of a transnational oil company's ownership of its investment project to the host

country. Expropriation risk is not an obsolete issue. Rather, it continues, especially in recently open developing countries with petroleum potential and limited experience in international commerce. The existence of fiscal risk in general, or expropriation risk in particular, results in either less-than-optimum petroleum exploration for given contract terms or less-favorable contract terms for given geological prospects. This research will explore whether the following proposed contractual feature can work in conjunction with other means of political risk management to ameliorate this circumstance.

A buyout option will be explicitly incorporated into a traditional production-sharing contract between a host government and a transnational oil company as a device to reduce expropriation risk. The buyout option gives the host government the right to take over the project at the beginning of any period during the project's life. Buyout risk, nevertheless, differs from expropriation risk in that the host government pays compensation, called a buyout value, which is determined by a prespecified mediator mechanism, to the transnational oil company in order to exercise its right to buy out the investment project. A buyout option in effect modifies expropriation risk as perceived by transnational oil companies, thus facilitating mutually advantageous petroleum exploration deals.

The second objective of this study is to investigate the theoretical properties of this novel form of contract. An optimal policy about when to exercise the buyout option from the host government's perspective will be constructed. An attempt to quantify the value of possessing a buyout option

and to identify fundamental features of this buyout option value will be made. An investment decision-making process of transnational oil companies in the presence of a buyout option will be studied. The buyout option model will also rationalize the existence of suboptimal strategies adopted by transnational oil companies in coping with political risk in general.

The final purpose of this research is to test in an experimental context whether in practice host governments and transnational oil companies behave as our theories dictate. An in-class experiment will be conducted to simulate the real negotiation process between host governments and transnational oil companies to learn about negotiating behavior and outcomes in the presence of a buyout option. Implications from this experiment and concluding remarks will complete this dissertation.

1.2 POLITICAL RISK IN THE PETROLEUM INDUSTRY

Political risk can be viewed as a subset of risk in general. In the financial theory of risk, political risk does not figure because for most of the circumstances in which the theory is applied, there is a very low probability that the government will interfere with project operations or even expropriate investment projects. In addition, political instability is implicitly assumed to have minimal impacts on the magnitude and distribution of the project cash flows. Accordingly, the assessment of risk is focused on the uncertainties inherent in the industry itself and in the financing of the specific project.

The issue of political risk typically arises when a transnational corporation operates in another country's jurisdiction where the probability of adverse governmental action is perceived as significant. Political risk is an aspect of operating globally and cross-culturally in modern business environments and thus an impasse that transnational corporations must encounter. The international petroleum industry is very politically sensitive in that it involves non-renewable resources and its exploration and development projects are large, highly visible, and subject to nationalistic concern.

Political risk affects the efficiency of resource allocation through international capital markets in several ways. First, it reduces the completeness of financial markets both within and across jurisdictions. Second, it creates a divergence between public and private returns or costs, thus diminishing the social efficiency of private choices. Third, by modifying the structure of financial claims, it also alters a project's incentives (Lessard, 1989). As a result, the misallocation of petroleum exploration effort has been phenomenal.

Recent studies have documented that the developing countries' share of the worldwide exploration effort in the past has been less than would be expected on the sole basis of their geological prospectivity: More than 75% of resource exploration has been devoted to oil and gas searches in highest-cost locations since the early 1970s (Blitzer, Cavoulacos, and Paddock, 1988). Specifically, one study shows that the United States and Canada accounted for almost 90% of exploration drilling activities in 1981, while the oil-importing developing countries accounted for only 4%. Furthermore,

although 92% of wildcat drilling occurred in developed countries, investment per barrel was approximately four times the world average (Blitzer et al., 1985b).

Although efforts have been made by local oil companies in developing countries to develop an oil industry, the exploration and development of petroleum has been viewed as too risky for them. Therefore, many developing countries must look to transnational oil companies for assistance in terms of capital and technical expertise. Attracting foreign investment for petroleum exploration is a common problem in most oil-importing developing countries. Geological promise is a necessary but not sufficient condition. Political risk has been cited as a primary reason for this continuing inefficiency in resource allocation (Blitzer, Cavoulacos, and Paddock, 1988; Broadman, 1985).

It is, however, impossible to eliminate political risk from any international petroleum investment. Even in the most favorable investment climates, such as the United States and the United Kingdom, governments have been observed to increase unilaterally their share of profits from national oil and gas resources. A fundamental dilemma exists in the world energy system: The lowest cost supply is perceived as politically unreliable. Until this perception is changed, the level of world trade in oil will remain at lower than optimal levels (Heal, 1992).

1.3 ASYMMETRY OF INFORMATION

Transnational oil companies have a keen interest in the exploration and production of oil and gas in developing countries because of their comparative advantage in terms of experience and information and, therefore, advanced technology. The objective of transnational oil companies is to maximize their expected profits subject to contract terms, geological and price uncertainties, and other political risks associated with developing countries. Incentives for transnational oil companies to invest in developing countries include higher discovery rates, lower exploration and development costs, relatively unrestrictive environmental regulations, and the saturation of the natural resource industries in developed countries (Robinson, 1988).

Objectives of developing country host governments are not as transparent as those of the transnational oil companies. Rather, their set of objectives is multi-dimensional. In addition to the economic efficiency objective of maximizing expected revenues from contractual arrangements, the host government may endeavor to satisfy other goals, such as industrializing its economy, improving its technological base, ensuring the security of the national petroleum supply, and maintaining domestic control over the petroleum industry. Some of these objectives may contradict each other; for example, economic efficiency and domestic control in the case of inferior domestic information and technology.

Moreover, some constraints affect the host government's choices. These include attitudes toward risk, informational and technological asymmetries between the government agencies and transnational oil companies, political and legislative constraints, such as minimum domestic/foreign employment ratios, and state participation in exploration and development activities.

The host government is, nevertheless, not at an absolute disadvantage compared to transnational oil companies regarding information, for the following reasons: (i) the host government has an advantage over transnational oil companies in terms of information about previous contracts and performances of transnational oil companies in the various areas in its jurisdiction. The host government may publicize or sell such information to interested companies and thus increase the future participation of transnational oil companies. The information would also raise expected bids, especially bids of less-informed transnational oil companies that might place greater value on such information (Mason, 1986); (ii) the host government may have better information about areas with a high probability of discovery rates and areas that border previous discoveries. These two factors would enhance the competitiveness in the bidding process and therefore may increase future bid values. Publishing such information would offset possible strategic behavior by more-informed companies during the bidding process and reduce the incentives for later mismanagement because of the perception of dealing with a more-informed host government; and (iii) since many state oil companies were previously owned or managed by

transnational oil companies, many national employees have experience in dealing with foreign managers and decision makers.

Asymmetry of information is a key element in determining the nature of the relationship between contracting parties—the host government and the transnational oil companies. First, the problem of incomplete information, defined as the information gap between the natural world and the contracting parties, explains the nature-and-contracting-parties game. Nature does not reveal full information about the existence, location, volume, and quality of its oil and gas resources. This information is a valuable commodity to the contracting parties. Expected profits are higher when better information is available, in the case of no or small distributive effect (Isaac, 1987). Second, the information gap between the contracting parties themselves accounts for the presence of information rents² and the transaction costs between the host government and transnational oil companies when it is associated with imperfect monitoring schemes.

The principal-agent theory demonstrates the game between the host government (principal and buyer) and the transnational oil company (agent and seller) in terms of their bargaining power and the boundaries that limit contract values as a result of cross asymmetric information. The transnational oil company usually has more information about the cost functions, while the host government has more information about the value of the product (Breyer and MacAvoy, 1976). In the case of unobservable invest-

² The transnational oil company earns information rents as long as it prevents other companies or the host government from knowing or utilizing such information. The transnational oil company has the option to capture information rents at once by selling the information when it receives an offer equal to or greater than the expected increase in its profits from the exclusive use of such information.

ments, the transnational oil company tends to invest less than the first best level associated with a symmetric-information, complete contract.³ However, in the case of observable investments, the level of investment may be higher or lower than in unobservable cases. An increase in investment by the transnational oil company reduces its cost and provides a positive externality to the host government. It also strengthens the host government's bargaining power because of the change in the host government's belief about the transnational oil company's costs; it may lead to a higher government share in the profits or rent. The transnational oil company may overinvest in cases where the cost reduction that results from higher investment softens the company's behavior in the bargaining process and has a large positive externality on the host government. In such cases, both the transnational oil company and host government are willing to overinvest beyond the first best level (Tirole, 1986).

The existence of asymmetric or incomplete information associated with limited observability may yield inefficient outcomes that are worsened by moral hazard, adverse selection, and the opportunistic behavior of the contracting parties. The moral hazard problem originates when the host government expected returns are decreased (or when expected costs are raised) by actions of the transnational oil companies about which the host government has incomplete information and limited observability. The adverse selection problem occurs when the host government's contract terms attract less-efficient rather than more-efficient transnational oil companies, which may result in smaller government returns (or in higher costs). Op-

³ Shavell (1981) defines a complete contract as one that contains the obligations of each party regarding all possible contingencies.

opportunistic behavior describes the *ex post* behavior of one of the contracting parties that does not maximize the joint profits when certain contingencies occur. It also refers to *ex post* behavior that ravages the other party, for example, expropriation of the other party's assets.⁴ These behavioral problems are of great significance because of the applicable characteristics of the petroleum industry.

1.4 THE DESIGN OF CONTRACTS

Political risk plays an important role in the formulation of petroleum exploration and development contract. Telser (1980) suggests that such political risk is minimized by a contract structure and logistical arrangements that hold both the host government and transnational oil company mutually hostage, so that failure by either party to carry out its commitments would not be justified on grounds of self-interest. Many precedents (Parsons, 1987; Tompkins, 1982) show that when the stakes are high enough a party may break the letter or the spirit of the contract. This breach can occur through mismanagement, resulting in an increase in the transnational oil company's returns to the detriment of the host government, or through the host government's unilateral departure from the contract terms or even through expropriation.

⁴ See Rasmusen (1990), Williamson (1989), and Joskow (1985) for literature on the adverse selection and opportunistic behavior problems. See also Fudenberg and Tirole (1990) and Parsons (1987) for the moral hazard problem.

Since transnational oil companies are needed to provide capital, technology, and expertise that are scarce local supply, the host government is unfortunately not in a position to fully specify all managerial actions by the transnational oil company. Examples of mismanagement include underexploring, under- or overspending on development, or producing at a too-rapid rate. Such managerial misbehaviors reduce the profits of the host country and even the fraction of the resource base that is ultimately recoverable.

Theoretically, the problem of inappropriate managerial incentives can be handled by rules and regulations. The host government can seek to counter the aforementioned incentive effects through close monitoring and control of management behavior. Nevertheless, this choice will be costly in terms of limited personnel resources. In addition, it is unlikely to be effective if there is a large gap between the technical capacity of transnational oil companies and the state agency responsible for monitoring their behavior.

The international petroleum industry's experience suggests that unilateral modifications of contractual arrangements should be expected and that the impact of such changes should be incorporated in the assessment of the attractiveness of the investment project considered. Contractual instability is a fundamental feature of the negotiating environment that reduces the level of activity in the host country and discourages the development of marginal discoveries. Unstable petroleum contracts may result from several factors: for instance, attempts to imitate petroleum contracts in suc-

cessful countries; endeavors to disguise the contract terms and conditions to attract transnational oil companies; and failure of host countries to understand transnational oil companies' expectations of high returns for assuming exploration risks and unwillingness to structure the contract accordingly.

Contractual nonperformance could theoretically be avoided by the design of a self-enforcing contract. A self-enforcing contract is one in which at all times each party perceives the loss of future benefits as eclipsing the short-term gains of breaking the contract. Self-enforceability would be especially important in international contracts where there is no absolute legal system to constrain and penalize undesirable behaviors. Therefore, it is imperative that the contract be designed to include such enforceable covenants aimed at reducing opportunism.

By incorporating changes in contract structures into the contract in advance, thus expanding the domain of the contract, contractual stability is dilated and the probability of expropriation reduced. The transnational oil company avoids at a later date seeking mutual concessions, applying negative sanctions, pursuing legal redress, and lobbying for restriction of imports from the host country (Buckley, 1987).

Although contracts are used extensively to address *ex post* opportunism, there exists in practice no complete contract that contains the obligations of each party regarding all possible contingencies. Shavell (1981) believes that it is in the mutual interests of contracting parties to leave con-

tracts incomplete because the possible adverse consequences of failure to provide for contingencies may not be sufficient to justify bearing the certain expenses of including terms for them in the contract plus the expected costs of verifying their occurrence.

Even though it may appear that a transnational oil company's loss by unilateral or retroactive changes is the host government's gain, uncertainty about future behavior and appropriateness of promised shares is apt to lead to costly gaming between the two parties and thus an abatement in the overall attractiveness of the project. Inefficient contracts can be assumed to result in either less-than-optimum exploration for given contract terms or less-favorable contract terms for given geological prospects. In any case, the issue is how to structure contracts, as a tool for political risk management, that overcome the informational impediments and that have self-enforcing properties.

CHAPTER 2

POLITICAL RISK MANAGEMENT

This chapter commences with a descriptive evaluation of what has been done heretofore with respect to political risk intrinsic in petroleum investment projects in developing countries. A fundamental overview of the practice of political risk assessment and its problems will be scrutinized and trends in the management of political risk studied. Reviews of the literature reveal an escalating role of contracts as a tool for managing political risk. This critical inspection will set the stage for a formal analysis of a new contractual feature that modifies political risk as perceived by transnational oil companies and that is thus promising in facilitating mutually advantageous petroleum exploration deals.

2.1 DEFINITIONS OF POLITICAL RISK

In this section we aim to explore distinguished definitions of political risk. By looking at past attempts to identify political risk, we can obtain a clearer vision of it. Although political risk is not a new phenomenon, concerns about it have increased tremendously in recent years. Its contemporary import is reflected in the number of articles on the subject and in the commitments of resources by a considerable number of international companies to assess political risk. The most significant indicator is the emergence of an extensive number of consulting companies that offer services to

help management come to grip with political problems abroad. An increase in attempts to manage political risk rather than simply avoiding it points to a diminishment of the role of political risk in impeding future cross-border business cooperation (Nigh and Smith, 1989).

From the corporate world's point of view, political risk may be defined as:

Changes in the operating conditions of foreign enterprises that arise out of the political process, either directly through war, insurrection, or political violence, or through changes in government policies that affect the ownership and behavior of the firm. Political risk can be conceptualized as events, or a series of events, in the national and international environments that can affect the physical assets, personnel, and operations of foreign firms.⁵

In addition, political risk is distinguished from customary economic risk, although such risk may have political causes as well.

A similar opinion of risk as a consequence of political environment is shared by Rice and Mahmoud (1986). They define political risk as the probability of not maintaining a viable business operation in an overseas country because of significant changes in the political environment.

From an academic perspective, political risk typically is viewed as the risk of political discontinuities that result in losses through expropriation or major policy shifts (Kobrin, 1979). Another way to define political

⁵ Jodice, D. A., "Trends in Political Risk Assessment: Prospects for the Future," in *International Political Risk Management: New Dimensions*. Washington, DC: Georgetown University Press, 1984, p. 8. See also Derryberry, J. H., "Project Finance and the Management of Risk: A Case Study," in the same book.

risk is potentially significant managerial contingencies generated by political events and processes (Kobrin, 1982).

Along with the term "political risk," we also hear terms such as "country risk." Country risk, broadly defined, encompasses risks associated with claims against economic agents in a particular country, including but not limited to claims on the government of that country. Country risk is also associated with risks of loans by commercial banks to developing countries (Lessard, 1989). This discussion coincides with a judgment by a management consultant that country risk is more of a financial and banking issue whereas political risk has more to do with corporate actors (Sacks, 1984).

Roberts (1988) regards country risk, sovereign risk, political risk, and global risk as interchangeable. His definition of such risk is a spectrum of risks arising from the economic, social, and political environments of a given country—including government policies framed in response to trends in these environments—that have potential favorable or adverse consequences for foreigners' debt and/or equity investments in that country.

Some believe that when speaking of transnational companies' risks, the term "government intervention risk" should be used in lieu of "political risk" (Poynter, 1984). This position mainly exists because government behavior that influences corporate decisions can originate in either economic or societal changes, or both. Political risk in this case refers more to the

likelihood and extent of change in policies of the ruling group and does not necessarily result in intervention in the affairs of particular companies.

Why host governments treat transnational companies differently is controversial. Discrimination lies in the differing characteristics of subsidiaries. A key element is the role of bargaining power associated with the subsidiary. In many instances the impact of politics on transnational companies varies widely, even given the same environmental scenario; it is a function of industry-, company-, and even project-specific characteristics. In other words, political risks are likely to result from the interaction of organizational strategy and structure with the environment, rather than from political events that affect all transnational companies in a particular country.

The relationship between governmental action and political risk is also discussed by Simon (1984), who recommends that political risk be viewed as governmental or societal action and policies originating either within or outside the host country, which negatively affect foreign business operations and environments, whether a select group or the majority.

Robock (1971) presents a comprehensive definition of political risk. He suggests that political risk in international business exists: when discontinuities occur in the business environment; when they are difficult to anticipate; and when they result from political changes. Robock further propounds that the broad range of managerial contingencies that arise from the political-economic environment are ordered along two dimensions. The

first involves a distinction between macro risks, or environmental events, which affect all foreign companies in a country, and micro risks, which are specific to an industry, a company, or a project. The second differentiates between contingencies that affect ownership of assets, such as full or partial divestment, and those that affect operations, thus constraining cash flows or returns.

Kobrin (1982) explains that most politically generated contingencies present micro rather than macro risks, and, increasingly, most affect operations rather than ownership. In most instances, political events do not lead to principal discontinuities or violence, but still may initiate consequential changes in policy toward some foreign investors, and thus create political risk.

The term "political instability" is frequently mentioned in place of political risk. However, it is debatable that the two are not the same since political instability does not necessarily affect project conditions or cash flows and that the magnitude and distribution of the latter is what really represents risk for international business. More interestingly, some constraints for international business such as the price of foreign exchange control and expropriation may eventuate from the regular functioning of the political processes.

The author hereby suggests that political risk in petroleum exploration and development be classified into fiscal risk and non-fiscal risk. Fiscal risk is defined as the risk associated with all host government actions

that result in a unilateral departure from the agreed-upon terms and conditions of a contract. Non-fiscal risk is designated as the risk intrinsic to the host country but unrelated to host government actions. This distinction has interesting similarities to project risk and systematic risk in finance theories and turns the focus of political risk assessment to the fiscal risk, especially the terms and conditions under which the project operates.

2.2 POLITICAL RISK ASSESSMENT

International business has lately been paying attention to political risk assessment. This is evidenced in part by the growth of the profession—the Association of Political Risk Analysts—and recent empirical studies on the structuring of risk assessment units in leading transnational companies (Jodice, 1984). Citicorp is a good example (Katz, 1987). The fact that transnational corporations must form new investment strategies when they enter new environments may partly explain the growth of the political-risk-assessment profession.

Convergence in the international business environment, which is being widely discussed in the popular press and trade and international business journals, has superseded in large part writings about risk analysis in what has been until recently an excessively restricted field (Malabre, 1986). Political risk assessment is an emerging managerial function; as with any such function, more effective performance requires setting objectives and

developing strategies and organizational structures to facilitate their implementation.

Reviews of the political-risk-assessment literature in international business generally record a threefold shift over the last decade: from macro analysis of the political factors that affect business conditions in individual countries to a more integrated analysis of the economic and political developments shaping the operating environment of individual companies, to an emphasis on the management of risk information in such a way that it can have greater impact on corporate decision making (Graham, 1988).

While the subject of political risk assessment may be novel to many American companies, the requisites of more effective performance of this newly emerging function are not. It requires developing strategies to make better use of available resources. Traditionally, political risk assessment focuses on appraising the effects of socioeconomic and political variables. This practice is still logical for commercial banks, but not for transnational companies. The latter find that forced joint ventures, unilateral contract negotiations, and the like top their register of concerns (Poynter, 1984).

The process and output of political predictions tend to be both verbal and qualitative. Although quantitative attempts to forecast political events are still problematic, considerable methodological sophistication has developed in the past decade. It is noteworthy that we are dealing with the first generation of attempts at quantitative modeling of political risk. Quantitative analysis is valuable presently for analytical purposes and should in-

crease in value in the future as databases are constructed and, more importantly, as a better understanding of underlying relationships among input variables develops.

Lerche and Said (1979) suggest that the methodological systems used by recent theorists are so self-contained that they fail to account for many substantive factors of political relevance dealt with by traditional, historical, ideological, or institutional approaches. Resolving the qualitative-quantitative debate requires that the insight of literacy and historical traditions of political scholarship be combined with the quantitative skills of analysis and verification.

One reason political risk assessment is so complicated a task is that it encompasses two separate bodies of knowledge: political science, which is country-specific, and management, which is company-specific (Turner, 1992). However, Burton and Inoue (1987) claim to have constructed a successful model to predict whether a host country government will expropriate a foreign investment. The model is based on the following variables: foreign direct investment per capita; foreign aid per capita; GDP growth rate; deficits; political instability; inflation; and GNP per capita.

Kobrin (1982) arranges political risk assessment methods into two categories. One utilizes observational data; the other employs expert-generated data. Observational data are obtained by the analyst from secondary sources, such as GDP, population, and regular or irregular political events.

Expert-generated data are categorized by their degree of structure and systemization.

Rummel and Heenan (1978) propose an integrated approach to political risk assessment with four independent dimensions. The method is similar to those used in the quantitative cross-national analysis of political instability and conflict. Indices measuring two components of instability—turmoil and rebellious conflict—are created by using a version of factor analysis applied to time-series political event data. Regression analysis is then performed to specify the predictive equations in terms of a number of socioeconomic and political variables. The independent variables are extrapolated into the future and used to predict values of the components of instability.

The Future Group (1980) suggests a method called Political Stability Prospects for measuring and predicting political stability. The method is based on observational data and formal models, but the final product takes expert-generated opinion into account. The first step is to construct a historical index of political stability on the basis of two subindices—a times series on destabilizing events and an economic deprivation measure—which Gurr (1971) and others regard as a significant determinant of the potential for political conflict. The two subindices are combined into a single index of political instability potential expressed in percentiles.

Whatever technique is employed, political risk analysts need a systematic and comprehensive theory and relevant data streams that will re-

place ad hoc explanations of particular cases. A systematic approach to country risk assessment is necessary and results in more-informed business decisions. In other words, social science techniques help identify significant indicators—two levels of analysis, at host government and transnational oil company levels, are necessary for understanding the dynamics of political risk. Graham (1988) accords with the systematic approach. He defines risk analysis as a systematic assessment of the policy context of an organization in which the analyst reports to a superior, verbally or in writing, the relevant risks and opportunities in that organization's operating environment.

A better understanding of the changing world of host government and foreign business relations has prompted a shift in political risk analysis. Transnational corporations now find that the assessment of broad political shocks is far less important than assessing the vulnerability of each subsidiary to intervention (Poynter, 1984). This enhances the significance of fiscal risk valuation in an investment project. Nevertheless, several particular problems arise while dealing with political risk assessment. These include:

Difficulty in Understanding. Understanding political dimensions of business environments is considerably more difficult in political assessment than in most business predictions. Managers in transnational corporations who assess political-environmental uncertainty often experience difficulties in understanding the nature of political processes and their relationships to their organization. It is thus arduous for them to specify outcomes and as-

sign probabilities for events in the political environment and impacts of the environment on the operation.

The necessity to come to grips with politics other than on an intuitive basis is quite new to transnational company managers. Few have developed the same conceptual understanding of politics as a process as they have of basic business processes, such as marketing or finance, or even of economics. Moreover, some managers tend to interpret political elements in the context of their home country's political perspective, which is sometimes seriously misleading.

Political assessment requires a compound prediction of, first, likely environmental scenarios and, second, the probable impact of each on a specific project. Whether violent activities or unscheduled changes in regimes are anomalous depends, to a large extent, on the context in which they occur. For instance, the implications of a coup d'état vary widely from country to country. In developing countries, a coup d'état may simply represent a change in ruling elites and may be neither destabilizing nor discontinuous (Sangsrit, 1991). Nonetheless, it may be both in other contexts or at other times.

Reliability of Data Sources. Another problem of political risk assessment is the reliability of the sources of information or figures used in the assessment. Data are doubtlessly the most influential element in analysis of any kind (Cloutz, 1987). According to Kobrin's survey, most respondents indicated that subsidiary or regional managers are the most im-

portant sources of information about overseas political environments. The banking community is the only external source of information rated as relatively important. Still, information from the banking community may not best serve the purpose of the transnational companies because of differences in business objectives.

The transnational company's own local managers may be biased because these managers typically have a vested interest in the outcome on which evaluations of political factors will bear. Nor are they neutral observers reporting dispassionately on the local scene. They are, rather, part of the local elite whose viewpoint is directly influenced by their positions. Moreover, when local or regional managers are host country nationals, the situation is more aggravating since the question of dual loyalties arises.

Top decision makers themselves are another source of information—they travel extensively, often meeting with high-ranking government officials. However, they tend to trust their own contacts and information rather than what comes up from political risk assessors on their internal staff. This is a useful observation in that political risk assessment seems to be aimed at a better anticipation of future contingencies and better management of contingencies once commitments are made. The problem here may be that, beyond a certain level of familiarity with local circumstances, there are severe limits on the extent to which the future can be anticipated.

Another article suggests that a blend of data would be ideal. Roberts (1988) adds that external consulting services and reporting sources draw on

a wealth of outside expertise and offer it to corporations who need global risk counseling. The in-house capabilities of consultants and questionnaire results make the final judgments and determinations of consultants company specific.

No Serious Integration of Political Risk Assessment. Aharoni (1966) found that transnational company managers did not formally integrate risk assessment into investment decision making; rather, they subjectively determined the degree of risk associated with a given country or area of the world and then avoided investments that had other-than-normal business risks. For best results, political risk assessment should be completely integrated.

More than twenty years later, this argument remains valid. Graham (1988) discusses that at present professionals in both public and private sectors are concerned with the limited success they have had in getting key decision makers to integrate into their work the issues and concerns derived from the broader context in which they operate. Graham also concludes that most transnational companies make foreign investment decisions on a "go" or "no-go" basis, subjectively integrating a general impression of the environment into the process. It is almost impossible to generalize about the political environment in any given country, or about different projects of a single company. The experience of transnational companies is not necessarily pertinent. In addition, it is arduous to establish a body of experience through which models of reality can be modified.

Furthermore, the integration of political risk assessment into investment decision making is subjective in the sense that the translation of qualitative summaries of environments into impacts on operations and forecasts of risk and return takes place intuitively through mental processes that are difficult if not impossible to make explicit, much less to replicate (Armstrong, 1978). It is also worth noting that integration of political risk assessment into corporate strategic planning is often more explicit because qualitative assessment is more germane to planning than to the quantitative capital budgeting process.

Communication Gap. One observation is that communication channels are frequently limited and unidirectional. Direct contact between risk assessment specialists and decision makers is the exception rather than the rule. In addition, communication is often the transmission of information upward in the hierarchy without corresponding feedback.

Shrinkage of Political Risk Assessment Units. As of 1988, political risk units in transnational companies have been reduced, eliminated, consolidated with other staff activities, or hired out. This phenomenon occurs in part because overhead costs associated with such specialized functions have been perceived as high; and the worth of the function has been difficult to quantify (Rogers, 1988). Stapenhurst (1992) believes that other possible reasons for the decline of political risk assessment units despite their importance to effective planning are fewer overseas operations, profit reductions, and failure to incorporate such units into organizations.

Technical Problems. Other problems concerning political risk assessment include the lack of a consensus within the researcher-user community on the definition of political risk; a correlative dissension about methodologies for assessing political risk; a qualitative-quantitative debate confronting theoreticians and practitioners; and the level-of-analysis problem (Brummersted, 1988).

2.3 POLITICAL RISK MANAGEMENT

After assessing the political risk intrinsic in an investment project in a foreign country and studying the prominent issues concerning it, it is logical to find the best way to manage such risk. The most inspiring credence is that political risk is manageable (Nigh and Smith, 1989). To Rossiter and Karplus (1984), the term "management" implies a conscious and coordinated program to deal with potential threats to corporate interests that can arise from political developments. Therefore, it should not mean calling political risk insurers after a host country makes things a reality rather than merely a risk.

Most techniques of political risk management are in various forms of insurance specific to a particular industry. For example, in the petroleum industry, the use of farm-outs, which is the taking on of partners once a lease has been granted, often diminishes an oil company's exposure to political risk in the future.

Rossiter and Karplus (1984) describe the consensus among their colleagues that dedicated political risk management of a strategic nature is rare. This sentiment is attributable to the absence or weakness of a linkage between systematic political foresight and risk management activities. They trust that mounting political uncertainties in most operating environments are sufficient to change the present inadequate practice.

Jodice (1984) propounds that the future promises both an increased demand for and supply of political risk assessment. However, the response committed to political risk assessment may lag behind real corporate needs. The introduction of political scientists into business and the training of existing corporate officers as political risk analysts should be expected.

The abating real cost of collecting and processing political and economic data will strengthen the quantitative side of political risk assessment. Macro-level system studies of economic performance and political stability can continue to be used as background data. These set the bounds within which risk affects specific companies and projects. For longer term planning, econometric forecasting methodologies are essential supplements to the current short-term perspective offered by techniques based on expert judgment.

Schwendiman (1984) perceives joint ventures as one way to try to deal with risk, although they are not risk free. No assessment or management system can be expected to work impeccably. Risk analysts and managers need to be good weather forecasters, bending with the wind at times.

A good sense of the possible and a pragmatic attitude can win much credibility and influence for the risk analyst or manager in the organization.

Poynter (1984) suggests that successful strategies are based on two separate activities: profitably maximizing a subsidiary's bargaining power and adapting its political behavior to its political profile. He explains that most subsidiaries of transnational companies are political actors within their host countries. Their economic importance and foreign character ensure inclusion in politics whenever economics affects political behavior. Hence, it is essential for a transnational company to adapt its political behavior properly. The view of transnational companies as political actors in domestic politics is shared by Gilpin (1975), who argues that in the modern world the relationship between politics and economics is reciprocal and that a global trend exists toward broader participation in national politics and deeper political involvement in economic activities.

Among the strategies that transnational companies can implement is raising the economic and political cost of government intervention. This trend is becoming more frequent (Knorr, 1979). Some transnational companies enter into joint ventures with companies from several influential nations. Some establish good contacts with host governments' key politicians and civil servants. Lately, state sovereignty tends to win out in determining the conditions under which such business companies are allowed to operate.

The key to the successful integration of political or environmental risk analysis into corporate strategy, according to Kennedy (1984), is not the organizational location of the analysis but rather the stress and importance attached to such activity. Scenario development and contingency planning on the basis of such analysis are other fundamental steps in proper risk management.

Micallef (1981) prescribes a sensible process for effective political risk management, as follows: (i) Identify elements of political risk associated with foreign business operations and develop an intelligence system to monitor and evaluate changing conditions of political risk in a host country; (ii) Allow the company to deal with changing conditions of political risk by integrating risk assessment within the company's strategic planning process; and (iii) Devise strategies to protect the company from political risk, especially expropriation.

Gregory (1988) suggests two political-risk-reduction techniques: Integrative and Protective. Integrative techniques are concerned with reducing the frequency of loss; their main objective is to influence relations with institutions and actors in the political environment. Protective techniques are constructed to reduce the severity of loss, albeit some techniques also reduce the frequency of loss. Transnational companies need to develop a concoction of integrative and protective techniques for every country in which they have a direct investment or project.

Financial techniques are the most important protective techniques for natural resource transnational companies. Financial techniques are useful both because of the high cost of natural resource projects and the fact that host governments have less control over these techniques. The author recommends two financial techniques for natural resource investments: maximization of debt; and joint ventures with third country transnational companies. These strategies not only decrease the loss to the natural resource transnational companies but also deter the host government from expropriation.

Buckley (1987) advises that political risk be measured by using a country-specific or company-specific approach. In addition, any investment in a foreign country should be structured to minimize political risk. Four ways to reduce political risk, as raised by Shapiro (1990), include: leasing assets; matching subsidiaries' cash flows with home currency; operating via other companies in the host country; and reducing the number of expatriate employees.

Smith (1989) propounds three principles of political risk management: (i) Establish contractual risk management procedures for controlling and managing foreign risks. Political risk should be incorporated into international risk management; (ii) Identify the types and phases of risk for each project; and (iii) Teach procedures to key personnel and specify their roles in carrying out the program.

2.4 CONTRACTS AND POLITICAL RISK MANAGEMENT

Political risk assessment and the development of appropriate strategies to manage political risk continue to be major challenges facing petroleum industry managers. The review of the literature on political risk reveals two key observations. The first is the increasing tendency to focus on project specific effects rather than general political environments. The second is the emphasis on integrating the assessment and management of political risk and making those tasks a part of the managerial function. Both observations suggest a stronger role for contracts as a tool for managing political risk; they do not supersede the other means of political risk management. Contracts provide a medium by which troublesome risks identified in the assessment phase can be addressed and reduced to manageable proportions.

The presence of fiscal risk, especially expropriation risk, in a petroleum investment project results in either less-than-optimum exploration for given contractual terms or less-favorable contractual terms given geological prospects. In general, contracts seek to constitute rules by which the most prominent contingencies are addressed and the accompanying risks reduced. Conventionally, these contingencies are geological or economic in nature. Nevertheless, in the international petroleum industry, where political risk is the concern, it is sensible and encouraging for contracts to also address political contingencies.

The role of contracts here is to mitigate fiscal risk as perceived by transnational oil companies given the same magnitude and distribution of project cash flows, thus increasing the transnational oil company's expectation of project payoff and decreasing its strategic mismanagement in coping with fiscal risk. This results in an alleviation of costly gaming behavior between the host government and transnational oil company. Consequently, the overall attractiveness of the investment project is enhanced and the zone of agreement between both parties is expanded. The author thus recommends use of self-enforcing contracts in conjunction with other aforementioned instruments for more effective management of political risk.

2.5 CONCLUDING REMARKS

The field of political risk has largely focused on the assessment and reduction of political risk for present and future investments. The reduction of political risk is of critical importance for transnational oil companies because by formulating an optimal mix of political risk reduction techniques, they may be able to reconcile environmental demands with strategic requirements.

As the number of environmental elements and the differences among them grow larger, prediction of the future environment—in the sense of specifying causal relationships—and its impact on corporate operations becomes more arduous. The emergence of the political assessment function reflects managerial perceptions of an increased probability of significant

contingencies emanating from the political environment. Political risk assessment aims at a better anticipation of future contingencies and better management of contingencies once commitments are made. Therefore, it should be a proactive part of corporate environments. The problem may be that there are limits on the extent to which the future can be anticipated.

The work in political risk assessment has tended increasingly to make a distinction between fiscal risk and non-fiscal risk. This distinction has resulted from an escalating recognition that non-fiscal risk may not affect project conditions and cash flows and that the magnitude and distribution of the latter is what matters from a transnational oil company's standpoint. The import of this observation is that the focus of political risk assessment has been turned away from the evaluation of political environments in the host country to the terms and conditions under which the project operates.

Contracts are project specific—they are the mechanism by which future perplexing contingencies are transmuted into manageable risks—and their administration is an ordinary part of management. The emphasis on integration of the assessment and management of political risk into the managerial function and on project specificity suggest an escalating role of contracts and their distinctive provisions. An introduction of a buyout option into a traditional production-sharing contract as a novel contractual format that addresses political contingencies will be made and a quantitative analysis will be performed.

CHAPTER 3

THE TWO-PERIOD MODEL WITH A BUYOUT OPTION

3.1 INTRODUCTION

When a transnational oil company undertakes an investment project in the jurisdiction of a country other than its own, it is in effect simultaneously writing a call option to the host country government on its project. Because expropriation risk typically diminishes the total potential benefits and thus the overall attractiveness of an investment project, mitigation of expropriation risk may be of mutual advantage. A tactic that reduces the probability of expropriation is to introduce a buyout option into a contract. The buyout option directly addresses the issue of unforeseen contingencies by explicitly incorporating this risk in a contractual arrangement between the host government and transnational oil company.

The characteristics of the buyout option considered here can be described as follows: the host government has the right to take over the project at the beginning of any period over the project's life but has to pay a monetary sum, called a buyout value, to the transnational oil company in order to exercise this right. The buyout value is to be specified by a predetermined mediator mechanism.

In general, not only does each party to a petroleum investment project not necessarily have the same set of information, each party may also

have differing perception of associated risks and possess differing attitude towards risk. Even each individual member of the same party may not possess the same risk attitude. Moreover, the completeness and degree of integration of domestic and international capital markets may result in differing abilities to diversify these risks by the transnational oil company as well as by the host government.

Asymmetry of project information, and differences in risk perception, attitude, and diversifiability constitute a framework for an integrative bargain. Consequently, a mediator mechanism may have a substantial value for both the host government and transnational oil company.

We shall explore a variation of traditional production-sharing contracts—a production-sharing contract with a mediated buyout option. The transnational oil company is solely responsible for making the initial project investment. The project's net cash flow exclusive of initial investment is, however, split between the host government and transnational oil company at the beginning of each period until project termination. To make matters simple, we shall assume: if the project's net cash flow is x then the host government receives a share $\delta \cdot x$ and the transnational oil company receives a share $(1-\delta) \cdot x$. The buyout option diminishes the probability that the transnational oil company's investment project will be expropriated.

A traditional production-sharing contract provides a share of the output or its monetary equivalent to the transnational oil company in return for its investment and operating costs. The transnational oil company bears

all the cost risk and a proportionate share of geological and revenue risk. In the standard production-sharing contract, the transnational oil company's reward comes in the form of a share of the physical oil produced, which it can then use or sell itself. Alternatively, the host government pays the transnational oil company a cash amount equivalent to the share of the production at market prices. The investment project covered by a production-sharing contract is, nevertheless, subject to expropriation by the host government.

This chapter contributes a model of a petroleum investment project with a time horizon of two periods and a buyout option, in which certain rules of the host government and transnational oil company behavior are postulated. A necessary and sufficient condition for the host government to exercise the buyout option will be provided. The cut-off value of the project payoff that leads to the host government choosing to buy out the project and the issue of its uniqueness will be examined. The expected payoff functions to the host government and transnational oil company will be studied and sensitivity analysis performed. Finally, this chapter conveys some strategic implications for the host government and transnational oil company.

3.2 THE MODEL

Suppose that a petroleum investment project has a time horizon of two periods. The host government (HG) and transnational oil company (TNO) agree in the initial period on a δ -sharing rule with a mediated buyout option in the terminal period. Initial acts available to the parties are either to agree jointly to a contract specified by a choice of δ —a payoff sharing rule—and a mediator mechanism or not to consummate any contract at all.

There are five key variables in this two-period model with a buyout option. These variables are:

- $\delta \in [0,1]$, interpretable as the tax rate that HG may impose on the TNO.
- X is the project payoff at termination, before interest and tax but after depreciation.
- $\xi_T(\delta)$ is the buyout risk, defined as the subjective probability the TNO assigns to the event “the HG exercises the buyout option” in agreement of a value of δ .
- $\psi(x)$ is the buyout value as determined by the mediator.
- I_T is the initial investment by the TNO.

Throughout this study, a random variable will be distinguished from a value assumed by it with capital and small letters. For example, the random variable X , the project payoff at termination, assumes a value x . In addition, the discount factor for returns in the terminal period is unity.

Initial assumptions are

- (A1) Conditional on $X = x$, the HG acts to maximize its payoff. Further, the HG acts *ex ante*, prior to observing $X = x$, to maximize its expectation of payoff.
- (A2) The support of X is $[0, \infty)$. For a more-than-two-period model (A2) may be inappropriate.
- (A3) The mediator's assigned buyout value $\psi(x)$ is, conditional on $X = x$, revealed to both parties.
- (A4) A priori, the function $\psi(x)$ is known with certainty by both parties.
- (A5) $\psi(x)$ is assumed to be a nonnegative concave function, monotone increasing with increasing x .

At termination, $X = x$ is realized. The HG encounters choices as in Figure 3.1, and the TNOC faces a lottery as in Figure 3.2. Intuitively, the HG will exercise the buyout option when the payoff $x - \psi(x)$ of doing so is greater than the share $\delta \cdot x$ it will receive by not exercising the buyout option. This idea is summarized in Proposition 1.

PROPOSITION 1 : Conditional on $X = x$, a necessary and sufficient condition for the HG to exercise the buyout option is $(1-\delta) \cdot x > \psi(x)$.

Proof :

The HG encounters a decision node as shown in Figure 3.1. By Assumption (A1), the HG compares its payoffs and chooses the act with the highest payoff. Namely, it is rational for the HG to exercise the buyout option if and only if

PAYOFF

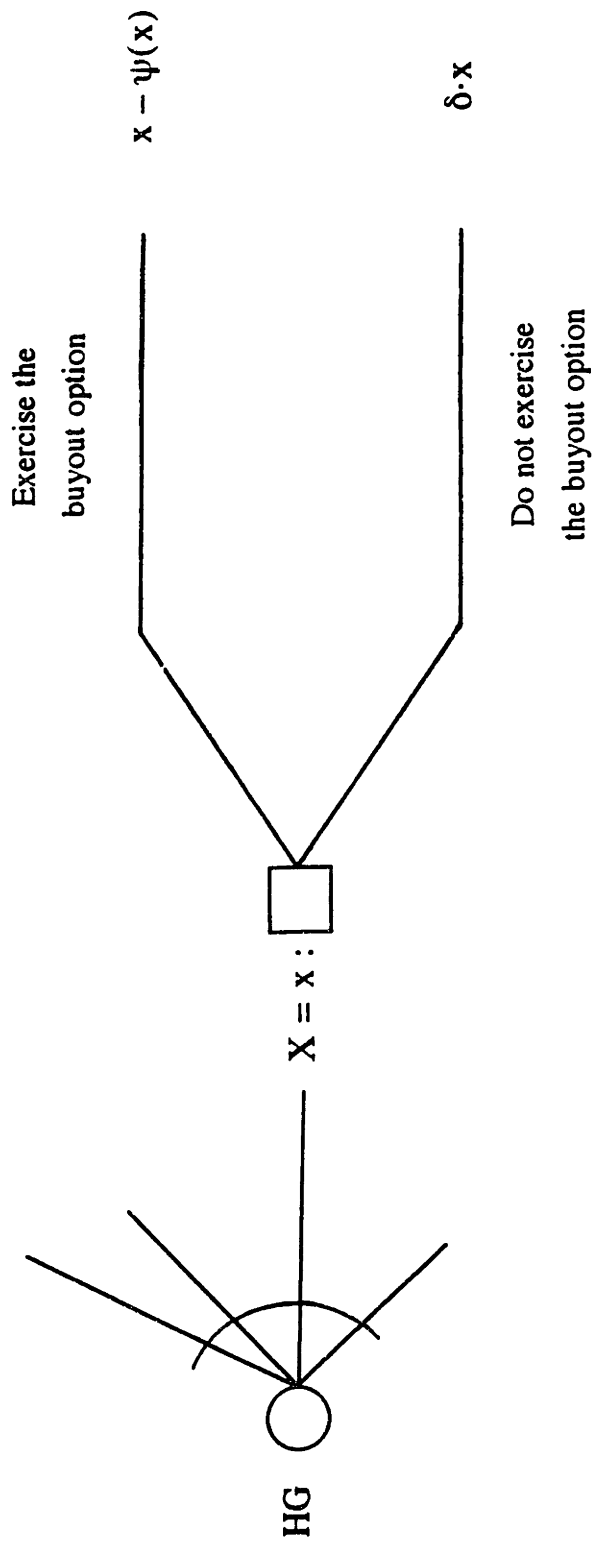


Figure 3.1 : The problem of the host government

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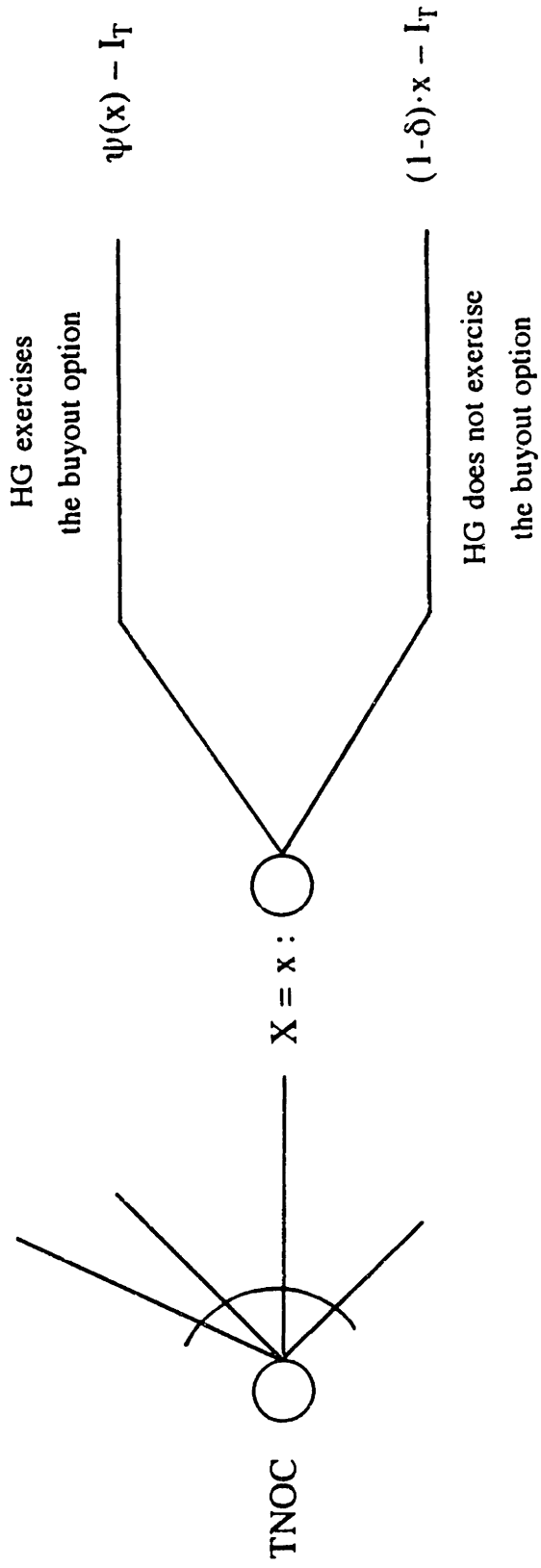


Figure 3.2 : The problem of the transnational oil company

$$x - \psi(x) > \delta \cdot x \quad \text{and}$$

$$x - \psi(x) > 0$$

or equivalently,

$$(1-\delta) \cdot x > \psi(x) \quad \text{and} \quad x > \psi(x).$$

Since $(1-\delta) \cdot x > \psi(x)$ is stronger than $x > \psi(x)$, a necessary and sufficient condition for the HG to exercise the buyout option is $(1-\delta) \cdot x > \psi(x)$.

Q.E.D.

We shall assume initially that both parties have access to full information about $\psi(x)$:

(A6) Both the HG and TNOC know that the HG will exercise the buyout option if and only if $(1-\delta) \cdot x > \psi(x)$.

and we shall further assume that the TNOC's objective is to maximize its expectation of payoff:

(A7) The TNOC acts *ex ante* to maximize its expectation of payoff.

If $\psi(x) \geq x$, then $x - \psi(x)$ is negative, and the HG will never exercise the buyout option. See Area 1 in Figure 3.3. However, if $\psi(x) < x$, in order to minimize the buyout risk, the TNOC would want to agree upon δ large enough to make "not exercising the buyout option" preferable from the HG's perspective. Namely, the TNOC would want to maximize Area 3 while keeping $(1-\delta) \cdot x < \psi(x)$.

Figure 3.4 shows that for a given δ , $(1-\delta) \cdot x$ must lie below $\psi(x)$ on $[0, \infty)$ no matter how peculiar the function $\psi(x)$ may be, in order that the

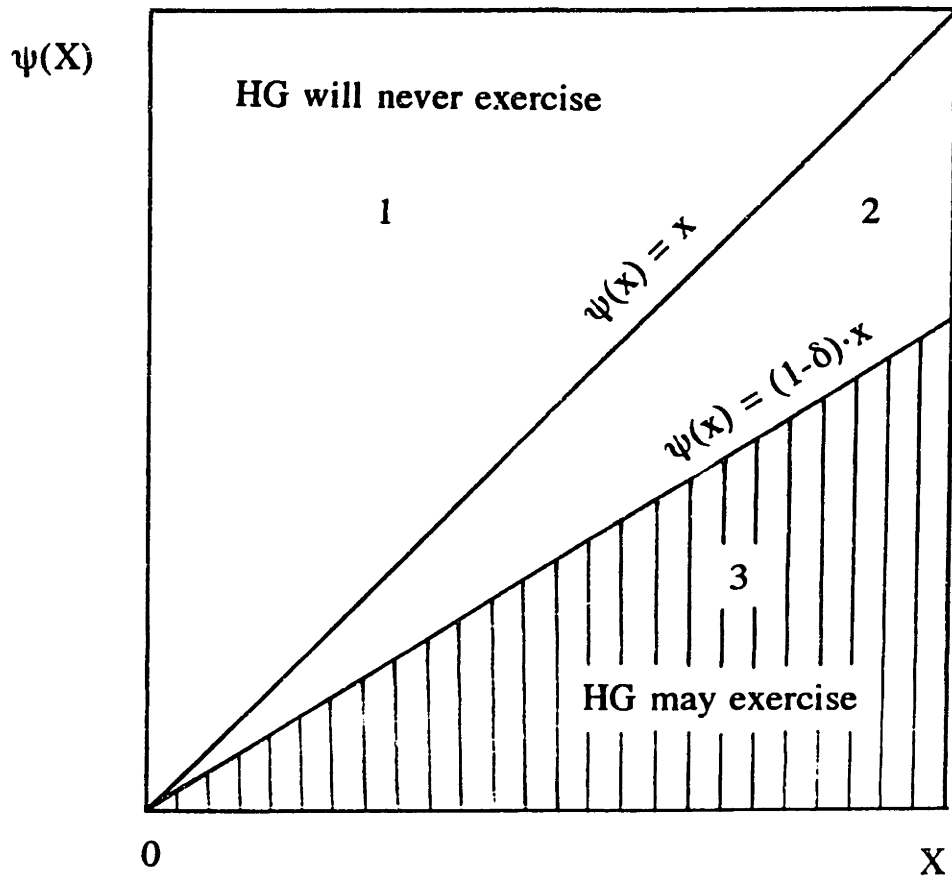


Figure 3.3 : Relationship between x and $\psi(x)$

HG will choose never to exercise the buyout option. The HG will choose to exercise the buyout option for values of x such that $(1-\delta)\cdot x > \psi(x)$. If $\psi(x)$ is as in Figure 3.5, the HG will exercise the buyout option in two regions. This figure suggests a prerequisite for a partition of $[0, \infty)$ into two intervals $[0, x_0)$ and $[x_0, \infty)$ such that the HG will buy out if $x \in (x_0, \infty)$, and will not buy out if $x \in [0, x_0)$. The HG will be indifferent if $x = x_0$. For this reason, Assumption (A5)— $\psi(x)$ is a nonnegative concave function, monotone increasing with increasing x —has been stipulated.

Figure 3.6 portrays the *ex post* (conditional on $X = x$) TNOC rationale for maximizing Area 3. Both $(1-\delta_1)\cdot x$ and $(1-\delta_2)\cdot x$ lines lie below $\psi(x)$ and serve as a disincentive for the HG to exercise the buyout option. Nevertheless, $(1-\delta_1)\cdot x$ maximizes Area 3 and thus gives a larger fraction of payoff to the TNOC.

3.3 THE EXPECTED PAYOFF FUNCTIONS

Define $\bar{V}_H(\delta)$ and $\bar{V}_T(\delta)$ as the HG's and TNOC's expected payoff respectively, from jointly agreeing on a buyout option with δ -sharing rule. Let $\bar{x}_H \equiv E_H(X)$ be the HG's expectation of X . From the HG's viewpoint, its expected payoff is

$$\begin{aligned} \bar{V}_H(\delta) &= E_H \text{ Max } \{ \delta \cdot X, X - \psi(X) \} \\ &= \delta \cdot \bar{x}_H + E_H \text{ Max } \{ 0, (1-\delta) \cdot X - \psi(X) \}. \\ & \dots\dots\dots(1) \end{aligned}$$

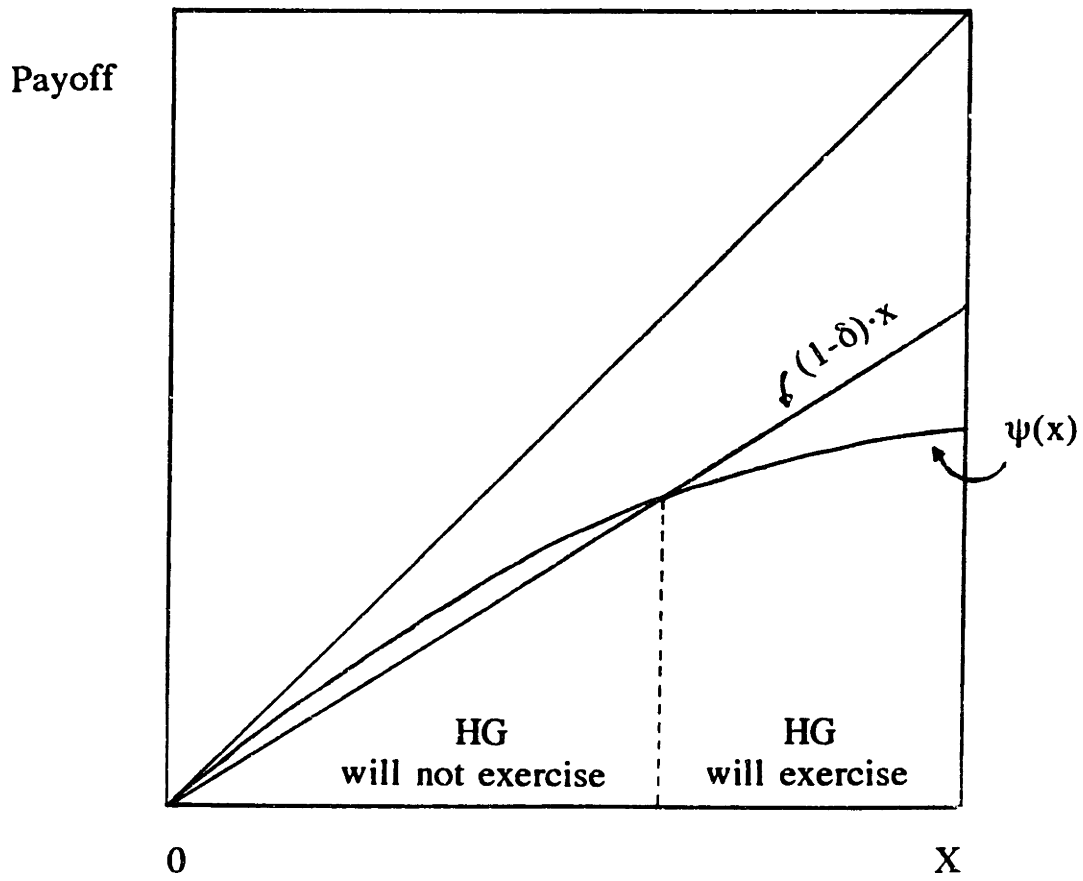


Figure 3.4 : Relationship between $(1-\delta) \cdot x$ and $\psi(x)$

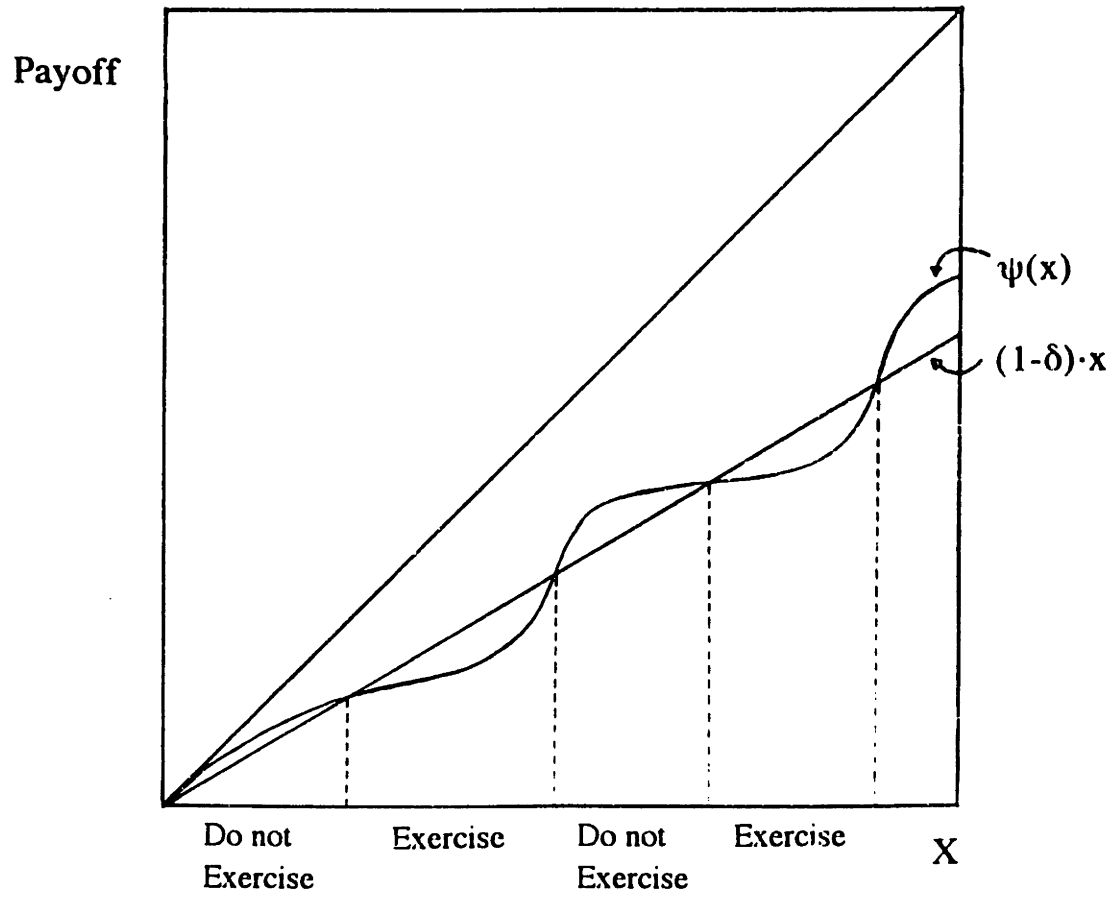


Figure 3.5 :
When will the host government exercise the buyout option?

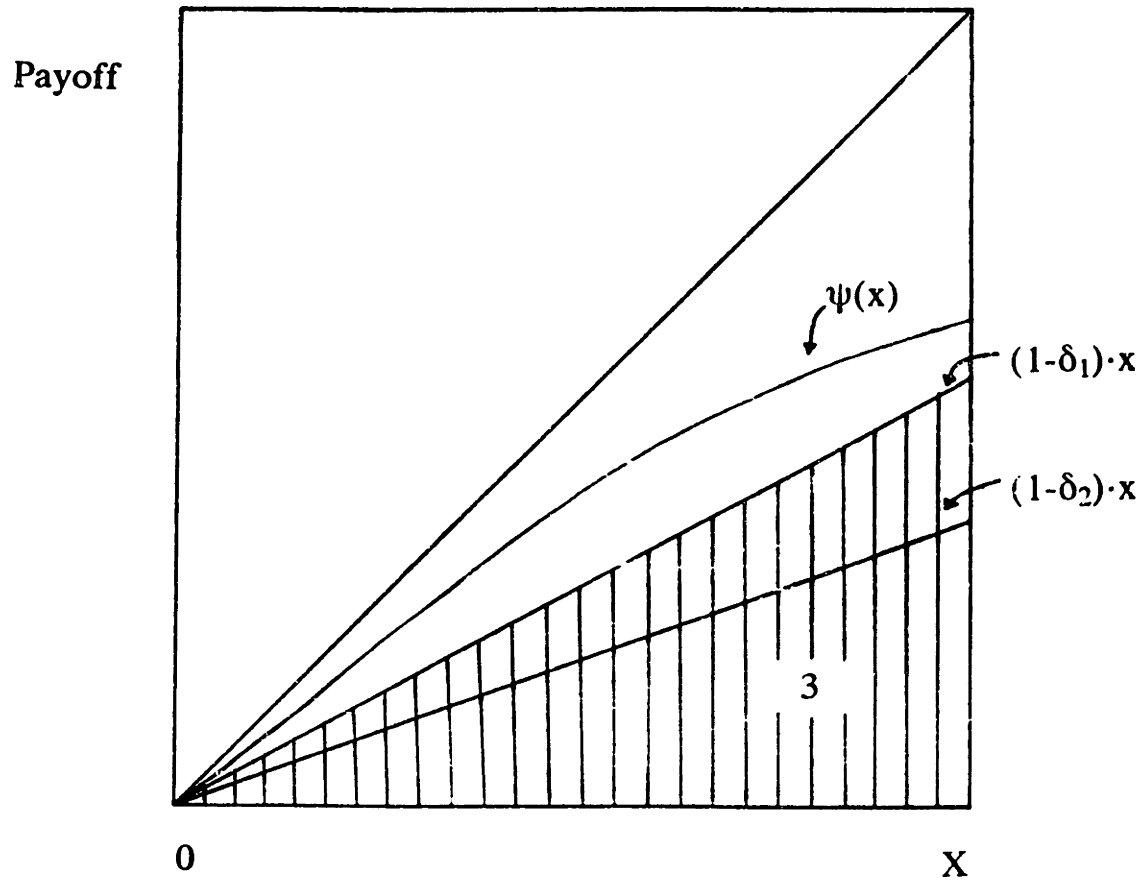


Figure 3.6 : Which δ is preferred?

Further let $\bar{x}_T \equiv E_T(X)$ denote the TNOC's expectation of X . Since $(1-\delta) \cdot x > \psi(x)$ will induce the HG to exercise the buyout option, the expected payoff to the TNOC is

$$\begin{aligned} \bar{V}_T(\delta) &= E_T \text{ Min } \{(1-\delta) \cdot X, \psi(X)\} - I_T \\ &= (1-\delta) \cdot \bar{x}_T - E_T \text{ Max } \{0, (1-\delta) \cdot X - \psi(X)\} - I_T. \end{aligned} \quad \dots\dots\dots(2)$$

Notice that if the HG and TNOC share identical assessments of X and there exists no probability of expropriation, then

$$\bar{V}_H(\delta) + \bar{V}_T(\delta) = \bar{x} - I_T. \quad \dots\dots\dots(3)$$

The following two conditions must obtain in order for an agreement on a buyout option with δ -sharing rule to be reached in the initial period:

$$\delta \cdot \bar{x}_H + E_H \text{ Max } \{0, (1-\delta) \cdot X - \psi(X)\} \geq 0 \quad \dots\dots\dots(4)$$

and

$$(1-\delta) \cdot \bar{x}_T - E_T \text{ Max } \{0, (1-\delta) \cdot X - \psi(X)\} - I_T \geq 0. \quad \dots\dots\dots(5)$$

Conditions (4) and (5) are needed to guarantee a positive return to both the HG and TNOC with respect to their expectations. If the HG demands a strictly positive expected return of at least γ , then 0 in Condition (4) is replaced by γ . If the TNOC also demands a strictly positive expected payoff of at least χ , then 0 in Condition (5) is supplanted by χ .

If X is allowed to take negative values x , then $(1-\delta)\cdot x$ is greater than $\psi(x)$ for all $x < 0$. Therefore, $E_H \text{ Max } \{0, (1-\delta)\cdot X - \psi(X)\}$ is positive for all $x < 0$. Even when \bar{x}_H is negative, it is possible that $E_H \text{ Max } \{0, (1-\delta)\cdot X - \psi(X)\}$ could exceed $\delta\cdot \bar{x}_H$; thus satisfying Condition (4). In reality, nonetheless, the HG would never enter into a contract if it anticipates that the project's expected payoff would be negative. This rationale calls for Assumption (A2)—the support of X is $[0, \infty)$.

In order to depict the relationships between the HG's expected payoff and δ and the TNOC's expected payoff and δ , properties of $\bar{V}_H(\delta)$ and $\bar{V}_T(\delta)$ must be examined in detail. Proposition 1 stipulates that $(1-\delta)\cdot x > \psi(x)$ is a necessary and sufficient condition for the HG to exercise the buyout option. Suppose that an agreement on a buyout option with δ -sharing rule is reached in the initial period. Let $x_o(\delta)$ be such that

$$(1-\delta)\cdot x_o(\delta) = \psi[x_o(\delta)]. \tag{6}$$

The function $x_o(\delta)$ is such that, conditional upon $X = x$, if $x > x_o(\delta)$ then $(1-\delta)\cdot x > \psi(x)$ and the HG will exercise the buyout option, and if $x < x_o(\delta)$ then the HG will not exercise the right to buy out the project. If $x = x_o(\delta)$ then the HG is indifferent. The number of solutions to Equation (6) for $x \in [0, \infty)$ clearly depends on properties of $x_o(\delta)$.

PROPOSITION 2 : Suppose that $\psi(x)$ is a positive concave function, monotone increasing with increasing x from $\psi(0) = 0$. Then in order for $(1-\delta)\cdot x_o(\delta) = \psi[x_o(\delta)]$ to possess a unique solution $x_o(\delta)$ in $(0, \infty)$, it is both necessary and sufficient that

$$[1 - \psi'(0)] < \delta < [1 - \psi'(\infty)].$$

Proof :

Let $q(x) \equiv (1-\delta) \cdot x - \psi(x)$ on $[0, \infty)$. At $x = 0$, $q(0) = -\psi(0)$ and $\psi(0) = 0$ so that $q(0) = 0$. As $q'(x) = (1-\delta) - \psi'(x)$ and $q''(x) = -\psi''(x)$, if $\psi(x)$ is concave on $[0, \infty)$ then $q''(x) > 0$. Since (i) $q(x)$ is convex on $[0, \infty)$ and (ii) $q(0) = 0$, $q(x) = 0$ has a unique solution in $(0, \infty)$ if and only if, (a) as $x \rightarrow 0^+$, $\lim q'(x) < 0$, or equivalently $(1-\delta) < \psi'(0)$, and (b) as $x \rightarrow \infty$, $\lim q'(x) > 0$, or equivalently $(1-\delta) > \psi'(\infty)$. It follows from (a) and (b) that $[1 - \psi'(0)] < \delta < [1 - \psi'(\infty)]$.

Q.E.D.

PROPOSITION 3 : If $\psi(x)$ is a positive concave function monotone increasing with increasing x from $\psi(0) = 0$, then

- (1) $x_0(\delta)$ is non-decreasing as δ increases; and
- (2) the buyout risk is non-increasing as δ increases.

Proof:

Let $\psi'[x_0(\delta)]$ denote the first derivative of $\psi(x)$ with respect to x evaluated at $x = x_0(\delta)$. Also let $x'_0(\delta)$ denote the first derivative of $x_0(\delta)$ with respect to δ . Equation (6) states that $x_0(\delta) = [\psi[x_0(\delta)] / (1-\delta)]$. Then

$$x'_0(\delta) = \psi[x_0(\delta)] \cdot (1-\delta)^{-2} + \{\psi'[x_0(\delta)] \cdot x'_0(\delta)\} \cdot (1-\delta)^{-1},$$

or equivalently,

$$x'_0(\delta) \cdot \{(1-\delta) - \psi'[x_0(\delta)]\} = \psi[x_0(\delta)] \cdot (1-\delta)^{-1}.$$

.....(7)

In order for a unique solution to $(1-\delta) \cdot x_0(\delta) = \psi[x_0(\delta)]$ to exist, $\psi'(\infty) < (1-\delta) < \psi'(0)$ by Proposition 2. At any point x such that $(1-\delta) - \psi'(x) < 0$, no such solution is possible. Look at the graph of $(1-\delta) \cdot x$ and

$\psi(x)$ on $[0, \infty)$. Therefore, $\psi'(x) \leq (1-\delta)$ is necessary for a solution at $x = x_o(\delta)$; thereby $x_o'(\delta) \geq 0$. We conclude that $x_o(\delta)$ is non-decreasing as δ increases.

Since the buyout risk is the probability that the HG will exercise the buyout option— $\xi_T(\delta) \equiv P\{X_T > x_o(\delta)\}$ where X is the project payoff at termination, it follows from our recently aforementioned conclusion that the buyout risk is non-increasing as δ increases.

Q.E.D.

Figure 3.7 is a visual demonstration that $x_o(\delta)$ is non-decreasing as δ increases, while Figure 3.8 portrays the buyout risk as a function of δ for choice of $F_T(x) = 1 - e^{-.05x}$ for $x \geq 0$.

We turn next to computation of expected payoffs to the HG and TNOC from choice of δ . Suppose that the HG assigns a cumulative distribution function

$$(A8) \quad F_H(x) = \text{Prob}(X_H \leq x)$$

to X_H , and that the TNOC assigns a cumulative distribution function

$$(A9) \quad F_T(x) = \text{Prob}(X_T \leq x)$$

to X_T . Further assume that

$$(A10) \quad X_H \text{ possesses a density } dF_H(x)/dx = f_H(x) \text{ with support } [0, \infty) \text{ and } X_T \text{ possesses a density } dF_T(x)/dx = f_T(x) \text{ also with support } [0, \infty).$$

Prior to observing $X = x$, the expected payoff from agreement of δ to each party is as follows: The expected payoff $\bar{V}_H(\delta)$ to the HG is

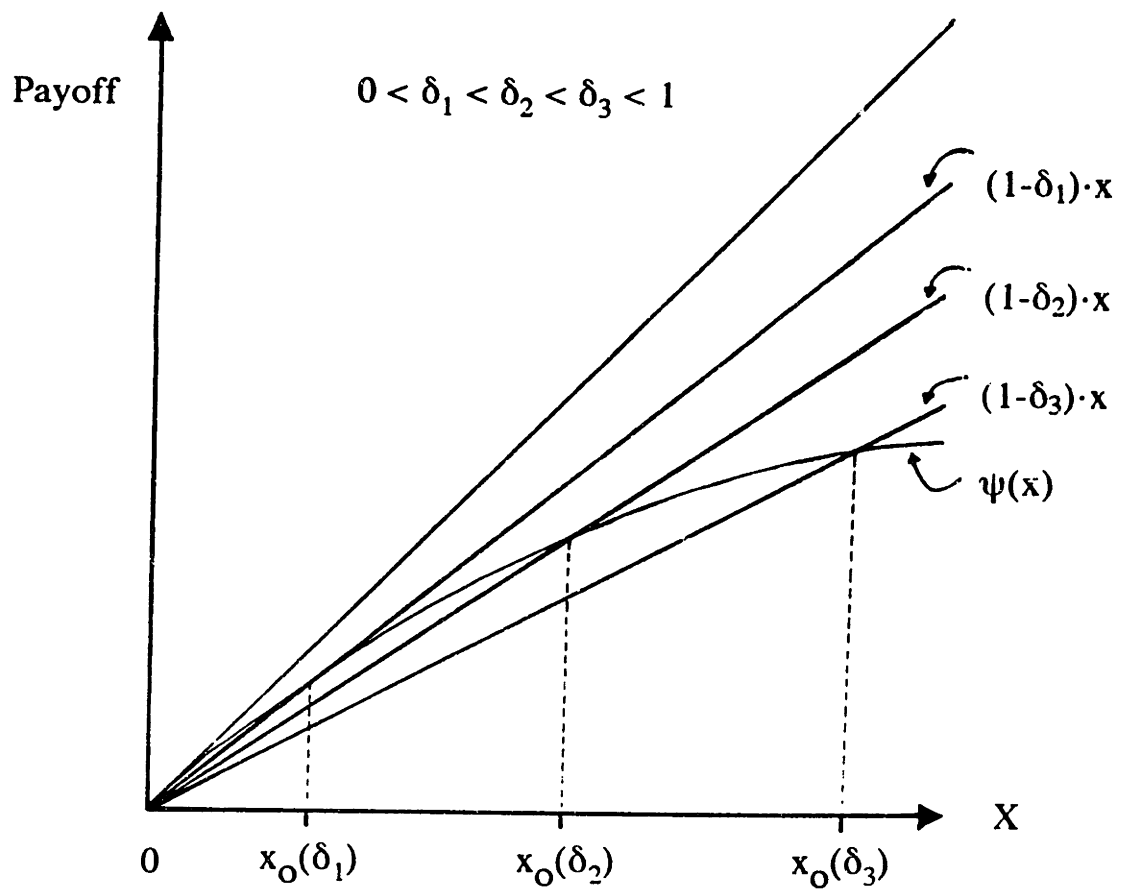


Figure 3.7 : Relationship between $x_0(\delta)$ and δ

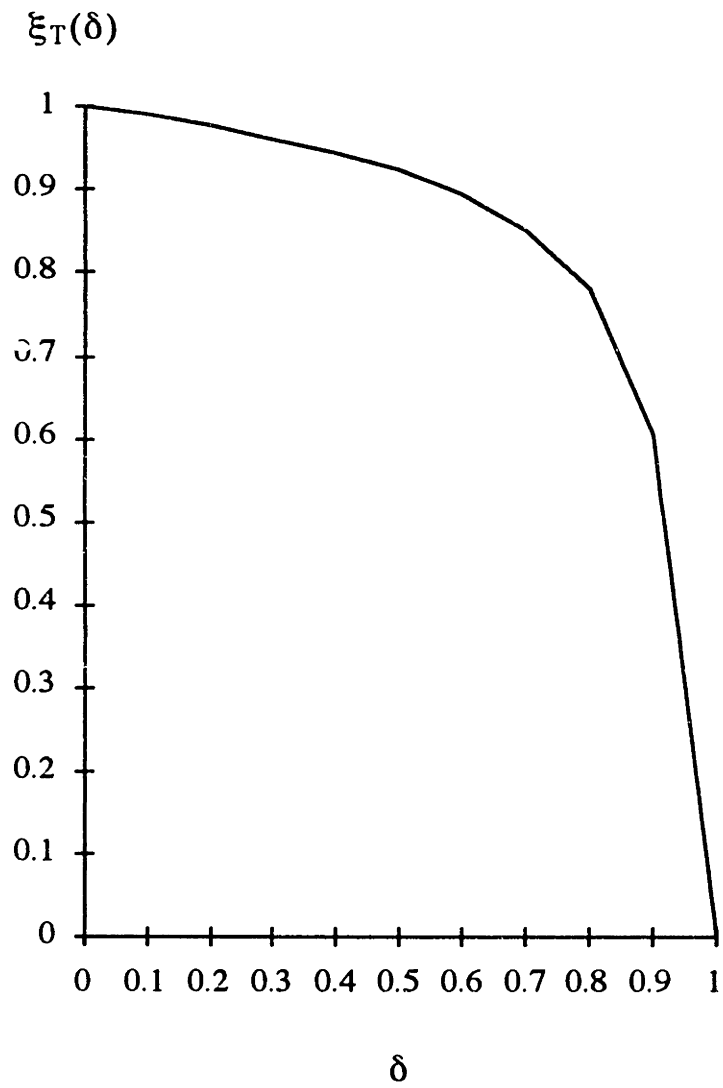


Figure 3.8 : The buyout risk as a function of δ

$$\begin{aligned} \bar{V}_H(\delta) &= \delta \int_0^{x_o(\delta)} x dF_H(x) + \int_{x_o(\delta)}^{\infty} [x - \psi(x)] dF_H(x) \\ &= \delta \cdot \bar{x}_H + \int_{x_o(\delta)}^{\infty} [(1-\delta) \cdot x - \psi(x)] dF_H(x). \end{aligned}$$

.....(8)

In addition,

$$\frac{d\bar{V}_H(\delta)}{d\delta} \equiv \bar{V}'_H(\delta) = \int_0^{x_o(\delta)} x dF_H(x)$$

.....(9)

and

$$\frac{d^2\bar{V}_H(\delta)}{d\delta^2} \equiv \bar{V}''_H(\delta) = x_o(\delta) f_H(x_o(\delta)) x'_o(\delta).$$

.....(10)

The expected payoff $\bar{V}_T(\delta)$ to the TNOC is

$$\bar{V}_T(\delta) = (1-\delta) \int_0^{x_o(\delta)} x dF_T(x) + \int_{x_o(\delta)}^{\infty} \psi(x) dF_T(x) - I_T.$$

.....(11)

Moreover,

$$\frac{d\bar{V}_T(\delta)}{d\delta} \equiv \bar{V}'_T(\delta) = - \int_0^{x_o(\delta)} x dF_T(x)$$

.....(12)

and

$$\frac{d^2\bar{V}_T(\delta)}{d\delta^2} \equiv \bar{V}''_T(\delta) = - x_o(\delta) f_T(x_o(\delta)) x'_o(\delta).$$

.....(13)

For some functions $\psi(x)$ and certain values of δ , $(1-\delta)\cdot x$ may be less than $\psi(x)$ for all $x \geq 0$. When $\psi(x)$ is concave (but not strictly concave) and monotone increasing with x , it is possible for a situation where as $x \rightarrow \infty$, $\lim \psi'(x) \geq 1-\delta$ for some values of δ to exist. We shall assume that $\psi(x)$ possesses this property. Namely,

(A11) There exists a value δ^* of δ such that $(1-\delta)\cdot x < \psi(x)$ for all $x \geq 0$ when $\delta \geq \delta^*$.

Then for $\delta \geq \delta^*$ the HG will never exercise the right to buy out the project. If $\delta < \delta^*$ there will then exist at least one interval of x values in $[0, \infty)$ in which the HG will exercise the right to buy out the project.

For future reference, Proposition 4 summarizes the characteristics of the HG's expected payoff function, whereas Proposition 5 recapitulates the properties of the TNOG's expected payoff function.

PROPOSITION 4 : The host government's expected payoff $\bar{V}_H(\delta)$ can be characterized as follows:

- (1) $\bar{V}_H(\delta)$ is convex upward on $[0, 1]$ and its slope is \bar{x}_H on $[\delta^*, 1]$;
- (2) The lower limit occurs at $\delta = 0$ and $\bar{V}_H(0) = E_H \text{Max} \{0, X - \psi(X)\}$; and
- (3) The upper limit occurs at $\delta = 1$ and $\bar{V}_H(1) = \bar{x}_H$.

Proof :

(1) Since $x_0(\delta)$ is non-decreasing as δ increases by Proposition 2, $\bar{V}_H(\delta) = \int_0^{x_0(\delta)} x dF_H(x) \geq 0$. Equation (7) indicates that $x'_0(\delta) \geq 0$ so

$\bar{V}_H''(\delta) = x_o(\delta) f_H(x_o(\delta)) x_o'(\delta) \geq 0$. Therefore, $\bar{V}_H(\delta)$ is convex upward on $[0, 1]$.

For $\delta^* \leq \delta \leq 1$, by Assumption (A11), $(1-\delta) \cdot x$ is less than $\psi(x)$ for all $x \geq 0$, implying that $x_o(\delta) = \infty$. Equation (8) thus dictates that $\bar{V}_H(\delta)$ is $\delta \cdot \bar{x}_H$; the slope of $\bar{V}_H(\delta)$ is \bar{x}_H on $[\delta^*, 1]$.

(2) Since the first derivative of $\bar{V}_H(\delta)$ is non-decreasing on $[0, \delta^*)$ as δ increases, the lower limit of $\bar{V}_H(\delta)$ must occur at $\delta = 0$. Equation (1) specifies that $\bar{V}_H(0) = E_H \text{Max} \{0, X - \psi(X)\}$.

(3) Since $\bar{V}_H(\delta)$ has slope \bar{x}_H on $[\delta^*, 1]$, it strictly increases on $\delta \in [\delta^*, 1]$; the upper limit must occur at $\delta = 1$. Equation (1) prescribes that $\bar{V}_H(1) = \bar{x}_H$.

Q.E.D.

PROPOSITION 5 : The transnational oil company's expected payoff $\bar{V}_T(\delta)$ can be characterized as follows:

- (1) $\bar{V}_T(\delta)$ is concave downward on $[0, 1]$ and its slope is $-\bar{x}_T$ on $[\delta^*, 1]$;
- (2) The lower limit occurs at $\delta = 1$ and $\bar{V}_T(1) = -I_T$; and
- (3) The upper limit occurs at $\delta = 0$ and $\bar{V}_T(0) = \bar{x}_T - E_T \text{Max} \{0, X - \psi(X)\} - I_T$.

Proof :

(1) Since $x_o(\delta)$ is non-decreasing as δ increases by Proposition 2, $\bar{V}_T'(\delta) = -\int_0^{x_o(\delta)} x dF_T(x) \leq 0$. Equation (7) indicates that $x_o'(\delta) \geq 0$ so $\bar{V}_T''(\delta) = -x_o(\delta) f_T(x_o(\delta)) x_o'(\delta) \leq 0$. Thus, $\bar{V}_T(\delta)$ is concave downward on $[0, 1]$.

For $\delta^* \leq \delta \leq 1$, by Assumption (A11), $(1-\delta) \cdot x$ is less than $\psi(x)$ for all $x \geq 0$, that is, $x_0(\delta) = \infty$. Equation (11) then prescribes that $\bar{V}_T(\delta)$ is $(1-\delta) \cdot \bar{x}_T - I_T$; the slope of $\bar{V}_T(\delta)$ is $-\bar{x}_T$ on $[\delta^*, 1]$.

(2) Since $\bar{V}_T(\delta)$ has slope $-\bar{x}_T$ on $[\delta^*, 1]$, it strictly decreases on $\delta \in [\delta^*, 1]$; the lower limit must occur at $\delta = 1$. Equation (2) specifies that $\bar{V}_T(1)$ is $-I_T$.

(3) Since the first derivative of $\bar{V}_T(\delta)$ is non-increasing on $[0, \delta^*]$ as δ increases, the upper limit of $\bar{V}_T(\delta)$ must occur at $\delta = 0$. Equation (2) indicates that $\bar{V}_T(0) = \bar{x}_T - E_T \text{Max} \{0, X - \psi(X)\} - I_T$.

Q.E.D.

The graphs of the HG's expected payoff as a function of δ and of the TNOC's expected payoff as a function of δ are portrayed in Figures 3.9, 3.10 and 3.11. Notice that in Figure 3.9, conditional on $x \in [0, \infty)$, the HG's expected payoff $\bar{V}_H(\delta)$ never takes on negative values for any δ in $[0,1]$. The worst scenario for the HG is when $x < \psi(x)$ at $\delta = 0$ and the HG receives nothing. However, this would not happen because the HG would never enter into an agreement of $\delta = 0$ at the outset.

Figure 3.10 illustrates the TNOC's expected payoff as a function of δ . Depending upon the TNOC's initial investment I_T , the relationship can be either 3.10 or 3.11. Notice that any $\delta > \delta_T$ will make the TNOC's expected payoff become negative. δ_T is thus the upper limit of δ that the TNOC is willing to agree upon in a δ -sharing agreement with a buyout option.

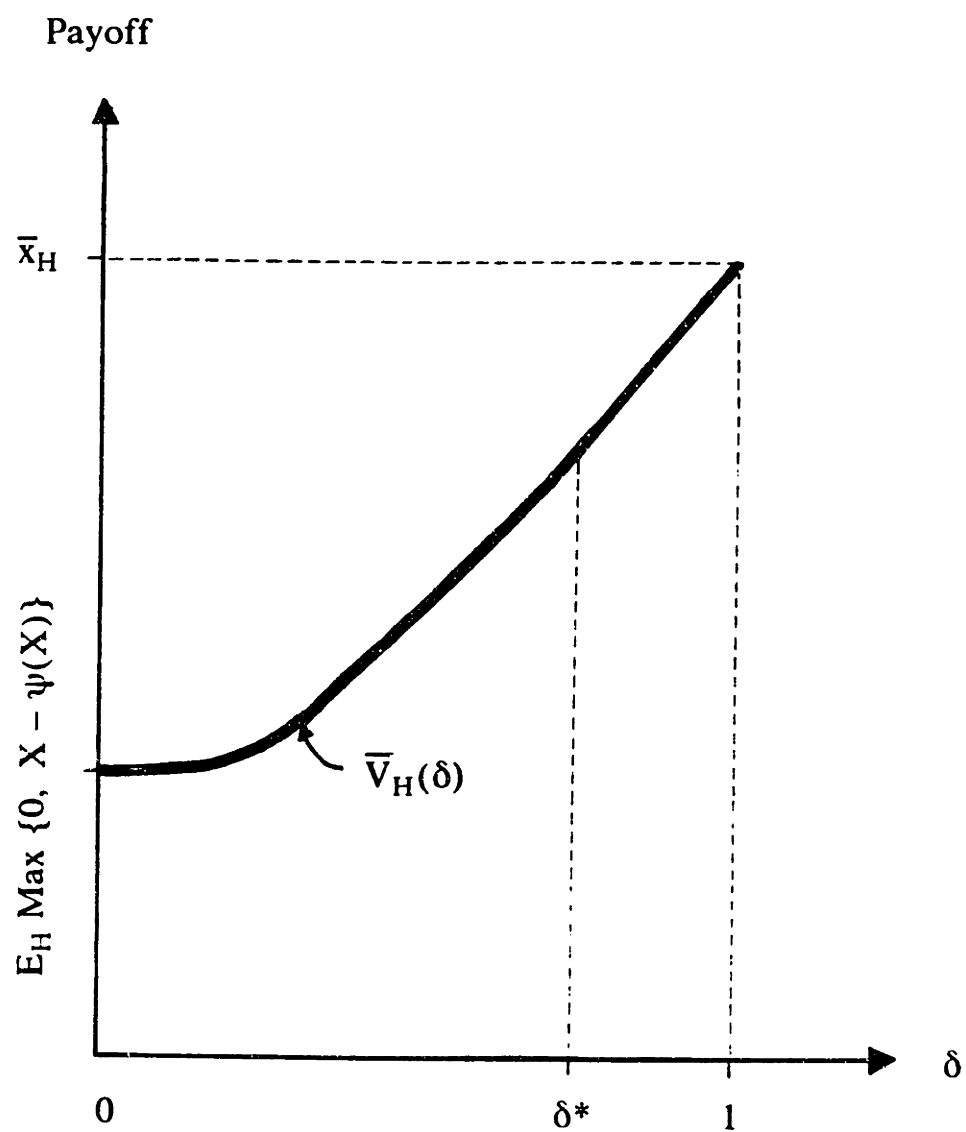


Figure 3.9 :
The host government's expected payoff as a function of δ

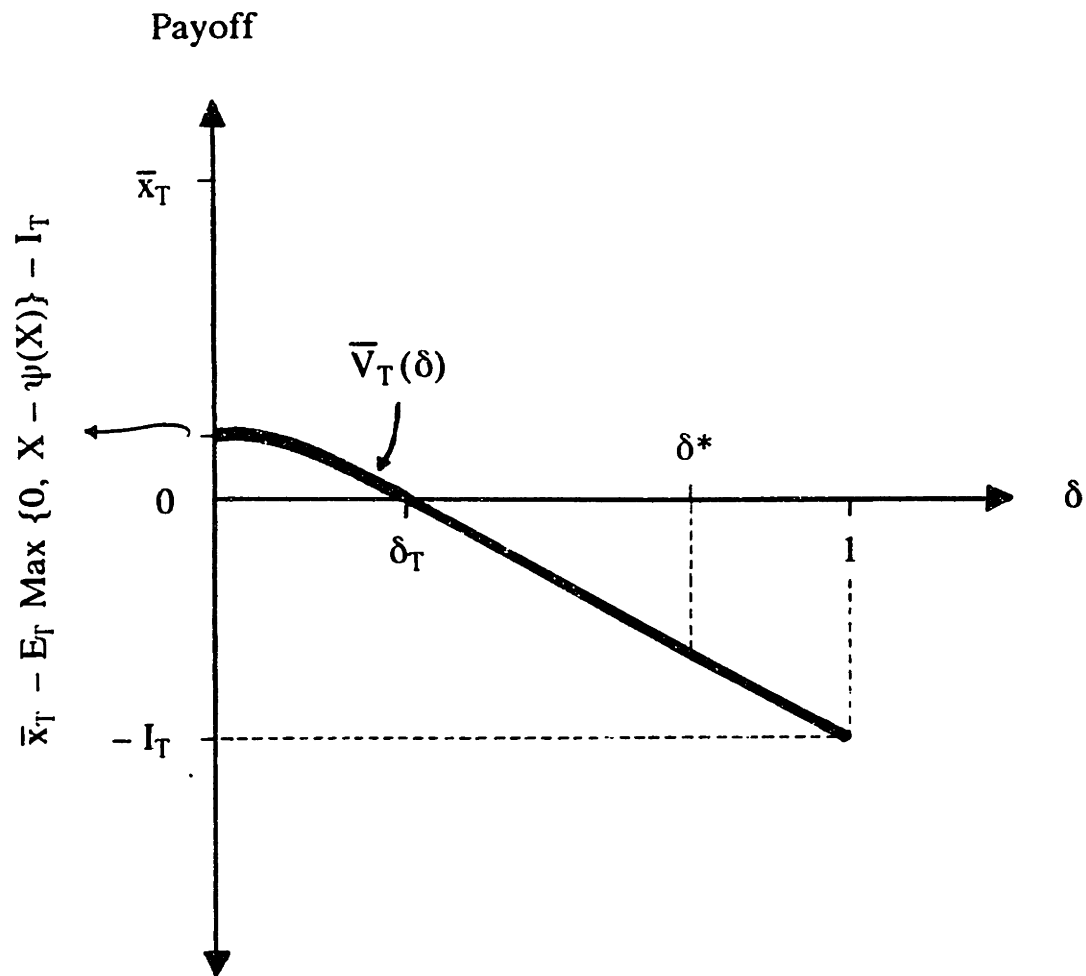


Figure 3.10 :
 The transnational oil company's expected payoff
 as a function of δ when I_T is large

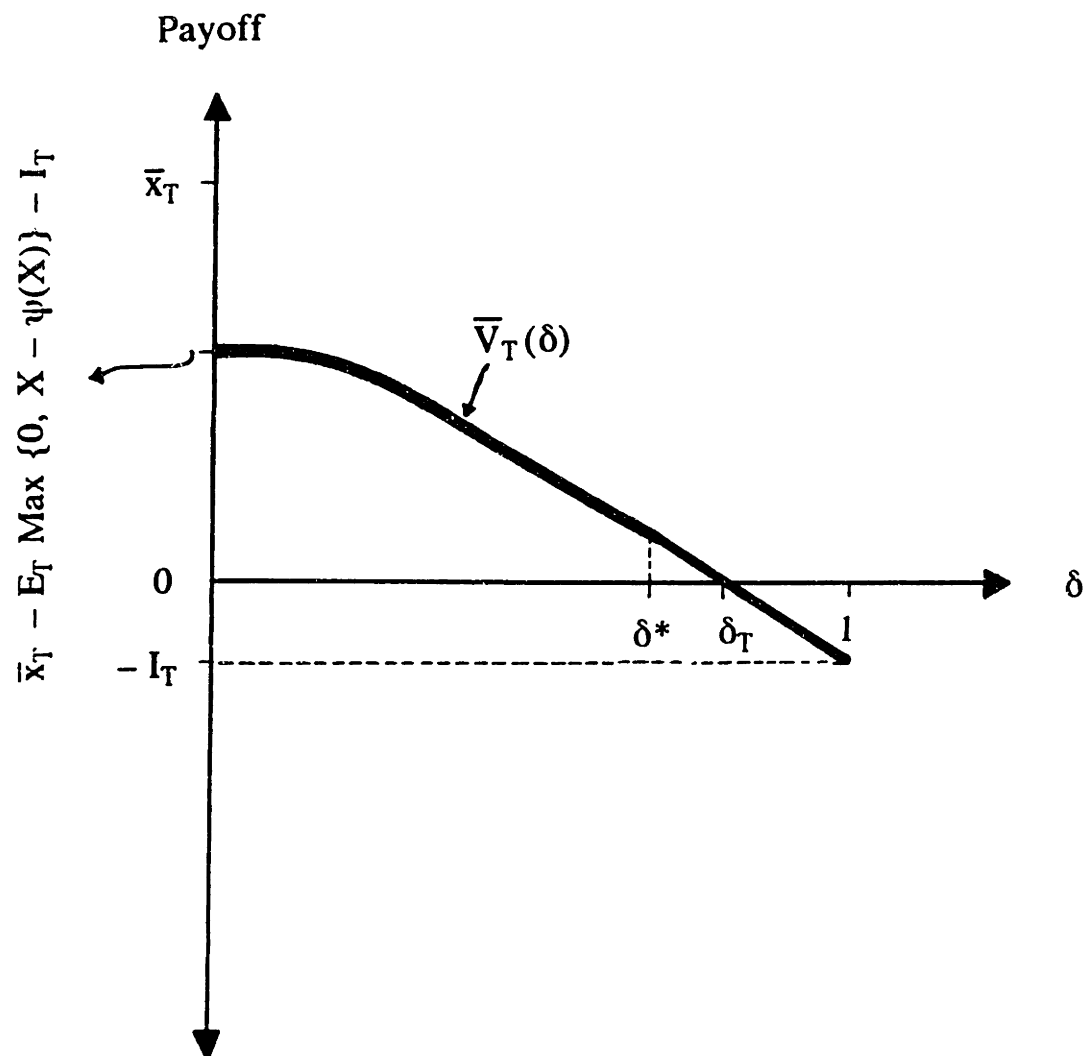


Figure 3.11 :
 The transnational oil company's expected payoff
 as a function of δ when I_T is small

If the TNOC's expected payoff turns out to be as in Figure 3.10, then there exists a chance that the HG will exercise the buyout option in the future for $\delta \leq \delta_T$. Since δ^* is known by both HG and TNOC, Figure 3.11 guarantees not only that the TNOC will receive a positive expected return from undertaking this investment project but also that the HG will never exercise the buyout option when $\delta^* \leq \delta \leq \delta_T$.

3.4 SENSITIVITY ANALYSIS

It is quite interesting to examine what happens to $\bar{V}_H(\delta)$ and $\bar{V}_T(\delta)$ when the HG and TNOC possess differing judgments about X (the project payoff at termination). Example I and Example II display the impact of differing perceptions of X on the HG's and TNOC's expected payoff for a range of values of δ , whereas Example III illustrates the impact of identical perceptions of X .

Example I :

Suppose that $F_H(x) = 1 - e^{-.05x}$ for $x \geq 0$, and

$F_T(x) = 1 - e^{-.06x}$ for $x \geq 0$.

Figure 3.12 depicts the graph of $x_0(\delta)$ as a function of δ for choice of $\psi(x) = 1 - e^{-x}$. This figure is in accordance with Proposition 2. For $I_T = 0$, the impact of differing perceptions of X on the HG's and TNOC's expected payoff from an incremental change of 0.1 in δ over the range of 0 and 1 is shown in Table 3.1.

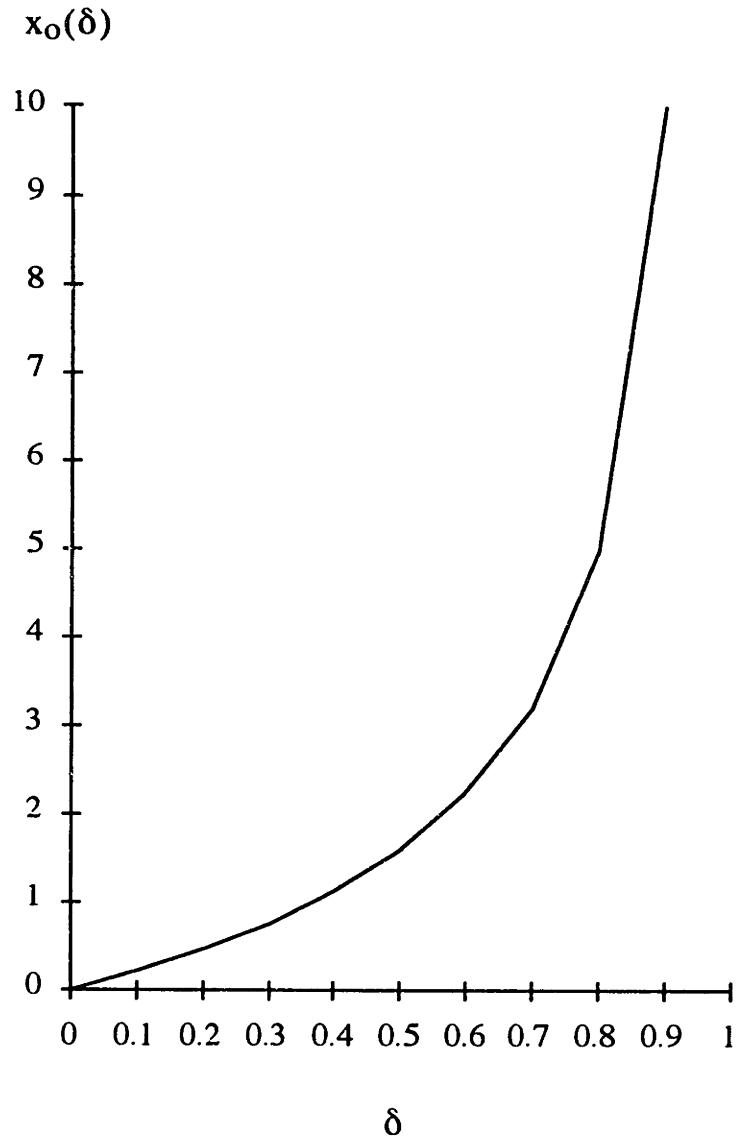


Figure 3.12 :
 $x_0(\delta)$ as a function of δ for choice of $\psi(x) = 1 - e^{-x}$, $x \geq 0$

Table 3.1 :
The expected payoffs to the HG and TNOC
for choice of $\psi(x) = 1 - e^{-x}$ and $I_T = 0$

δ	$x_0(\delta)$	$\bar{V}_H(\delta)$	$\Delta\bar{V}_H(\delta)$	$\bar{V}_T(\delta)$	$\Delta\bar{V}_T(\delta)$
0.0	0.00	19.04762	0.00004	0.94340	-0.00005
0.1	0.21	19.04766	0.00029	0.94335	-0.00034
0.2	0.46	19.04795	0.00092	0.94301	-0.00111
0.3	0.76	19.04887	0.00215	0.94190	-0.00257
0.4	1.13	19.05102	0.00440	0.93933	-0.00522
0.5	1.59	19.05542	0.00849	0.93411	-0.01006
0.6	2.23	19.06391	0.01652	0.92405	-0.01947
0.7	3.20	19.08043	0.03503	0.90458	-0.04093
0.8	4.97	19.11546	0.09760	0.86365	-0.11167
0.9	10.00	19.21306	0.78694	0.75198	-0.75198
1.0	∞	20.00000	n/a	0.00000	n/a

Example II :

This example replicates Example I but in a reverse order. Namely,

$$\begin{aligned}F_H(x) &= 1 - e^{-.06x} && \text{for } x \geq 0, \text{ and} \\F_T(x) &= 1 - e^{-.05x} && \text{for } x \geq 0.\end{aligned}$$

The impact of differing perceptions of the project payoff in the terminal period on the HG's and TNOC's expected payoff from an incremental change of 0.1 in δ over $[0, 1]$, for the same choice of $\psi(x)$ and I_T , is displayed in Table 3.2.

Example III :

$$\begin{aligned}\text{Suppose that } F_H(x) &= 1 - e^{-x} && \text{for } x \geq 0, \text{ and} \\F_T(x) &= 1 - e^{-x} && \text{for } x \geq 0.\end{aligned}$$

The impact of identical expectations of the project payoff at termination on the HG's and TNOC's expected payoff, for the same choice of $\psi(x)$ and I_T , is similarly exhibited in Table 3.3.

An analysis of impact of identical and differing perceptions of the project payoff at termination on the HG's and TNOC's expected payoff in the above three examples reveals that

(1) If the HG and TNOC share identical assessments of X (the project payoff at termination) this δ negotiation is a zero-sum game. See Equation (3) and Example III. Since $\bar{x} - I_T$ is constant, what the HG gains from an incremental change in δ is what the TNOC loses. However, if the TNOC perceives a chance of being expropriated, then this δ negotiation becomes a positive-sum game.

Table 3.2 :
The expected payoffs to the HG and TNOG
for choice of $\psi(x) = 1 - e^{-x}$ and $I_T = 0$

δ	$x_0(\delta)$	$\bar{V}_H(\delta)$	$\Delta\bar{V}_H(\delta)$	$\bar{V}_T(\delta)$	$\Delta\bar{V}_T(\delta)$
0.0	0.00	15.72327	0.00005	0.95238	-0.00004
0.1	0.21	15.72332	0.00034	0.95234	-0.00029
0.2	0.46	15.72366	0.00111	0.95205	-0.00092
0.3	0.76	15.72477	0.00256	0.95113	-0.00215
0.4	1.13	15.72733	0.00522	0.94898	-0.00440
0.5	1.59	15.73255	0.01006	0.94458	-0.00849
0.6	2.23	15.74261	0.01948	0.93609	-0.01652
0.7	3.20	15.76209	0.04092	0.91957	-0.03503
0.8	4.97	15.80301	0.11167	0.88454	-0.09760
0.9	10.00	15.91468	0.75199	0.78694	-0.78694
1.0	∞	16.66667	n/a	0.00000	n/a

Table 3.3 :
The expected payoffs to the HG and TNOG
for choice of $\psi(x) = 1 - e^{-x}$ and $I_T = 0$

δ	$x_0(\delta)$	$\bar{V}_H(\delta)$	$\Delta\bar{V}_H(\delta)$	$\bar{V}_T(\delta)$	$\Delta\bar{V}_T(\delta)$
0.0	0.00	0.50000	0.00067	0.50000	-0.00067
0.1	0.21	0.50067	0.00465	0.49933	-0.00465
0.2	0.46	0.50532	0.01253	0.49468	-0.01253
0.3	0.76	0.51785	0.02413	0.48215	-0.02413
0.4	1.13	0.54198	0.03897	0.45802	-0.03897
0.5	1.59	0.58095	0.05623	0.41905	-0.05623
0.6	2.23	0.63718	0.07425	0.36282	-0.07425
0.7	3.20	0.71143	0.08994	0.28857	-0.08994
0.8	4.97	0.80137	0.09863	0.19863	-0.09863
0.9	10.00	0.90000	0.10000	0.10000	-0.10000
1.0	∞	1.00000	n/a	0.00000	n/a

(2) If the HG and TNOC do not share identical assessments of X , this δ negotiation is not necessarily a zero-sum game. The impact of an incremental change in δ on the expected payoffs is subject to each party's judgment about the project payoff at termination.

(3) When the HG and TNOC possess differing perceptions of X , there may or may not exist a positive-sum game for some values of δ . For instance, Example I is not a positive-sum game for any value of δ in the range of 0.0 and 0.9. In contrast, for the same range of values of δ in Example II, the sum of $\Delta\bar{V}_H(\delta)$ and $\Delta\bar{V}_T(\delta)$ is positive. This may be used as a strategic basis for a distributive bargain between the HG and TNOC. In this case, the TNOC may agree upon an incremental change in δ in return for a portion of the difference between the sums of $\Delta\bar{V}_H(\delta)$ and $\Delta\bar{V}_T(\delta)$ for that value of δ .

3.5 THE STRATEGIC PRACTICE

Since the value on which γ , χ and I_T could take in Conditions (4) and (5) may vary from one situation to another, it is quite strenuous to work from $\bar{V}_H(\delta)$ and $\bar{V}_T(\delta)$ on conditions for a positive-sum bargain in a precise form. Nevertheless, we know that for an agreed-upon value of δ , $\bar{V}_H(\delta) + \bar{V}_T(\delta) > \gamma + \chi$. It is, thus, sensible to explore an alternative—a possibility of increasing the value of δ from the agreed-upon level while keeping the bargain positive-sum.

PROPOSITION 6 : For a positive-sum bargain of $\Delta\bar{V}_H(\delta)$ and $\Delta\bar{V}_T(\delta)$ to exist, the following two conditions are sufficient:

- (1) $F_T(x)$ stochastically dominates $F_H(x)$ for $x \in [0, x_o(\delta)]$; and
- (2) $\int_0^{x_o(\delta)} [F_T(x) - F_H(x)] dx > x_o(\delta) \cdot [F_T(x_o(\delta)) - F_H(x_o(\delta))]$.

Proof :

Equation (9) states that $\bar{V}'_H(\delta) = \int_0^{x_o(\delta)} x dF_H(x)$ and Equation (12) indicates that $\bar{V}'_T(\delta) = - \int_0^{x_o(\delta)} x dF_T(x)$. Since the solution $x_o(\delta)$ to Equation (6) is unique for concave $\psi(x)$, integration by parts yields

$$\bar{V}'_H(\delta) + \bar{V}'_T(\delta) = \int_0^{x_o(\delta)} [F_T(x) - F_H(x)] dx - x_o(\delta) \cdot [F_T(x_o(\delta)) - F_H(x_o(\delta))].$$

.....(14)

The first condition dictates that $F_T(x) \geq F_H(x)$ for $x \in [0, x_o(\delta)]$ ⁶, while the second condition guarantees that Equation (14) will never become negative. Consequently, the sum of $\bar{V}'_H(\delta)$ and $\bar{V}'_T(\delta)$ as in Equation (14) is positive for all values of δ ; resulting in a positive sum of $\Delta\bar{V}_H(\delta)$ and $\Delta\bar{V}_T(\delta)$.

Q.E.D.

Proposition 6 explains why some TNOCs have been observed to administer a strategy to maintain tight control over the project operations through vertical integration and by controlling its transportation channels for inputs and outputs, export markets, and technology. This strategy is a TNOC's attempt to motivate the HG to adhere to the contract in order to

⁶ Let cumulative distribution functions F and G share the same domain of support \mathcal{L} . Then F is said to stochastically dominate G if and only if for all $x \in \mathcal{L}$, $F(x) \geq G(x)$, and for some interval \mathcal{A} of positive Lebesgue measure in \mathcal{L} , $F(x) > G(x)$ for $x \in \mathcal{A}$.

receive a share of δ of the project payoff, which is larger when assessed by the HG as implied by the stochastic dominance of $F_T(x)$ over $F_H(x)$; should a buyout occur, the HG's assessment of the project value will decrease because of the TNOC's closely guard control of the project operations.

When a production-sharing contract with a buyout option dominates a traditional production-sharing contract is another interesting scheme for the HG and TNOC. Recall that the expected payoff to the HG from a traditional production-sharing contract is

$$\delta \cdot \bar{x}_H,$$

whereas the expected payoff to the HG from a production-sharing contract with a buyout option is

$$\delta \cdot \bar{x}_H + \int_{x_o(\delta)}^{\infty} [(1-\delta) \cdot x - \psi(x)] dF_H(x).$$

It is transparent that for given tax rate δ , the HG prefers to hold a buyout option because of the opportunity to receive a higher expected payoff.

Similarly, the expected payoff to the TNOC from a traditional production-sharing contract is

$$(1-q_1) \cdot (1-\delta) \cdot \bar{x}_T - I_T,$$

where q_1 denotes the subjective probability the TNOC assigns to the event that the HG expropriates the project without compensation in the absence of a buyout option. Also the expected payoff to the TNOC from a production-sharing contract with a buyout option is

$$(1-q_2) \cdot \left[(1-\delta) \int_0^{x_o(\delta)} x dF_T(x) + \int_{x_o(\delta)}^{\infty} \psi(x) dF_T(x) \right] - I_T,$$

where q_2 is the subjective probability the TNOC assigns to the event that the HG expropriates the project without compensation in the presence of a buyout option.

Let $d(\delta)$ be the value of δ for the TNOC under a traditional production-sharing contract that renders the same expected payoff for choice of δ under a production-sharing contract with a buyout option. Let $\tilde{\delta} \in [0, 1]$ be such that $d(\tilde{\delta}) = \tilde{\delta}$. If $\delta > \tilde{\delta}$ then the TNOC expected payoff from a production-sharing contract with a buyout option exceeds that from a traditional production-sharing contract, and if $\delta < \tilde{\delta}$ then the TNOC expected payoff from a production-sharing contract with a buyout option is less than that from a traditional production-sharing contract. This implies that from the TNOC's perspective, a production-sharing contract with a buyout option dominates a traditional production-sharing contract for $\delta > \tilde{\delta}$.

As a result, for any $\delta \in (\tilde{\delta}, 1]$, both the HG and TNOC prefer a production-sharing contract with a buyout option to a traditional production-sharing contract for the particular setting of q_1 , q_2 , $F_H(x)$, $F_T(x)$, and $\psi(x)$. In addition, the TNOC generally perceives that $q_1 > q_2$, thus an increase in the maximum value of the TNOC's negotiable δ that justifies a positive net present value from undertaking this investment project under a production-sharing contract with a buyout option. Although the HG sets $q_1 = q_2 = 0$, for given required minimum expected payoff, the HG can agree on a lower-or-equal-to tax rate under a production-sharing contract with a buyout option. These two impelling forces in effect broaden the zone of agreement on value of δ between the HG and TNOC.

3.6 IMPLICATIONS

This chapter develops theoretical properties in the presence of a buy-out option of a petroleum investment project with a time horizon of two periods, in which certain rules of the host government and transnational oil company behavior are postulated. The host government and transnational oil company agree in the initial period on a mediated buyout option with value of δ , interpretable as the severance tax rate that will be imposed on the project payoff in the terminal period. At termination, if the project payoff exceeds a certain value the host government will exercise the right to buy out the project. Although the probability that the host government will exercise the buyout option decreases as δ increases, the main objective of the transnational oil company is to maximize its expectation of payoff from undertaking the project—not to reduce the buyout risk; the agreed-upon δ may induce the host government to exercise the buyout option while it maximizes the transnational oil company's expected payoff.

In this two-period model with a buyout option, the negotiation on a value of δ is not necessarily a zero-sum game. The host government and transnational oil company's differing perceptions of the project payoff in the terminal period are primary determinants. Positive-sum scenarios may be used as a strategic basis for a distributive bargain between the host government and transnational oil company. This model also clarifies the transnational oil company's rationale for administering a policy of maintaining tight control over project operations.

Whether a production-sharing contract with a mediated buyout option dominates a traditional production-sharing contract depends on the following factors: the perceived probabilities of expropriation in the absence of and in the presence of a buyout option; the contracting party's assessment of the project payoff; and the mediator's function for determining the buyout value. Nevertheless, a tax range under which expected payoffs from a production-sharing contract with a buyout option are Pareto optimal from the perspective of both the host government and transnational oil company is identifiable. Moreover, the buyout option expands the zone of agreement between both parties.

CHAPTER 4

THE N-PERIOD MODEL WITH A BUYOUT OPTION

4.1 INTRODUCTION

In order to divide difficulties and set the stage for a more general analysis, a buyout option model for a petroleum investment project with a time horizon of only two periods was studied in the preceding chapter together with relationships among its variables and some propositions and strategic implications for the host government and transnational oil companies. Even the two-period model is rich in implications. In this chapter, we extend the analysis to $N \geq 3$ periods to learn more and fathom the intricacy of the real problem.

This chapter contributes a model of a petroleum investment project with a time horizon of N periods and a buyout option, in which certain behavioral assumptions of the host government and transnational oil company are posited. Fundamental properties of the expected payoff functions to the host government and transnational oil company will be studied. The cut-off value of the project payoff in each period that leads to the host government choosing to buy out the project and the issue of its uniqueness will be discussed, and an optimal policy for the host government regarding the buyout option proposed. In addition, we shall examine underlying characteristics of the buyout option, and offer strategic implications for the host governments and transnational oil company.

4.2 THE MODEL

Suppose now that a petroleum investment project has a time horizon of N periods. There are three parties involved in this contract: the host government (HG), the transnational oil company (TNO), and a mediator. The HG and TNO agree in the first period on a value of δ —the severance tax rate that the HG will impose on the TNO's future project cash flows. A buyout option is in force at the beginning of each period of the project's life. In each period to termination, the mediator determines the project's buyout value—the amount the HG has to pay the TNO upon exercising the right to buy out the project—and announces this value to the parties.⁷ The HG then decides whether or not to exercise the option.

Key assumptions in this generalized N -period model about markets and oil prices are:

- (A12) There exists no market clearing price mechanism to determine the true market value of this investment project.
- (A13) Except for oil prices, all variables determining the project's per-period cash flows in all periods are known with certainty by all parties—the HG, TNO and mediator.
- (A14) Although all parties perceive the same current oil price, they may assign differing judgments to future oil prices and consequently to future project cash flows.
- (A15) Cash flows occur at the beginning of each period other than periods N and 0 .

⁷ The mechanism by which the mediator determines the project's buyout value certainly influences the HG's and TNO's assignment of values.

(A16) The HG may exercise the buyout option only once at the beginning of each period other than periods N and 0 .

For n equal to $N, N-1, \dots, 2, 1, 0$, let P_n denote the uncertain quantity "oil price when n periods remain." If P_n takes on value p_n , then with n periods remaining

- $h_n(p_n)$ is the HG's assignment of the project's cash flow from its operations at period n , if the HG chooses to buy out the project,
- $t_n(p_n)$ is the TNOC's assignment of the project payoff at period n , before interest and tax but after depreciation,
- $\mathcal{P}_n = (p_N, p_{N-1}, \dots, p_{n+1}, p_n)$, regarded elliptically as a surrogate for the history of oil prices observed at and prior to period n ,
- $\mathfrak{P}_n = (P_{n-1}, P_{n-2}, \dots, P_2, P_1, P_0)$, regarded as the uncertain vector of future oil prices from period $n-1$ to period 0 ,
- $w_n(\mathfrak{P}_n)$ is the present value of the project from current and future cash flows at period n ,
- $\bar{w}_n(\mathcal{P}_n)$ is the expected present value of the project at period n , given history of oil prices \mathcal{P}_n .

We shall assume that throughout this generalized N -period model

(A17) The mediator perceives the buyout value as a function of $\bar{w}_n(\mathcal{P}_n)$.⁸

⁸ There are many possibilities to define a protocol for the mediator's assignment of buyout value in light of uncertain $w_n(\mathfrak{P}_n)$.

Then for a given \mathcal{P}_n , other key variables are:

- $\psi(\bar{w}_n(\mathcal{P}_n))$ is the buyout value of the project specified by the mediator.⁹
- $\bar{V}_{n-1}^*(\delta; \mathcal{P}_n)$ is the expected value at period n-1 of an optimal HG policy regarding when to exercise the right to buy out the project in the future, given tax rate δ and history of oil prices \mathcal{P}_n .
- $\xi_n(\delta; \mathcal{P}_n)$ is the buyout risk at period n, defined as the subjective probability that the TNOC assigns to the event "the HG exercises the buyout option."
- $\zeta_n(\delta; \mathcal{P}_n)$ is the TNOC's expected present value of the project from current and future cash flows, adjusted for buyout risk.
- ρ represents the discount factor on returns in the subsequent period, assuming that neither party is oil-price-risk sensitive.

At the beginning of period N, the TNOC makes an investment of I_T , which is the present value of its initial investment and future serial investments. Table 4.1 displays typical project cash flows to the HG and TNOC conditional on a buyout occurring at k periods remaining. After the HG exercises the buyout option at k periods remaining, its per-period payoffs are $h_j(p_j)$, $j = k, k-1, \dots, 1$ and zero at termination. The TNOC, on the other hand, receives a compensation $\psi(\bar{w}_k)$ at the time of buyout and nothing afterwards.

⁹ Recall that there is only one mediator and that both the host government and transnational oil company have complete knowledge about the mediator's buyout value function ψ . The shape of the buyout value function could be considered another issue for negotiation.

Table 4.1 : Distribution of cash flows between the HG and TNOG
when the buyout occurs at k periods remaining

# of Periods Remaining	HG	TNOG
N	0	$-I_T$
N-1	$\delta t_{N-1}(p_{N-1})$	$(1-\delta) t_{N-1}(p_{N-1})$
N-2	$\delta t_{N-2}(p_{N-2})$	$(1-\delta) t_{N-2}(p_{N-2})$
.	.	.
.	.	.
.	.	.
k+1	$\delta t_{k+1}(p_{k+1})$	$(1-\delta) t_{k+1}(p_{k+1})$
k	$h_k(p_k)$	$\psi(\bar{w}_k)$
k-1	$h_{k-1}(p_{k-1})$	0
.	.	.
.	.	.
.	.	.
2	$h_2(p_2)$	0
1	$h_1(p_1)$	0
0	0	0

In order to simplify analysis, we shall assume that the HG and TNOC are equally efficient at managing the project. Thus, if the HG chooses to exercise the buyout option,

$$(A18) \quad h_n(P_n) = t_n(P_n) \quad \text{for } n \text{ equal to } N-1, N-2, \dots, 2, 1.$$

Assumptions (A15) and (A16) imply that $h_0(p_0) = t_0(p_0) = h_N(p_N) = t_N(p_N) = 0$. Tables 4.2 and 4.3 tie together the two-period model and the generalized N -period model. In these tables, at 1 period remaining the mediator observes with certainty the project's final value $t_1(p_1)$ which is $\bar{w}_1(\mathcal{P}_1)$ by definition.

At the start of the project, both the HG and TNOC must negotiate agreement on a value of δ in order to activate the contract. Otherwise, no contract is in force. The respective payoffs at the outset are displayed in Figures 4.1 and 4.2. At n periods remaining for n equal to $N-1, N-2, \dots, 2, 1$, the HG must decide whether or not to exercise the buyout option given a mediator's buyout value. Payoffs to the HG and TNOC, depending on the HG's choice, are shown in Figures 4.3 and 4.4.

For n equal to $N-1, \dots, 2, 1$, other relevant assumptions are:

(A19) $\psi(\bar{w}_n(\mathcal{P}_n))$ is a nonnegative concave function monotone increasing with increasing $\bar{w}_n(\mathcal{P}_n)$, and $\psi(0) = 0$.

(A20) Once the project is terminated as a result of contract expiration, its terminal value is zero.

If both parties agree upon a value of δ when N periods remain, the HG takes no action at period N and expects to receive its share in the fol-

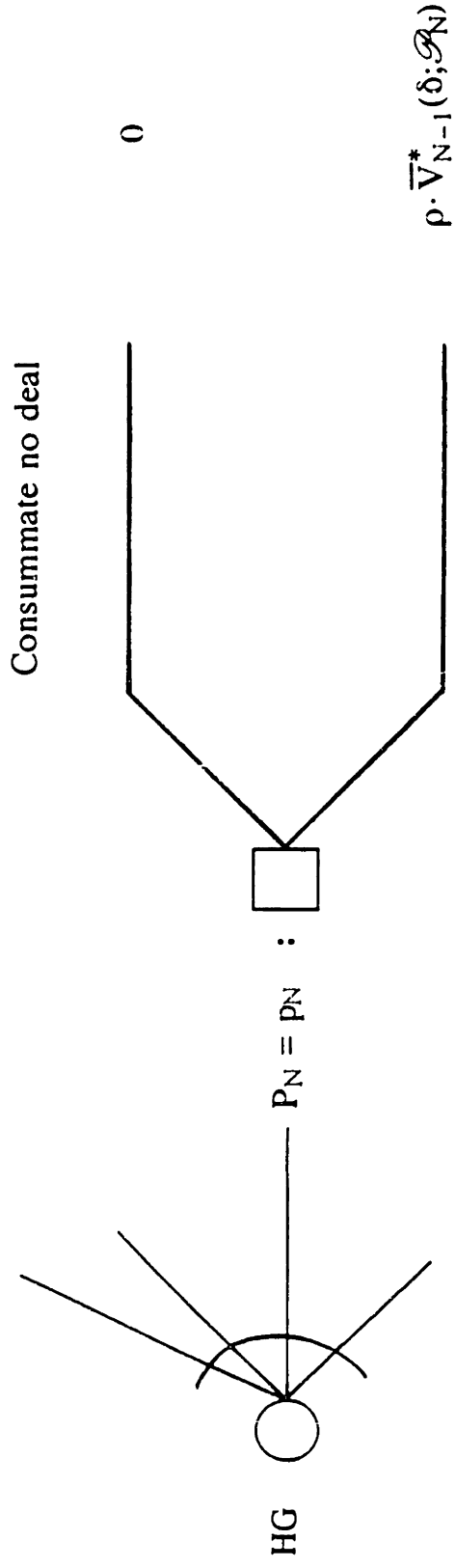
Table 4.2 : Distribution of cash flows between the HG and TNOC
in the two-period model without project buyout

# of Periods Remaining	HG	TNOC
2	0	$-I_T$
1	$\delta \cdot t_1(p_1)$	$(1-\delta) \cdot t_1(p_1)$
0	0	0

Table 4.3 : Distribution of cash flows between the HG and TNOC
in the two-period model with project buyout

# of Periods Remaining	HG	TNOC
2	0	$-I_T$
1	$t_1(p_1) - \psi(t_1(p_1))$	$\psi(t_1(p_1))$
0	0	0

PAYOFF



Agree on δ -sharing rule
 with buyout option and mediation

Figure 4.1 : The HG's decision node when N periods remain

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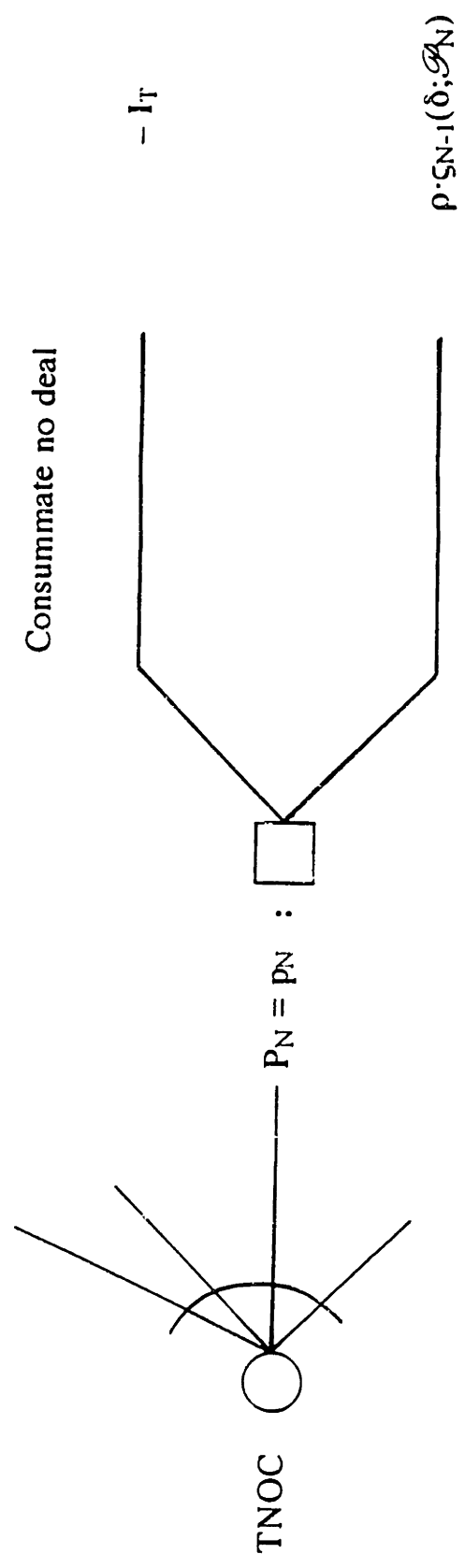


Figure 4.2 : The TNOC's decision node when N periods remain

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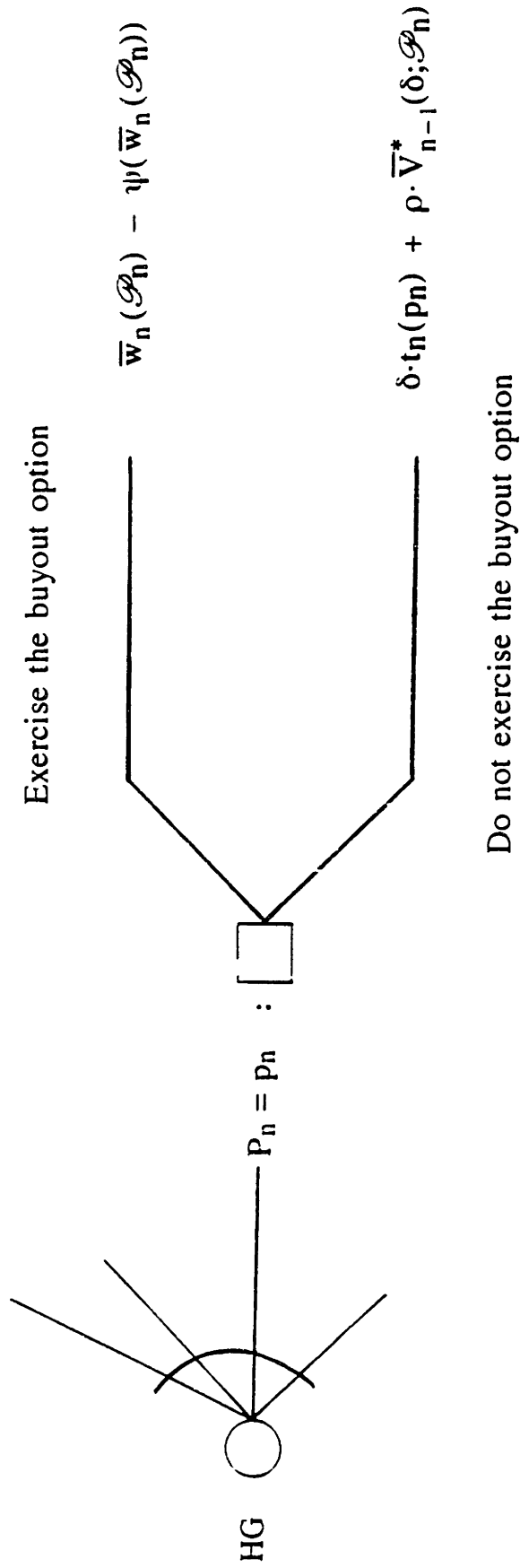


Figure 4.3 : The HG's decision node when n periods remain for $n = N-1, N-2, \dots, 2, 1$

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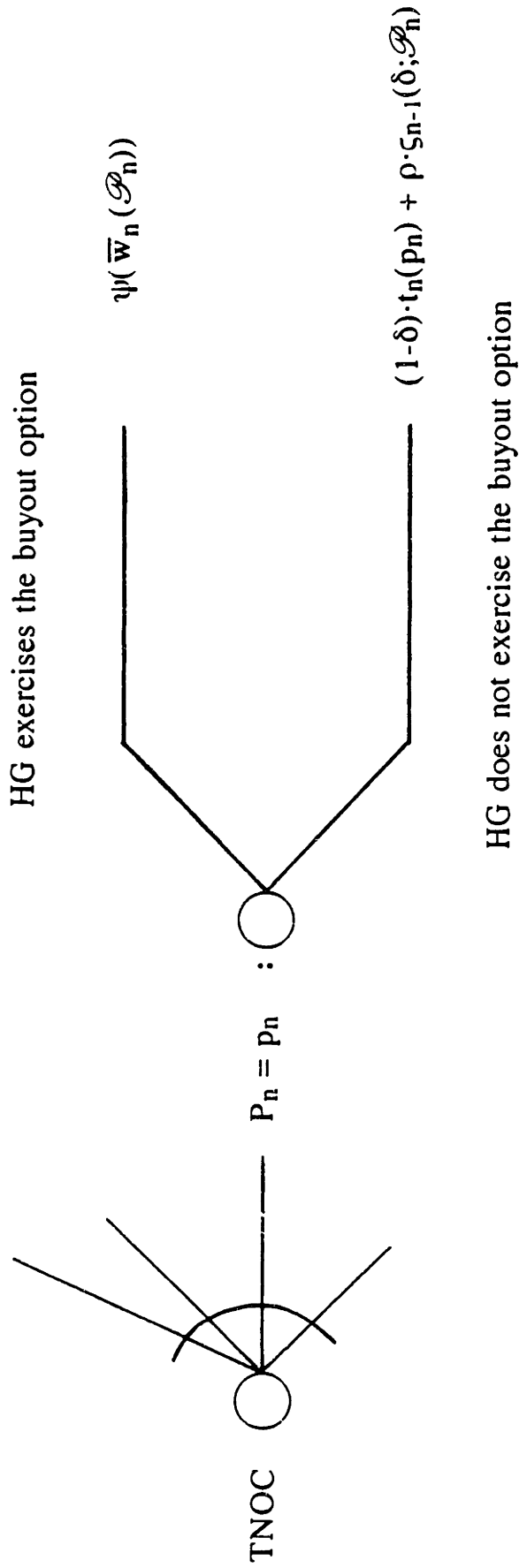


Figure 4.4 : The lottery faced by the TNOC when n periods remain for $n = N-1, N-2, \dots, 2, 1$

lowing periods. Common sense dictates that if there exists a gain for the HG to buy out at the outset of the project then there would be no need to sign such a contract. Consequently, a dynamic programming for valuation of an optimal HG strategy with respect to future policies at period N when $P_N = p_N$ begins with

$$\bar{V}_N^*(\delta; \mathcal{P}_N) = \rho \cdot \bar{V}_{N-1}^*(\delta; \mathcal{P}_N). \tag{15}$$

Since no decision beyond negotiating a value of δ is made at period N, Equation (15) does not include a choice of buyout or not.

We shall further assume that

(A21) Initially, δ is not re-negotiable.

The HG, therefore, chooses δ at period N to maximize $\bar{V}_N^*(\delta; \mathcal{P}_N)$. Before specifying conditions for choice of δ , we shall analyze the problem assuming that δ is a fixed fraction.

At the beginning of period n, for n equal to N-1, N-2, ... , 2, 1, given the history of oil prices \mathcal{P}_n , the expected value to the HG of buying out the project is

$$\bar{w}_n(\mathcal{P}_n) - \psi(\bar{w}_n(\mathcal{P}_n)). \tag{16}$$

The expected value to the HG of continuing the contract must incorporate the value of an option to buy out the project at a future date. Thus, the expected value to the HG of continuing the contract with a negotiated severance tax rate of δ is

$$\delta \cdot t_n(p_n) + \rho \cdot \bar{V}_{n-1}^*(\delta; \mathcal{P}_n).$$

.....(17)

The Principle of Optimality together with (16) and (17) yield a dynamic programming equation for valuation of an optimal HG policy at period n, for n equal to N-1, N-2, ... , 2, 1:

$$\bar{V}_n^*(\delta; \mathcal{P}_n) = \text{Max} \{ \bar{w}_n(\mathcal{P}_n) - \psi(\bar{w}_n(\mathcal{P}_n)), \delta \cdot t_n(p_n) + \rho \cdot \bar{V}_{n-1}^*(\delta; \mathcal{P}_n) \}.$$

.....(18)

Regardless of oil price p_0 , Assumption (A20) states that the HG assumes zero salvage value for the project at termination, namely, $\bar{w}_0(\mathcal{P}_0) = 0$. Therefore, by Assumptions (A15) and (A19), $\bar{V}_0^*(\mathcal{P}_0) = 0$. If the HG believes that there is a positive salvage value ε for the project, then 0 will be replaced by ε .

Boundary conditions for the dynamic programming equations (15) and (18) are

$$\bar{V}_0^*(\delta; \mathcal{P}_0) = 0, \quad \forall \delta \text{ and } \forall \mathcal{P}_0;$$

.....(19)

Equations (18) and (19) thus yield

$$\bar{V}_1^*(\delta; \mathcal{P}_1) = \text{Max} \{ \bar{w}_1(\mathcal{P}_1) - \psi(\bar{w}_1(\mathcal{P}_1)), \delta \cdot t_1(p_1) \}.$$

.....(20)

The behavior of $\bar{w}_n(\mathcal{P}_n)$ as history of oil prices evolves is a principal factor in determining the HG's optimal policy. Therefore, it is sensible to explore properties of $\bar{w}_n(\mathcal{P}_n)$. We shall suppose that $t_n(p_n)$ is perceived by all three parties to the contract as:

$$t_n(p_n) = p_n \cdot q_n, \quad \dots\dots\dots(21)$$

where q_n is the amount of oil produced in barrels at period n . Specifically, for a 30-year investment project,

$$\begin{aligned} q_n &= \int_{n-1}^n e^{-\beta(30-t)} dt \\ &= \left[\frac{1 - e^{-\beta}}{\beta} \right] \cdot e^{-\beta(30-n)}. \end{aligned} \quad \dots\dots\dots(22)$$

Here we simplify the production profile by assuming exponential decline, as is conventional among petroleum engineers.

Furthermore, oil prices are governed by the following equation:

$$P_j = \alpha \cdot P_{j+1} + \mu + \varepsilon_j; \quad |\alpha| < 1, \quad \dots\dots\dots(23)$$

where ε_j 's are independently and normally distributed around mean 0 and known variance σ^2 , and α and μ are taken to be nonstochastic. At time of negotiation—period N , oil price p_N is observed and Equation (23) yields

$$E[P_j | \mathcal{P}_N] = \alpha^{N-j} \cdot p_N + \mu \cdot \sum_{k=0}^{N-j-1} \alpha^k \quad \dots\dots\dots(24)$$

for j equal to $N-1, N-2, \dots, 1, 0$. For simplicity, we shall assume that

$$p_N = \mu \cdot (1-\alpha)^{-1}. \quad \dots\dots\dots(25)$$

Then for $|\alpha| < 1$, Equation (24) is tantamount to

$$E[P_j | \mathcal{P}_N] = p_N \quad \text{for } j = N-1, N-2, \dots, 1, 0. \quad \dots\dots\dots(26)$$

Equations (21) and (26) imply that for n equal to $N-1, N-2, \dots, 2, 1$:

$$\begin{aligned} \bar{w}_n(\mathcal{P}_n) &= p_N \cdot \left[\frac{1 - e^{-\beta}}{\beta} \right] \cdot e^{-\beta(30-n)} \cdot \sum_{j=1}^n (\rho e^{-\beta})^{n-j} \\ &= p_N \cdot \left[\frac{1 - e^{-\beta}}{\beta} \right] \cdot e^{-\beta(30-n)} \cdot \left[\frac{1 - (\rho e^{-\beta})^{n+1}}{1 - \rho e^{-\beta}} - (\rho e^{-\beta})^n \right]. \end{aligned} \quad \dots\dots\dots(27)$$

For choice of $\beta = .1$, the relationship between $\bar{w}_n(\mathcal{P}_n)$ and n is portrayed in Figure 4.5. This figure has an analogue to exponential production decline—Given Equations (21), (22), (23), and (25), $\bar{w}_n(\mathcal{P}_n)$ decreases exponentially as n decreases.

In addition, we know that $\bar{w}_n(\mathcal{P}_n)$, for n equal to $N-1, N-2, \dots, 2, 1$, are determined by the following relations:

$$\bar{w}_n(\mathcal{P}_n) = t_n(p_n) + \rho \cdot \bar{w}_{n-1}(\mathcal{P}_n), \quad \dots\dots\dots(28)$$

where boundary conditions are

$$\bar{w}_0(\mathcal{P}_0) = 0 \quad \dots\dots\dots(29)$$

and

Expected Present Value
of the Project

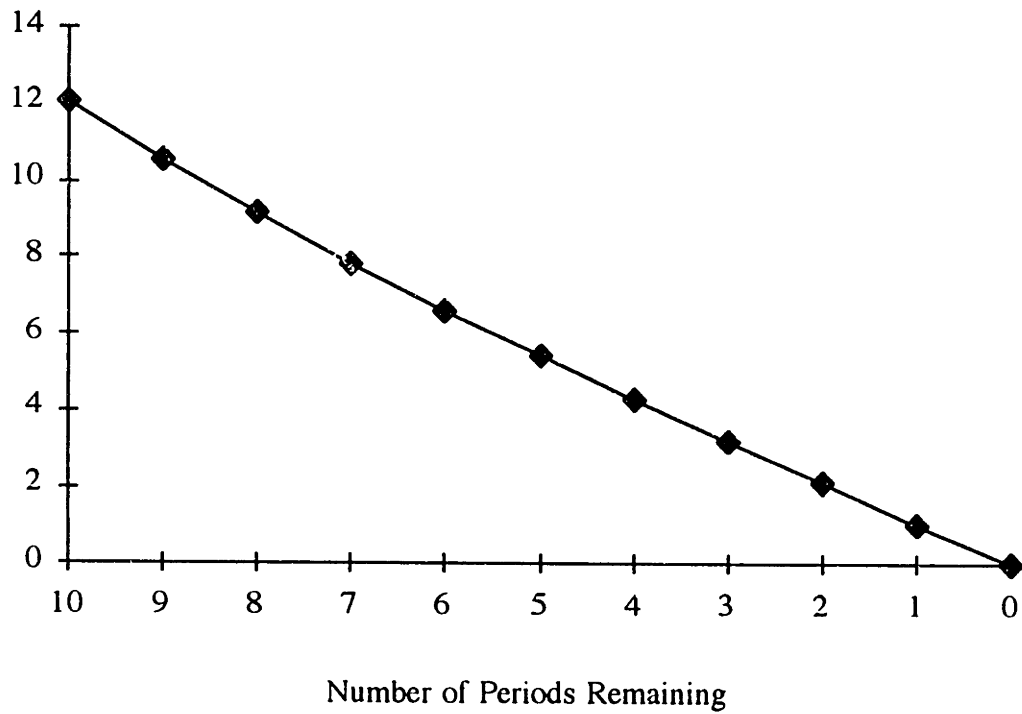


Figure 4.5 :
Relationship between $\bar{w}_n(\mathcal{P}_n)$ and n

$$\bar{w}_N(\mathcal{P}_N) = \rho \cdot \bar{w}_{N-1}(\mathcal{P}_N). \tag{30}$$

Figure 4.6 displays that $\bar{w}_n(\mathcal{P}_n)$ is independent of δ as indicated by Equations (28), (29), and (30).

4.3 THE HOST GOVERNMENT OPTIMAL POLICY

In this generalized N-period model with a buyout option, the HG encounters the dynamic programming equations (15) and (18) and boundary conditions (19). Recall the relationship between $\bar{w}_n(\mathcal{P}_n)$ and $\bar{w}_{n-1}(\mathcal{P}_n)$ as in Equation (28):

$$\bar{w}_n(\mathcal{P}_n) = t_n(p_n) + \rho \cdot \bar{w}_{n-1}(\mathcal{P}_n).$$

Therefore, Equation (18) can be rewritten as

$$\begin{aligned} \bar{V}_n^*(\delta; \mathcal{P}_n) = \text{Max} \{ & \bar{w}_n(\mathcal{P}_n) - \psi(\bar{w}_n(\mathcal{P}_n)), \\ & \delta \cdot \bar{w}_n(\mathcal{P}_n) - \delta \cdot \rho \cdot \bar{w}_{n-1}(\mathcal{P}_n) + \rho \cdot \bar{V}_{n-1}^*(\delta; \mathcal{P}_n) \}, \end{aligned}$$

or equivalently,

$$\begin{aligned} \bar{V}_n^*(\delta; \mathcal{P}_n) = & \delta \cdot \bar{w}_n(\mathcal{P}_n) + \\ & \text{Max} \{ (1-\delta) \cdot \bar{w}_n(\mathcal{P}_n) - \psi(\bar{w}_n(\mathcal{P}_n)), \\ & \rho \cdot [\bar{V}_{n-1}^*(\delta; \mathcal{P}_n) - \delta \cdot \bar{w}_{n-1}(\mathcal{P}_n)] \}. \end{aligned} \tag{31}$$

Here $\delta \cdot \bar{w}_n(\mathcal{P}_n)$ is the expected value to the HG at period n of continuing the contract to termination at a negotiated severance tax rate of δ in a standard production-sharing contract with no buyout option. Moreover, $\rho \cdot [\bar{V}_{n-1}^*(\delta; \mathcal{P}_n) - \delta \cdot \bar{w}_{n-1}(\mathcal{P}_n)]$ is interpretable as the expected value to the

$$\bar{w}_n(\mathcal{P}_n) = t_n(p_n) + \rho \cdot \bar{w}_{n-1}(\mathcal{P}_n)$$

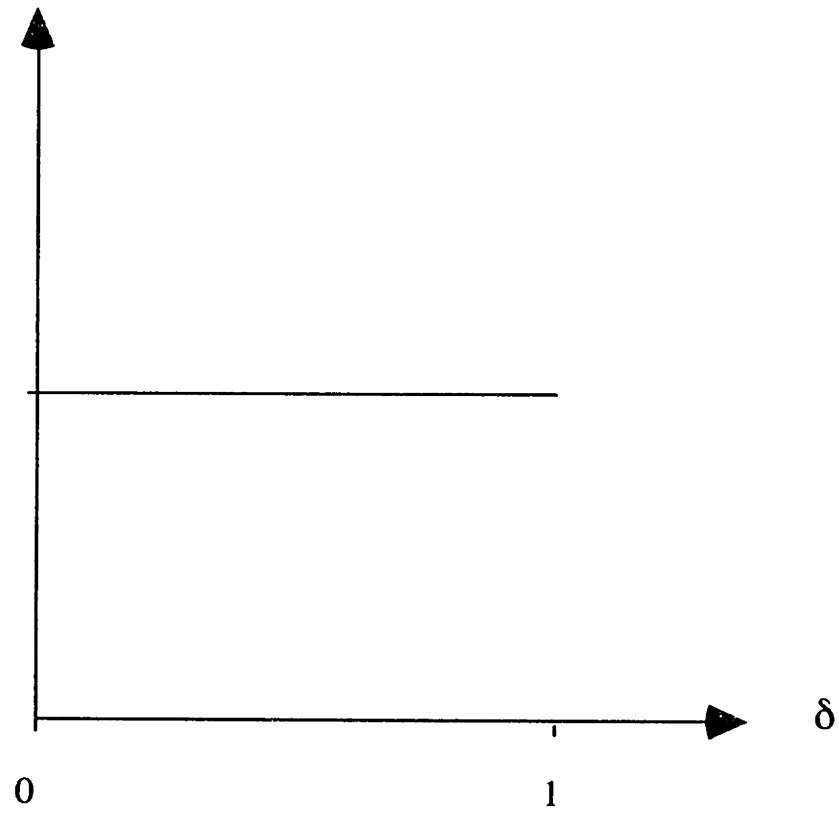


Figure 4.6 : Relationship between $\bar{w}_n(\mathcal{P}_n)$ and δ

HG at period n of possessing a buyout option at period $n-1$. We shall later examine underlying characteristics of the buyout option and its value.

Equation (31) prescribes that, for given \mathcal{P}_h , the HG's optimal policy at period n , where n may equal $N-1, N-2, \dots, 2, 1$, is as follows:

- (1) if $(1-\delta)\bar{w}_n(\mathcal{P}_n) - \psi(\bar{w}_n(\mathcal{P}_n)) > \rho \cdot [\bar{V}_{n-1}^*(\delta; \mathcal{P}_n) - \delta \cdot \bar{w}_{n-1}(\mathcal{P}_h)]$
then the HG will choose to buy out the project,
- (2) if $(1-\delta)\bar{w}_n(\mathcal{P}_n) - \psi(\bar{w}_n(\mathcal{P}_n)) < \rho \cdot [\bar{V}_{n-1}^*(\delta; \mathcal{P}_n) - \delta \cdot \bar{w}_{n-1}(\mathcal{P}_h)]$
then the HG will choose to continue the contract, and
- (3) if $(1-\delta)\bar{w}_n(\mathcal{P}_n) - \psi(\bar{w}_n(\mathcal{P}_n)) = \rho \cdot [\bar{V}_{n-1}^*(\delta; \mathcal{P}_n) - \delta \cdot \bar{w}_{n-1}(\mathcal{P}_h)]$
then the HG will be indifferent between project buyout and contract continuation.

Equation (20) implies that the HG will exercise the buyout option at period 1 if and only if

$$\bar{w}_1(\mathcal{P}_1) - \psi(\bar{w}_1(\mathcal{P}_1)) > \delta \cdot t_1(p_1), \tag{32}$$

or equivalently,

$$\bar{w}_1(\mathcal{P}_1) - \psi(\bar{w}_1(\mathcal{P}_1)) > \delta \cdot \bar{w}_1(\mathcal{P}_1). \tag{33}$$

Further let $\bar{w}_1^* \equiv \bar{w}_1^*(\delta; \mathcal{P}_1)$ be a project's present value at period 1 such that

$$\bar{w}_1^* - \psi(\bar{w}_1^*) = \delta \cdot \bar{w}_1^*. \tag{34}$$

Equation (34) thus implies the uniqueness of \bar{w}_1^* in Proposition 7, which is the same as Proposition 2 in the two-period model. A solution \bar{w}_1^* is such that if $\bar{w}_1(\mathcal{P}_1) > \bar{w}_1^*$ then $\bar{w}_1^* - \psi(\bar{w}_1^*) > \delta \cdot \bar{w}_1^*$ and the HG will exercise the right to buy out the project, and if $\bar{w}_1(\mathcal{P}_1) < \bar{w}_1^*$ then the HG will not exercise the buyout option. If $\bar{w}_1(\mathcal{P}_1) = \bar{w}_1^*$ then the HG is indifferent.

PROPOSITION 7 : For concave $\psi(x)$ increasing with increasing x from $\psi(0) = 0$, in order for $\bar{w}_1(\mathcal{P}_1) - \psi(\bar{w}_1(\mathcal{P}_1)) = \delta \cdot \bar{w}_1(\mathcal{P}_1)$ to possess a unique solution in $(0, \infty)$, it is both necessary and sufficient that

$$[1 - \psi'(0)] < \delta < [1 - \psi'(\infty)].$$

Proof :

Same as that of Proposition 2.

Q.E.D.

We now turn next to period n where $n > 1$. Let $\bar{w}_n^* \equiv \bar{w}_n^*(\delta; \mathcal{P}_n)$ be a project's present value at period n , for n equal 2, 3, ... , $N-2$, $N-1$, such that

$$\bar{w}_n^* - \psi(\bar{w}_n^*) = \delta \cdot t_n(p_n) + \rho \cdot \bar{V}_{n-1}^*(\delta; \mathcal{P}_n) \dots\dots\dots(35)$$

PROPOSITION 8 : For concave $\psi(x)$ increasing with increasing x from $\psi(0) = 0$, in order for $\bar{w}_n(\mathcal{P}_n) - \psi(\bar{w}_n(\mathcal{P}_n)) = \delta \cdot t_n(p_n) + \rho \cdot \bar{V}_{n-1}^*(\delta; \mathcal{P}_n)$ to possess a unique solution in $(0, \infty)$, it is both necessary and sufficient that

$$[1 - \psi'(0)] < \delta < [1 - \psi'(\infty)].$$

Proof :

For $n = 1$, Proposition 7 says that it is both necessary and sufficient that $[1 - \psi'(0)] < \delta < [1 - \psi'(\infty)]$ in order for $\bar{w}_1(\mathcal{P}_1) - \psi(\bar{w}_1(\mathcal{P}_1)) = \delta \cdot \bar{w}_1(\mathcal{P}_1)$ to possess a unique solution \bar{w}_1^* in $(0, \infty)$. Now suppose that \bar{w}_{n-1}^* is unique for the same range of δ . Then we need to demonstrate that \bar{w}_n^* is also unique. The Principle of Optimality tells the HG at period n to choose the act corresponding to

$$\text{Max} \{ \bar{w}_n(\mathcal{P}_n) - \psi(\bar{w}_n(\mathcal{P}_n)), \delta \cdot t_n(p_n) + \rho \cdot \bar{V}_{n-1}^*(\delta; \mathcal{P}_n) \}.$$

Given unique \bar{w}_{n-1}^* , there are two possible cases:

(1) If $\bar{w}_{n-1}(\mathcal{P}_{n-1}) \leq \bar{w}_{n-1}^*$, then the payoff to the HG at period $n-1$ is $\delta \cdot \bar{w}_{n-1}(\mathcal{P}_{n-1})$. Therefore, the HG chooses at period n the act that

$$\text{Max} \{ \bar{w}_n(\mathcal{P}_n) - \psi(\bar{w}_n(\mathcal{P}_n)), \delta \cdot t_n(p_n) + \rho \cdot \delta \cdot \bar{w}_{n-1}(\mathcal{P}_{n-1}) \},$$

or equivalently,

$$\text{Max} \{ \bar{w}_n(\mathcal{P}_n) - \psi(\bar{w}_n(\mathcal{P}_n)), \delta \cdot \bar{w}_n(\mathcal{P}_n) \}$$

since Equation (28) states that $\bar{w}_n(\mathcal{P}_n) = t_n(p_n) + \rho \cdot \bar{w}_{n-1}(\mathcal{P}_{n-1})$. This is the same as the problem at period 1. Thus, we conclude that \bar{w}_n^* is unique.

(2) If $\bar{w}_{n-1}(\mathcal{P}_{n-1}) > \bar{w}_{n-1}^*$, it implies that the HG will exercise the buyout option at period $n-1$. The payoff to the HG at period n if the buyout option continues to be held is

$$\delta \cdot t_n(p_n) + \rho \cdot [\bar{w}_{n-1}(\mathcal{P}_{n-1}) - \psi(\bar{w}_{n-1}(\mathcal{P}_{n-1}))],$$

or equivalently, by Equation (28),

$$\delta \cdot t_n(p_n) + \rho \cdot [t_{n-1}(p_{n-1}) + \rho \cdot \bar{w}_{n-2}(\mathcal{P}_{n-2}) - \psi(\bar{w}_{n-1}(\mathcal{P}_{n-1}))].$$

This is tantamount to

$$\delta \cdot \bar{w}_n(\mathcal{P}_n) + C,$$

where $C = \rho \cdot [(1-\delta) \cdot t_{n-1}(p_{n-1}) + (1-\delta) \cdot \rho \cdot \bar{w}_{n-2}(\mathcal{P}_{n-2}) - \psi(\bar{w}_{n-1}(\mathcal{P}_{n-1}))]$.

Hence, the HG chooses at period n the act corresponding to

$$\text{Max } \{ \bar{w}_n(\mathcal{P}_n) - \psi(\bar{w}_n(\mathcal{P}_n)), \delta \cdot \bar{w}_n(\mathcal{P}_n) + C \}.$$

Since $C = \rho \cdot [(1-\delta) \cdot t_{n-1}(p_{n-1}) + (1-\delta) \cdot \rho \cdot \bar{w}_{n-2}(\mathcal{P}_{n-2}) - \psi(\bar{w}_{n-1}(\mathcal{P}_{n-1}))]$ is a known constant in this backward looking valuation, Proposition 2 proves that \bar{w}_n^* is unique.

Mathematical induction thereby implies that provided that $[1 - \psi'(0)] < \delta < [1 - \psi'(\infty)]$, for n equal to 1, 2, ... , $N-2$, $N-1$, \bar{w}_n^* is unique.

Q.E.D.

Propositions 7 and 8 indicate that necessary and sufficient conditions for choice of δ to make \bar{w}_n^* unique are $[1 - \psi'(0)] < \delta < [1 - \psi'(\infty)]$ for all n equal to $N-1$, ... , 2, and 1. \bar{w}_n^* is a unique solution to Equation (35) in $(0, \infty)$ such that if $\bar{w}_n > \bar{w}_n^*$ then $\bar{w}_n^* - \psi(\bar{w}_n^*) > \delta \cdot t_n(p_n) + \rho \cdot \bar{V}_{n-1}^*(\delta; \mathcal{P}_n)$ and the HG will exercise the right to buy out the project, and if $\bar{w}_n < \bar{w}_n^*$ then the HG will not exercise the buyout option. If $\bar{w}_n = \bar{w}_n^*$ then the HG is indifferent. The set of $\bar{w}_n^*(\delta; \mathcal{P}_n)$ for n equal to 1, 2, ... , $N-2$, $N-1$, defines an optimal policy for the HG regarding when to exercise the buyout option at a future period. Proposition 9 reveals the behavior of $\bar{w}_n^*(\delta; \mathcal{P}_n)$ as history of oil prices evolves and δ changes.

PROPOSITION 9 : For n equal to $N-1$, $N-2$, ... , 1, if $\psi(x)$ is a concave function monotone increasing with increasing x from $\psi(0) = 0$, then $\bar{w}_n^*(\delta; \mathcal{P}_n)$ is non-decreasing as δ increases.

Proof:

Recall that $\bar{w}_n^*(\delta; \mathcal{P}_n)$ is a project's present value at period n such that $\bar{w}_n^*(\delta; \mathcal{P}_n) - \psi(\bar{w}_n^*(\delta; \mathcal{P}_n)) = \delta \cdot t_n(p_n) + \rho \cdot \bar{V}_{n-1}^*(\delta; \mathcal{P}_n)$. As the buyout value function ψ and $t_n(p_n)$ are independent of δ ,

$$d\bar{w}_n^*(\delta; \mathcal{P}_n)/d\delta = t_n(p_n) + \rho \cdot [d\bar{V}_{n-1}^*(\delta; \mathcal{P}_n)/d\delta].$$

Since $t_n(p_n)$ is defined as the project cash flow at period n , exclusive of investments, $t_n(p_n) \geq 0$. Further, $\bar{w}_n(\mathcal{P}_n) \geq 0$ by definition. The Principle of Optimality, as in Equation (31), thus implies that $d\bar{V}_{n-1}^*(\delta; \mathcal{P}_n)/d\delta \geq 0$.

Consequently, $d\bar{w}_n^*(\delta; \mathcal{P}_n)/d\delta \geq 0$. In other words, $\bar{w}_n^*(\delta; \mathcal{P}_n)$ is non-decreasing as δ increases.

Q.E.D.

Figure 4.7 portrays Proposition 9 for choice of $\bar{w}_n(\mathcal{P}_n)$ as in Equation (27). In view of $\bar{w}_n(\mathcal{P}_n)$, we shall check some interesting properties of the HG's expected payoff function in the presence of a buyout option in this N -period model. Proposition 10 is comparable to Proposition 4 in the two-period model.

PROPOSITION 10 : Given history of oil prices \mathcal{P}_n , the expected value at period n to the host government of its optimal future policies regarding the buyout option is convex upward on $\delta \in [0, 1]$.

Proof:

$$\text{For } n = 1, \bar{V}_1^*(\delta; \mathcal{P}_1) = \text{Max} \{ \bar{w}_1(\mathcal{P}_1) - \psi(\bar{w}_1(\mathcal{P}_1)), \delta \cdot \bar{w}_1(\mathcal{P}_1) \}.$$

With $\bar{w}_1(\mathcal{P}_1)$ in place of $E_H(X)$, $\bar{V}_1^*(\delta; \mathcal{P}_1)$ is $\bar{V}_H(\delta)$ as in Equation (1). By Proposition 4, $\bar{V}_1^*(\delta; \mathcal{P}_1)$ is convex upward on $\delta \in [0, 1]$.

Suppose that given history of oil prices \mathcal{P}_n this proposition is valid for period $n-1$, then we need to demonstrate that it is also valid for period n . Specifically, suppose that $\bar{V}_{n-1}^*(\delta; \mathcal{P}_n)$ is convex upward on $\delta \in [0, 1]$. Then $\bar{V}_n^*(\delta; \mathcal{P}_n)$ as in Equation (18) is the maximum of

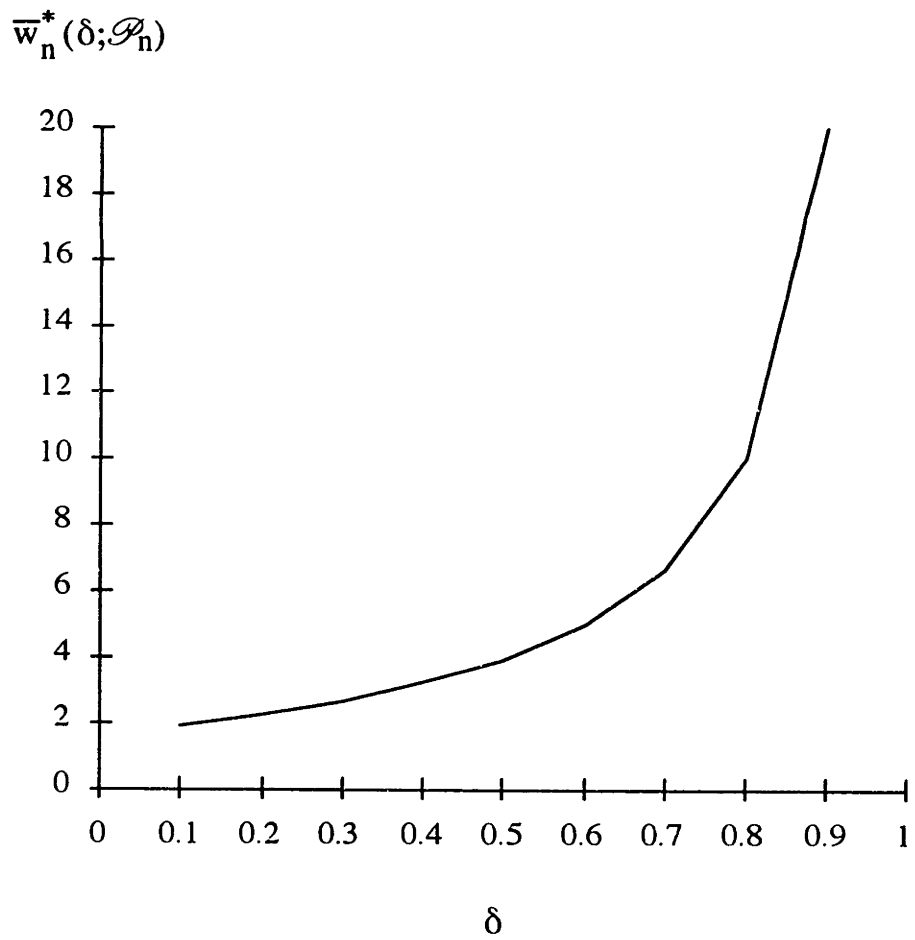


Figure 4.7 :
 $\bar{w}_n^*(\delta; \mathcal{P}_n)$ as a function of δ

- (a) $\bar{w}_n(\mathcal{P}_n) - \psi(\bar{w}_n(\mathcal{P}_n))$ which is realized at the beginning of period n as a fixed value and independent of δ ; and
- (b) $\delta \cdot t_n(p_n) + \rho \cdot \bar{V}_{n-1}^*(\delta; \mathcal{P}_n)$ which is nonnegative by definition of $t_n(p_n)$ and monotone increasing with increasing δ .

If (a) \leq (b) for all $\delta \in [0, 1]$, then the HG "realized value" of an optimal policy at period n is depicted in Figure 4.8. If (a) $>$ (b) for some $\delta \in [0, 1]$, then the graph of the HG "realized value" of an optimal policy at period n is as in Figure 4.9. In expectation, however, by independence in δ of (a) and upward convexity in δ of (b), the graph of $\bar{V}_n^*(\delta; \mathcal{P}_n)$ is as shown in Figure 4.10: $\bar{V}_n^*(\delta; \mathcal{P}_n)$ is convex upward on $\delta \in [0, 1]$. It is conclusive that if $\bar{V}_{n-1}^*(\delta; \mathcal{P}_n)$ is convex upward on $\delta \in [0, 1]$, then so is $\bar{V}_n^*(\delta; \mathcal{P}_n)$. Mathematical induction thereby implies that $\bar{V}_n^*(\delta; \mathcal{P}_n)$ is convex upward on $\delta \in [0, 1]$.

Q.E.D.

We shall assume that for n equal to $N-1, N-2, \dots, 2, 1$:

- (A24) Given history of oil prices \mathcal{P}_n , there exists a value δ_n of $\delta \in [0, 1]$ such that $(1-\delta) \cdot \bar{w}_n(\mathcal{P}_n) - \psi(\bar{w}_n(\mathcal{P}_n)) < \rho \cdot [\bar{V}_{n-1}^*(\delta; \mathcal{P}_n) - \delta \cdot \bar{w}_{n-1}(\mathcal{P}_n)]$ for each period n when $\delta \geq \delta_n$.

Thus, for $\delta \geq \delta_n$, the HG will never exercise the buyout option in the future, but for $\delta < \delta_n$, the HG will buy out the project at period n .

Depending upon the valuation of $\bar{w}_n(\mathcal{P}_n)$ and $\psi(\bar{w}_n(\mathcal{P}_n))$, the graph of $\bar{V}_n^*(\delta; \mathcal{P}_n)$ can be depicted as in Figure 4.10. Notice that any $\delta \geq \delta_n$ will make the HG choose to continue the contract. In other words, the HG will

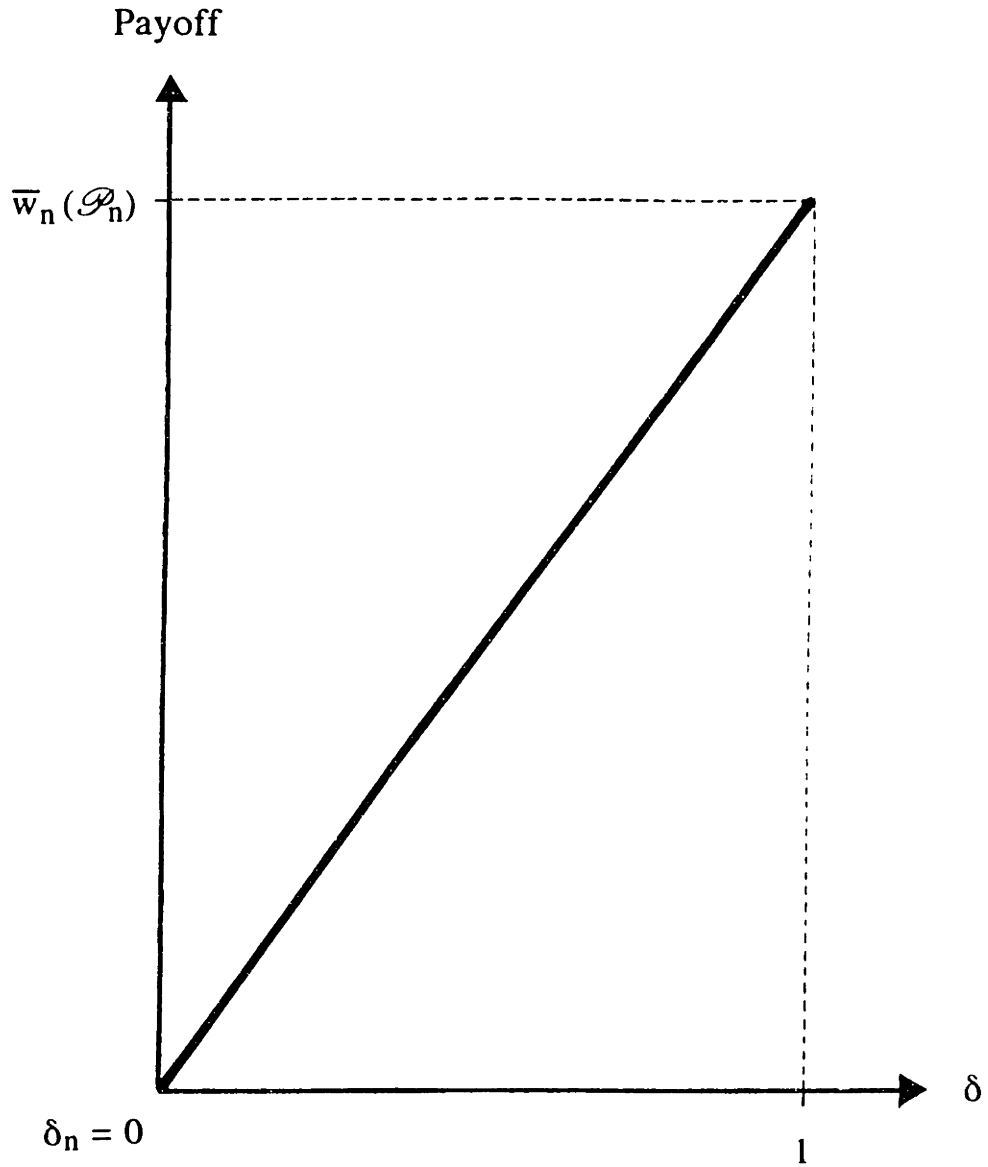


Figure 4.8 :
 The value to the HG of an optimal policy at period n
 when $\bar{w}_n(\mathcal{P}_n) - \psi(\bar{w}_n(\mathcal{P}_n)) \leq \delta \cdot t_n(p_n) + \rho \cdot \bar{V}_{n-1}^*(\delta; \mathcal{P}_n)$ for all $\delta \in [0, 1]$

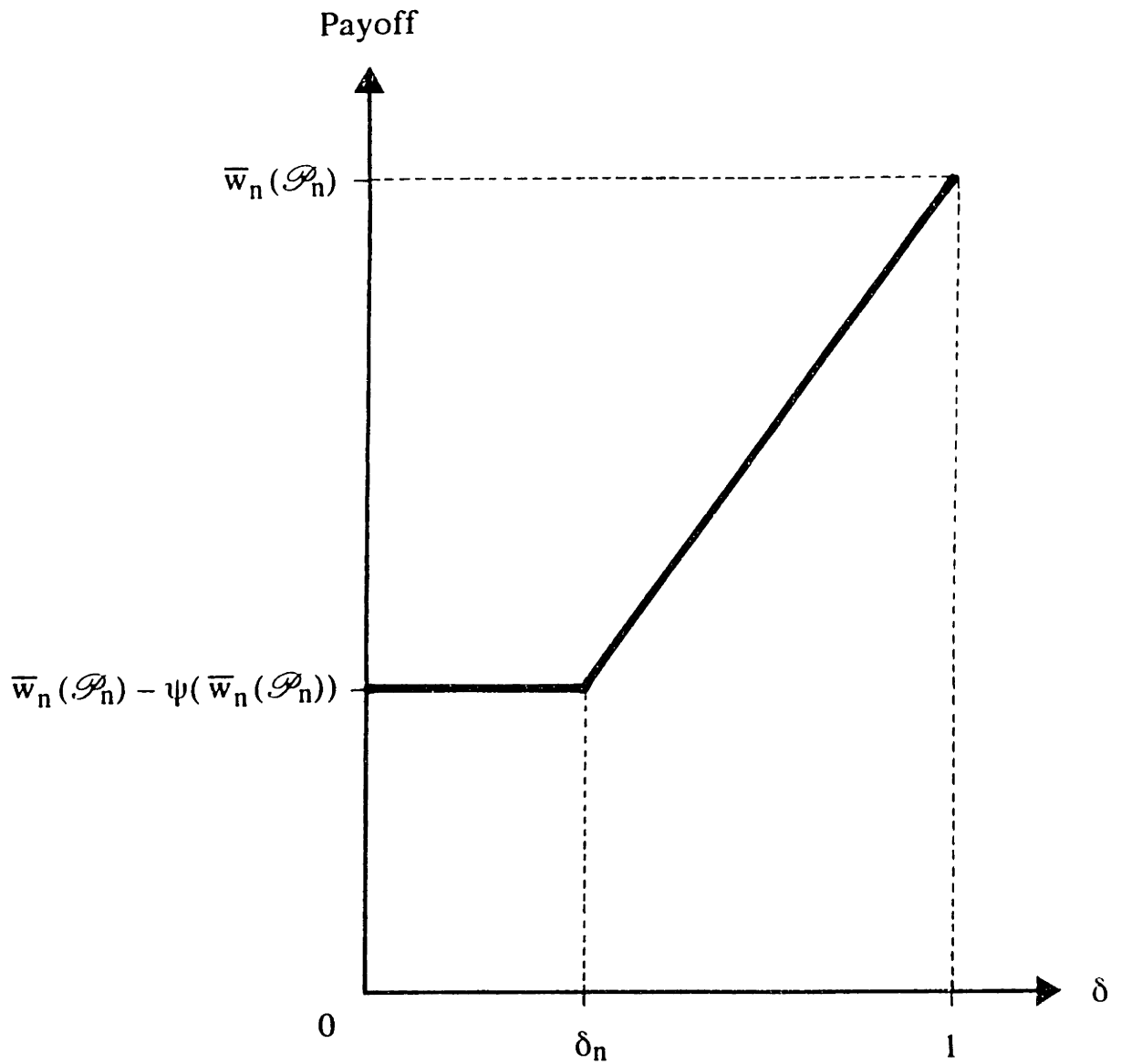


Figure 4.9 :

The value to the HG of an optimal policy at period n
 when $\bar{w}_n(\mathcal{P}_n) - \psi(\bar{w}_n(\mathcal{P}_n)) > \delta \cdot t_n(p_n) + \rho \cdot \bar{V}_{n-1}^*(\delta; \mathcal{P}_n)$ for $\delta \in [0, \delta_n)$

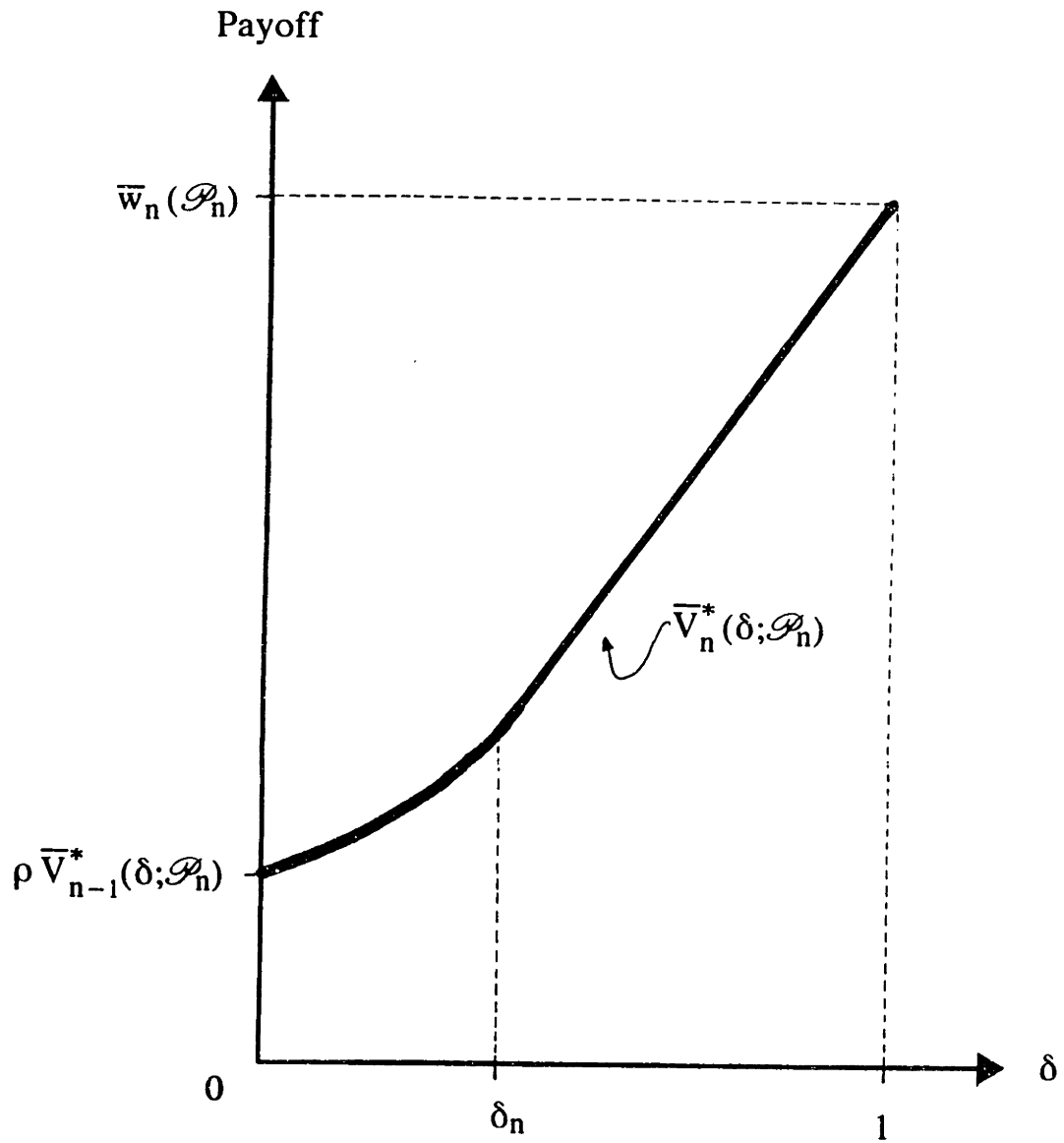


Figure 4.10 :
The expected value to the HG of an optimal policy at period n

never exercise the buyout option at a future date only if the HG and TNOc agree upon a tax rate δ_N , which is the maximum of δ_n for all n . However, the TNOc may negotiate for a tax rate lower than δ_N because its objective is to maximize its expected payoff from the project at time of negotiation—not to prevent the HG from buying out the project.

The dynamic programming equations (15) and (31) together with boundary conditions (19) constitute a framework for the HG to establish an optimal policy regarding when to exercise the right to buy out the project. In backward order, given a negotiated tax rate δ and history of oil prices \mathcal{P}_n , the HG can derive, using the criteria in Propositions 7 and 8, a series of optimal strategies for each period n , for n equal to $N, N-1, \dots, 2, 1$.

Unfortunately, there is a fundamental problem if an attempt is made to use a dynamic programming approach to institute an optimal policy in the case when cash flows are price-path dependent and the initial state space defined by oil price paths is multidimensionally large. These complexities rule out an analytic solution using dynamic programming methods. Nevertheless, our problem is formulated in a way that the HG, TNOc, and mediator observe the same initial oil price p_N at time of negotiation. Despite the fact that if their perceptions about future oil price paths differ the problem is more complicated, the dynamic programming approach can in principle manage this complexity.

4.4 A BINOMIAL LATTICE PRICE PATH EXAMPLE

We shall now show by example how the HG can construct an optimal policy regarding the buyout option, employing the binomial lattice method first described by Cox, Ross, and Rubenstein (1979). The rationale for this approach is the same as the rationale adopted for analysis of stock options: Option pricing provides a useful alternative to the conventional discounted cash flow method in situations where cash flows are uncertain and where that technique fails to recognize the changing risk structure during the project's life. The option valuation technique makes efficient use of market information and minimizes reliance on subjective and arbitrary data input, such as single risk-adjusted discount rates. This facilitation eliminates a potentially large source of error and thus reduces the number of judgmental factors in valuation of most petroleum properties. Consequently, the option valuation technique tends to reveal a truer picture of the worth of the investment project than any other currently available technique; it has the potential to constitute a proper basis for the negotiation of contract terms between host governments and transnational oil companies.

The simplicity of the binomial lattice implementation has an advantage of providing insight into how the host government can construct an optimal policy regarding when to exercise the buyout option. The volatility of fluctuations in oil price is presumed to be 22%¹⁰ and thus the price movement is characterized as follows: at the beginning of each period throughout the project's life, oil price will have moved either up by a fac-

¹⁰ This is the average volatility of fluctuations in the price of developed reserves observed in the U.S. over the period 1985-1989.

tor of 1.22, or down by a factor of .78, with a probability of .5 in each direction.

In order to calculate the risk-adjusted probability of each price direction, we apply market equilibrium arguments. Let the risk-free interest rate in real terms be r , and the payout rate on developed reserves be α .¹¹ Then the expected price of developed reserves in the next period must increase by $(r-\alpha)$ relative to the current "equilibrium oil price."¹² For instance, for the current equilibrium oil price of \$20.00/bbl, the risk-free interest rate of 4%, and the payout rate of 13%, the expected price in the next period must be $(1+.04-.13)\cdot(20) = \$18.20/\text{bbl}$. It is the current equilibrium price that conveys useful information regarding future price expectations. From this particular choice of value for risk-free interest rate, payout rate, and price volatility, Pickles and Smith (1993) show that the risk-adjusted probability of a price increase is .295454 and the risk-adjusted probability of a price decrease .704545. It is noteworthy that the history of oil prices \mathcal{P}_n does not figure in this binomial lattice.

In this example, the cash flow at period n from a 30-year investment project, in U.S. billion dollars, is taken to be

$$t_n(p_n) = p_n \cdot q_n,$$

where q_n is the amount of oil produced in barrels at period n . Specifically,

$$q_n = \int_{n-1}^n e^{-\beta(30-t)} dt = \left[\frac{1 - e^{-\beta}}{\beta} \right] \cdot e^{-\beta(30-n)}.$$

¹¹ The payout rate is the difference between the investor's required rate of return and the rate of price appreciation earned on developed reserves.

¹² The equilibrium price is the price that creates neither excess supply nor excess demand.

Here we simplify the production profile by assuming exponential decline, as is conventional among petroleum engineers. Using the more rigorous hyperbolic decline function would not only considerably increase reserves but also complexity. Further, β is assumed to be 10% (Adelman, 1988; Siegel, Smith, and Paddock, 1987). Therefore,

$$t_n(p_n) = p_n \cdot \left[\frac{1 - e^{-.1}}{.1} \right] \cdot e^{-.1(30-n)}.$$

In addition, we assume that given history of oil prices \mathcal{P}_n , the expected present value of the project at period n , or $\bar{w}_n(\mathcal{P}_n)$, for n equal to $N-1, N-2, \dots, 2, 1$ are determined by: $\bar{w}_n(\mathcal{P}_n) = t_n(p_n) + \rho \cdot \bar{w}_{n-1}(\mathcal{P}_n)$, where boundary conditions are $\bar{w}_0(\mathcal{P}_0) = 0$ and $\bar{w}_N(\mathcal{P}_N) = \rho \cdot \bar{w}_{N-1}(\mathcal{P}_N)$. If the expected present value of the project at period n is x and the mediator's buyout value function is of the form

$$\psi(x) = 2(1 - e^{-x}),$$

then this buyout value function satisfies the condition, prescribed by Proposition 8, for uniqueness of the HG optimal policy.

For a petroleum investment project of four periods, Figure 4.11 shows the results of each step in this backward looking valuation approach at each of the nine nodes in the lattice. At each node the figure exhibits the prevailing price of developed reserves, value if the buyout option is exercised, value if the buyout option continues to be held, and the cut-off δ for which any negotiated tax rate less than it will induce the HG to exercise the buyout option. In this example, an optimal policy vis-à-vis the buyout option from the HG's perspective when the initial oil price is \$20.00/bbl

reads: At the beginning of each period, a current oil price is realized and the HG compares the negotiated tax rate δ with the cut-off tax rate and chooses the corresponding act. If the HG and TNOC agree upon $\delta = .40$, for instance, then the HG will buy out the project in period 3 only if the realized oil price is \$24.40/bbl, and will not exercise the buyout option at a later date.

4.5 THE VALUE OF THE BUYOUT OPTION

Recall that $\bar{V}_n^*(\delta; \mathcal{P}_n)$ is the HG's expected value at period n of an optimal policy with respect to the buyout option, given the tax rate δ and history of oil prices \mathcal{P}_n . A lower bound is what the HG would anticipate receiving in present value terms from the TNOC under a standard production-sharing contract without a buyout option. Specifically,

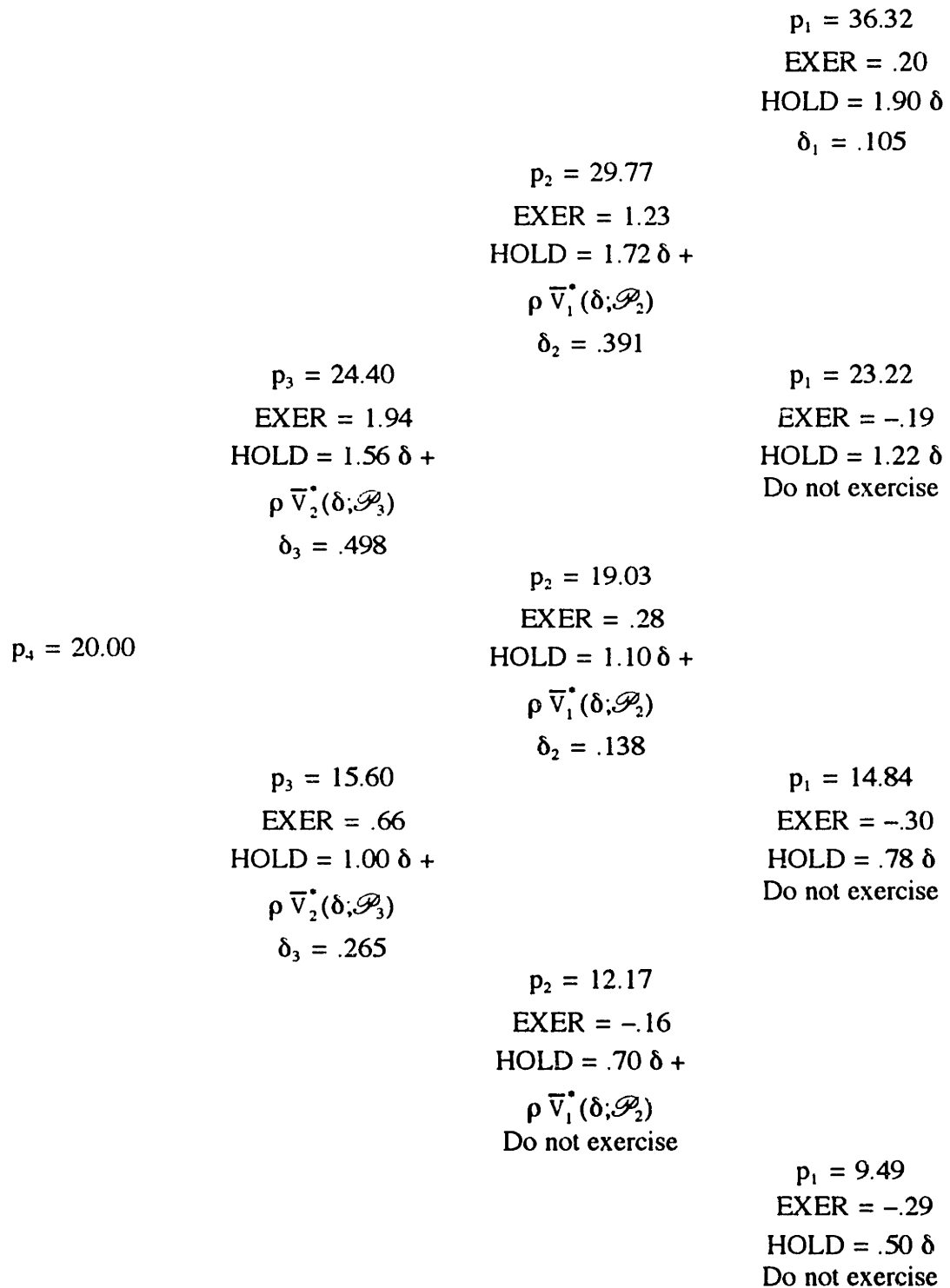
$$\bar{V}_n^*(\delta; \mathcal{P}_n) \geq \delta \cdot \bar{w}_n(\mathcal{P}_n). \tag{36}$$

Let $\Omega(\delta; \mathcal{P}_n)$ denote the value to the HG of the buyout option, conditional on the negotiated tax rate δ and history of oil prices \mathcal{P}_n , then

$$\Omega(\delta; \mathcal{P}_n) = \bar{V}_n^*(\delta; \mathcal{P}_n) - \delta \cdot \bar{w}_n(\mathcal{P}_n) \geq 0. \tag{37}$$

Equation (37) together with Equation (31) indicate that

$$\begin{aligned} \Omega(\delta; \mathcal{P}_n) = \text{Max} \{ & (1-\delta) \cdot \bar{w}_n(\mathcal{P}_n) - \psi(\bar{w}_n(\mathcal{P}_n)), \\ & \rho \cdot [\bar{V}_{n-1}^*(\delta; \mathcal{P}_n) - \delta \cdot \bar{w}_{n-1}(\mathcal{P}_n)] \} \geq 0 \end{aligned} \tag{38}$$



Remarks: EXER denotes the value to the HG if the buyout option is exercised;
HOLD denotes the value to the HG if the buyout option continues to be held; and
 δ_n is the break-even value of δ such that if $\delta \leq \delta_n$ the HG will exercise the option.

Figure 4.11 :
A binomial lattice for a four-period model

which is consistent with the options literature assertion that options have intrinsic nonnegative values.¹³

The HG's expected value of an optimal policy regarding when to exercise the buyout option has its maximum value when the HG receives exclusively all future cash flows from the project. More specifically,

$$\bar{V}_n^*(\delta; \mathcal{P}_n) = \Omega(\delta; \mathcal{P}_n) + \delta \cdot \bar{w}_n(\mathcal{P}_n) \leq \bar{w}_n(\mathcal{P}_n). \quad \dots\dots\dots(39)$$

Equations (37) and (39) together prescribe that

$$0 \leq \Omega(\delta; \mathcal{P}_n) \leq (1-\delta) \cdot \bar{w}_n(\mathcal{P}_n). \quad \dots\dots\dots(40)$$

Therefore, the maximum value which $\Omega(\delta; \mathcal{P}_n)$ can assume decreases as δ increases.

PROPOSITION 11 : For given tax rate δ and history of oil prices \mathcal{P}_n , at each period n , for n equal to $N-1, N-2, \dots, 2, 1$, the value of a buyout option to the host government is:

- (1) zero if $\delta \in [\delta_n, 1]$;
- (2) $(1-\delta) \cdot \bar{w}_n(\mathcal{P}_n) - \psi(\bar{w}_n(\mathcal{P}_n))$ if $\delta \in [0, \delta_n)$.

Proof :

If the negotiated δ is between δ_n and 1, then the HG's optimal policy will not call for buying out the project in the future by assumption of δ_n and $\bar{V}_n^*(\delta; \mathcal{P}_n)$ is thus $\delta \cdot \bar{w}_n(\mathcal{P}_n)$. Equation (37), hence, indicates that the value of a buyout option to the HG is zero.

¹³ For a comprehensive background on options theories, see Cox and Rubinstein (1985).

If the negotiated δ is between 0 and δ_n , then, by assumption of δ_n , the HG will buy out the project at this period, and Equation (38) states that the additional value to the HG of having a buyout option at period n is then $(1-\delta) \cdot \bar{w}_n(\mathcal{P}_n) - \psi(\bar{w}_n(\mathcal{P}_n))$.

Q.E.D.

To graphically illustrate Proposition 11, the value to the HG of a buyout option as a function of δ is depicted in Figure 4.12: For given history of oil prices \mathcal{P}_n , the value to the HG of having a buyout option decreases as δ increases for $\delta \in [0, \delta_n)$ and is zero otherwise. The binomial lattice example in section 4.4 epitomizes this remark: At $p_2 = 29.77$, if $\delta = .1$ then Figure 4.11 displays that the HG will exercise the buyout option and secure \$1.23 instead of $.1(1.72) + .295454(.1)(1.90) + .704545(.1)(1.22) = \0.31 from holding the buyout option until project termination. Hence, $\Omega(.1; \mathcal{P}_2) = 1.23 - .31 = \0.92 . For $\delta = .3$, the HG still prefers \$1.23 from exercising the buyout option to $.3(1.72) + .295454(.3)(1.90) + .704545(.3)(1.22) = \0.94 from holding the buyout option; resulting in $\Omega(.3; \mathcal{P}_2) = 1.23 - .94 = \0.29 . It is then obvious that the value to the HG of having a buyout option decreases as δ increases for $\delta \in [0, .391)$. Moreover, any $\tilde{\delta} \geq .391$ instructs the HG not to exercise the buyout option in the future, namely, $\Omega(\tilde{\delta}; \mathcal{P}_2) = 0$.

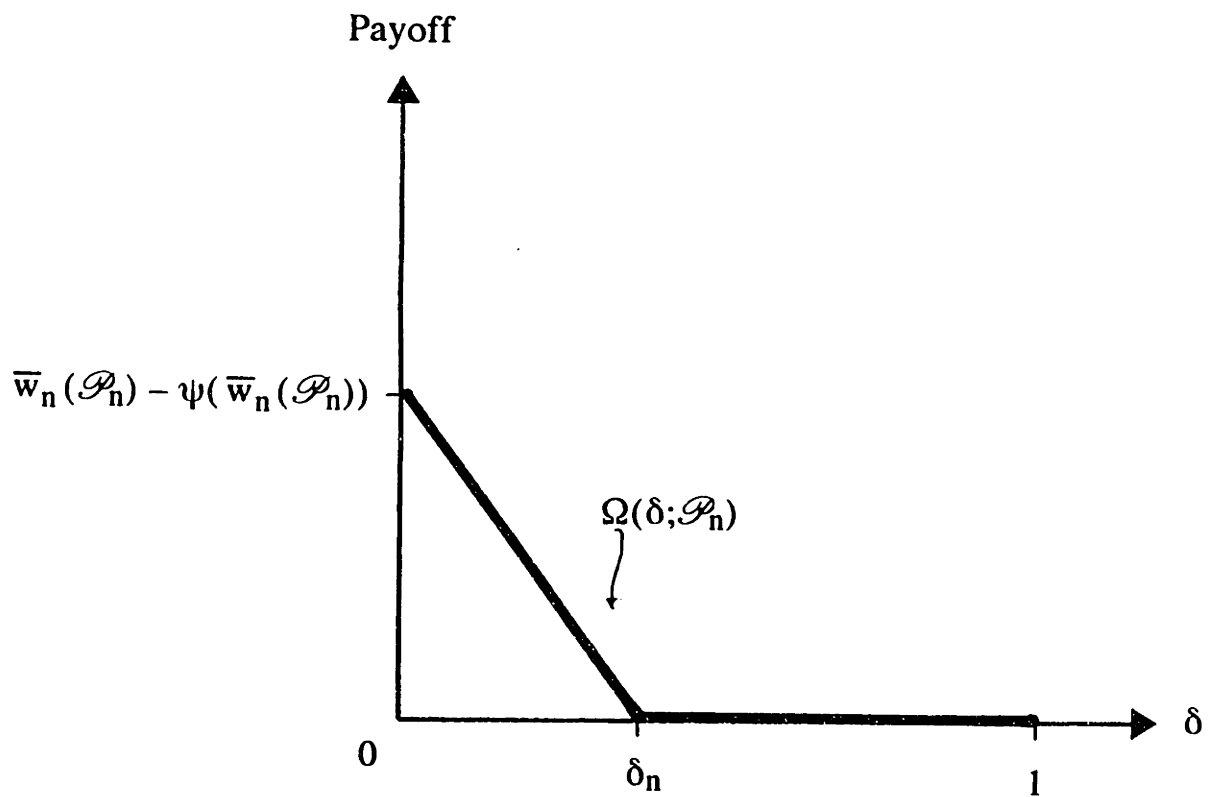


Figure 4.12 :
The value of a buyout option as a function of δ

4.6 THE INVESTMENT DECISION MAKING

Recall that $\zeta_n(\delta; \mathcal{P}_n)$ denotes the TNOC's expected present value of the project from current and future cash flows, adjusted for buyout risk. From the TNOC's perspective, no cash flow is produced from this investment project at termination regardless of oil price p_0 by Assumption (A15). Hence, boundary conditions are

$$\zeta_0(\delta; \mathcal{P}_0) = 0, \quad \forall \delta \text{ and } \forall \mathcal{P}_0. \quad \dots\dots\dots(41)$$

At the beginning of each period n , where n may equal $N-1, N-2, \dots, 2, 1$, the TNOC expects, conditional on the HG's optimal policy vis-à-vis the buyout option, the present value of current and future cash flows from the project given the history of oil prices \mathcal{P}_n to be

$$\zeta_n(\delta; \mathcal{P}_n) = \text{Min} \{ \psi(\bar{w}_n(\mathcal{P}_n)), (1-\delta) \cdot t_n(p_n) + \rho \cdot \zeta_{n-1}(\delta; \mathcal{P}_n) \} \quad \dots\dots\dots(42)$$

If both parties agree upon a value of δ when N periods remain, the TNOC makes an investment of I_T , which is the present value of its initial investment and future serial investments, at the beginning of period N and expects to receive its share in the following periods. $\zeta_N(\delta; \mathcal{P}_N)$ at the start of the project cannot use Equation (42) since a buyout is not allowed by Assumption (A16). However, $\zeta_N(\delta; \mathcal{P}_N)$ can be derived from:

$$\zeta_N(\delta; \mathcal{P}_N) = \rho \cdot \zeta_{N-1}(\delta; \mathcal{P}_N). \quad \dots\dots\dots(43)$$

Proposition 12 is a variation of investment decision-making criterion commonly employed in finance theories.

PROPOSITION 12 : Given the host government's optimal policy vis-à-vis the buyout option, the transnational oil company's investment criterion is to undertake a petroleum investment project given agreement on a value of δ if and only if $\zeta_N(\delta; \mathcal{P}_N) - I_T > 0$.

Proof :

The value $\zeta_N(\delta; \mathcal{P}_N)$ is the expected present value of the project adjusted for buyout risk as perceived by the TNOC at the decision node in Figure 4.2, thereby being used in the TNOC's decision making process whether to undertake this investment project.

The TNOC deducts its initial investment I_T from $\zeta_N(\delta; \mathcal{P}_N)$ at the time of negotiation; yielding the "net" present value of this investment. If $\zeta_N(\delta; \mathcal{P}_N) - I_T = 0$, then the TNOC is indifferent between undertaking the project and reaching no deal with the HG. The net-present-value principle recommends that when $\zeta_N(\delta; \mathcal{P}_N) - I_T$ turns out to be positive the TNOC undertake this investment project for agreement on particular δ .

Q.E.D.

In order to better understand the transnational oil company behavior in coping with buyout risk, we shall investigate properties of $\zeta_n(\delta; \mathcal{P}_n)$.

PROPOSITION 13 : Given history of oil prices \mathcal{P}_n , the transnational oil company's expected present value of the project, adjusted for buyout risk, is concave downward on $\delta \in [0, 1]$.

Proof:

For n equal to 1, $\zeta_1(\delta; \mathcal{P}_1) = \text{Min} \{ \psi(\bar{w}_1(\mathcal{P}_1)), (1-\delta) \cdot \bar{w}_1(\mathcal{P}_1) \}$. With $\bar{w}_1(\mathcal{P}_1)$ in place of $E_T(X)$ in Equation (2), Proposition 5 says that $\zeta_1(\delta; \mathcal{P}_1)$ is concave downward on $\delta \in [0, 1]$.

Suppose that given history of oil prices \mathcal{P}_n , this proposition is true for period $n-1$, then we need to verify that it is also true for period n . Specifically, suppose that $\zeta_{n-1}(\delta; \mathcal{P}_n)$ is concave downward on $\delta \in [0, 1]$. Then $\zeta_n(\delta; \mathcal{P}_n)$ as in Equation (42) is the minimum of

- (a) $\psi(\bar{w}_n(\mathcal{P}_n))$ which is realized at the beginning of period n as a fixed value and independent of δ ; and
- (b) $(1-\delta) \cdot t_n(p_n) + \rho \cdot \zeta_{n-1}(\delta; \mathcal{P}_n)$ which is nonnegative by definition of $t_n(p_n)$ and monotone decreasing with increasing δ .

If (a) \geq (b) for all $\delta \in [0, 1]$, then the TNOC "realized value" of the project at period n is depicted in Figure 4.13. If (a) $<$ (b) for some $\delta \in [0, 1]$, then the graph of the TNOC "realized value" of the project at period n is as in Figure 4.14. In expectation, however, by independence in δ of (a) and downward concavity in δ of (b), the graph of $\zeta_n(\delta; \mathcal{P}_n)$ is as shown in Figure 4.15: $\zeta_n(\delta; \mathcal{P}_n)$ is concave downward on $\delta \in [0, 1]$. It is conclusive that if $\zeta_{n-1}(\delta; \mathcal{P}_n)$ is concave downward on $\delta \in [0, 1]$, then so is $\zeta_n(\delta; \mathcal{P}_n)$. Mathematical induction thereby implies that $\zeta_n(\delta; \mathcal{P}_n)$ is concave downward on $\delta \in [0, 1]$.

Q.E.D.

At time of negotiation—at period N —where buyout is not allowed, the graph of $\zeta_N(\delta; \mathcal{P}_N)$, as governed by Equations (30), (42), and (43), is displayed in Figures 4.16 and 4.17, depending on the size of I_T . Notice that

any $\delta > \delta_T$ will make the TNOC's expected payoff become negative. δ_T is thus the upper limit of δ that the TNOC is willing to agree upon with the HG in a δ -sharing agreement. If the TNOC's expected payoff turns out to be as in Figure 4.16, then the HG will exercise the buyout option in the future for $\delta \leq \delta_T$. Since δ_N is known by both HG and TNOC, Figure 4.17 guarantees not only that the TNOC will receive a positive expected return from undertaking this project but also that the HG will never exercise the buyout option when $\delta_N \leq \delta \leq \delta_T$. Proposition 14 summarizes characteristics of the probability of buyout as δ changes.

PROPOSITION 14 : For n equal to $N-1, N-2, \dots, 1$, the probability of buyout at period n is non-increasing as δ increases.

Proof:

Given history of oil prices \mathcal{P}_n , the probability of buyout at period n , or $\xi_n(\delta; \mathcal{P}_n)$, is defined as the subjective probability that the TNOC assigns to the event "the HG exercises the buyout option." According to the HG's optimal policy set by Propositions 7 and 8, $\xi_n(\delta; \mathcal{P}_n) \equiv P\{\bar{w}_n(\mathcal{P}_n) > \bar{w}_n^*(\delta; \mathcal{P}_n)\}$. Because (i) Figure 4.6 shows that $\bar{w}_n(\mathcal{P}_n)$ is independent of δ , and (ii) Proposition 9 affirms that for concave $\psi(\bar{w}_n(\mathcal{P}_n))$ monotone increasing with increasing $\bar{w}_n(\mathcal{P}_n)$ from $\psi(0) = 0$, $\bar{w}_n^*(\delta; \mathcal{P}_n)$ is non-decreasing as δ increases, we conclude that $\xi_n(\delta; \mathcal{P}_n)$ is non-increasing as δ increases.

Q.E.D.

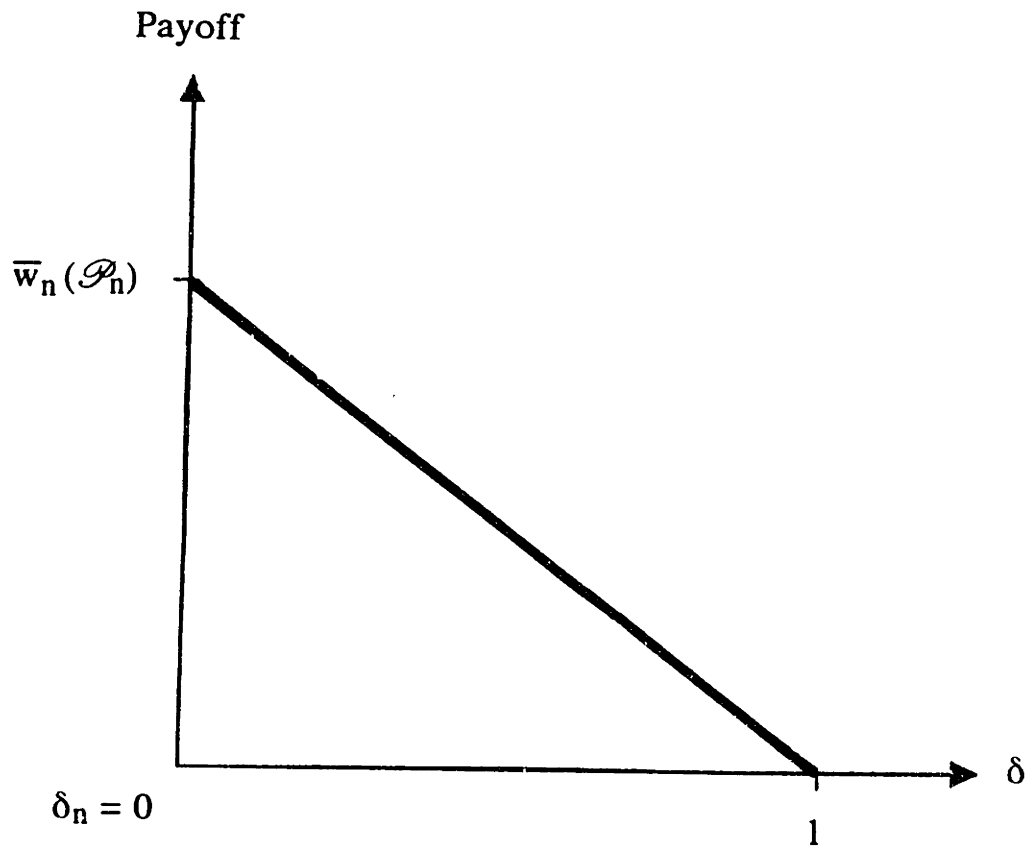


Figure 4.13 :
 The TNOC's present value of the project at period n
 when $\psi(\bar{w}_n(\mathcal{P}_n)) \geq (1-\delta) \cdot t_n(p_n) + \rho \cdot \zeta_{n-1}(\delta; \mathcal{P}_n)$ for all $\delta \in [0, 1]$

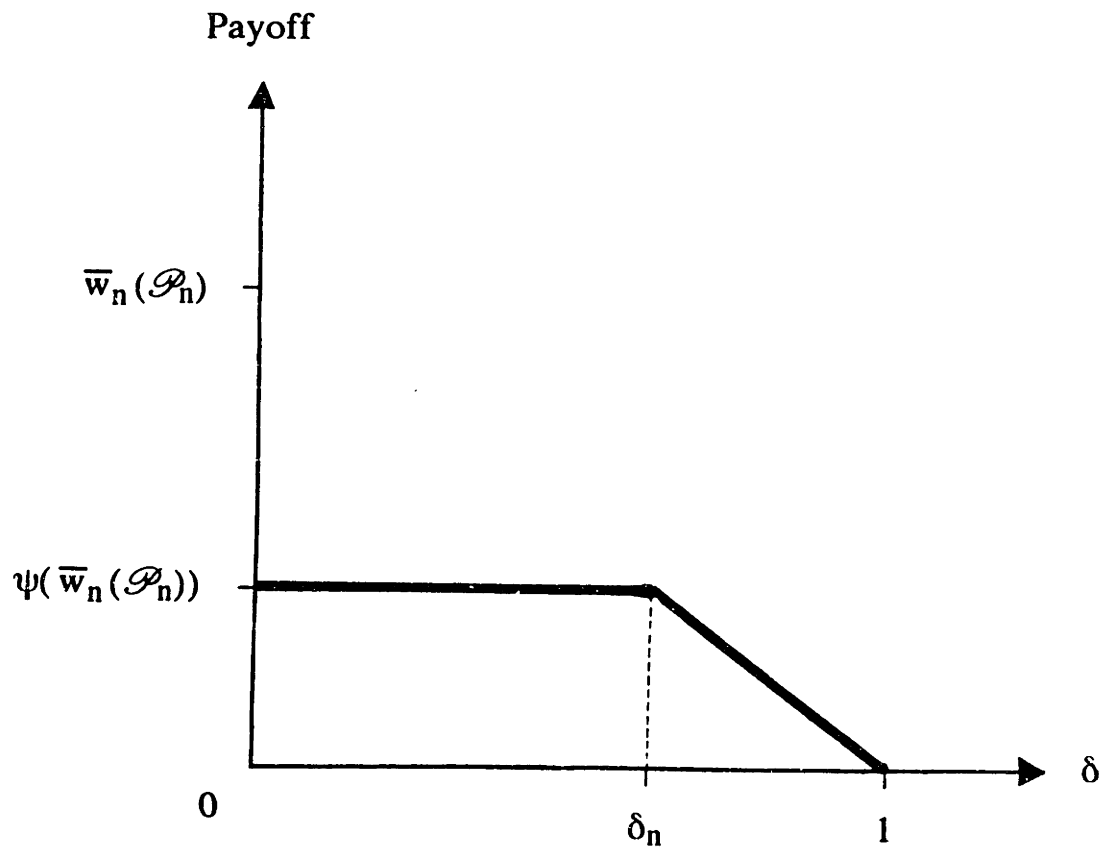


Figure 4.14 :
 The TNOC's present value of the project at period n
 when $\psi(\bar{w}_n(\mathcal{P}_n)) \geq (1-\delta) \cdot t_n(p_n) + \rho \cdot \zeta_{n-1}(\delta; \mathcal{P}_n)$ for $\delta \in [0, \delta_n)$

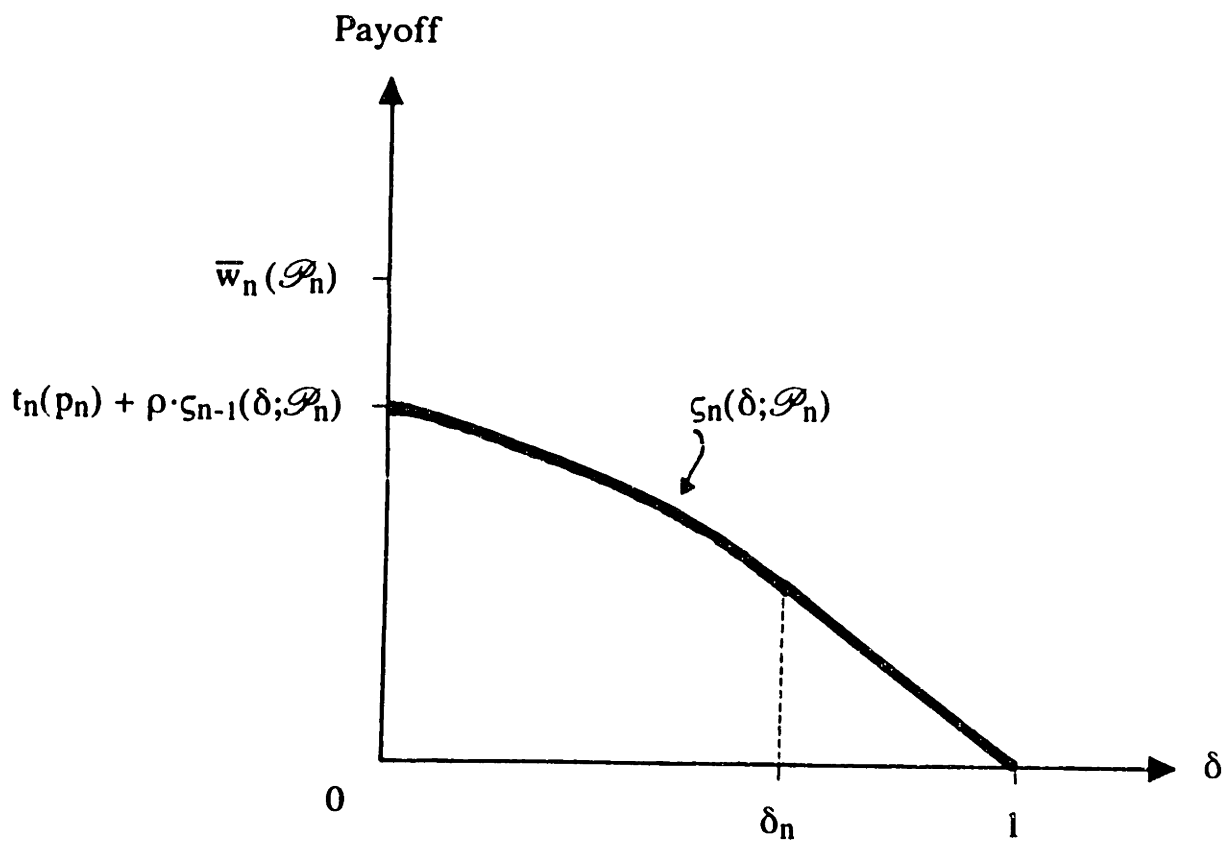


Figure 4.15 :
The TNO's expected present value of the project at period n

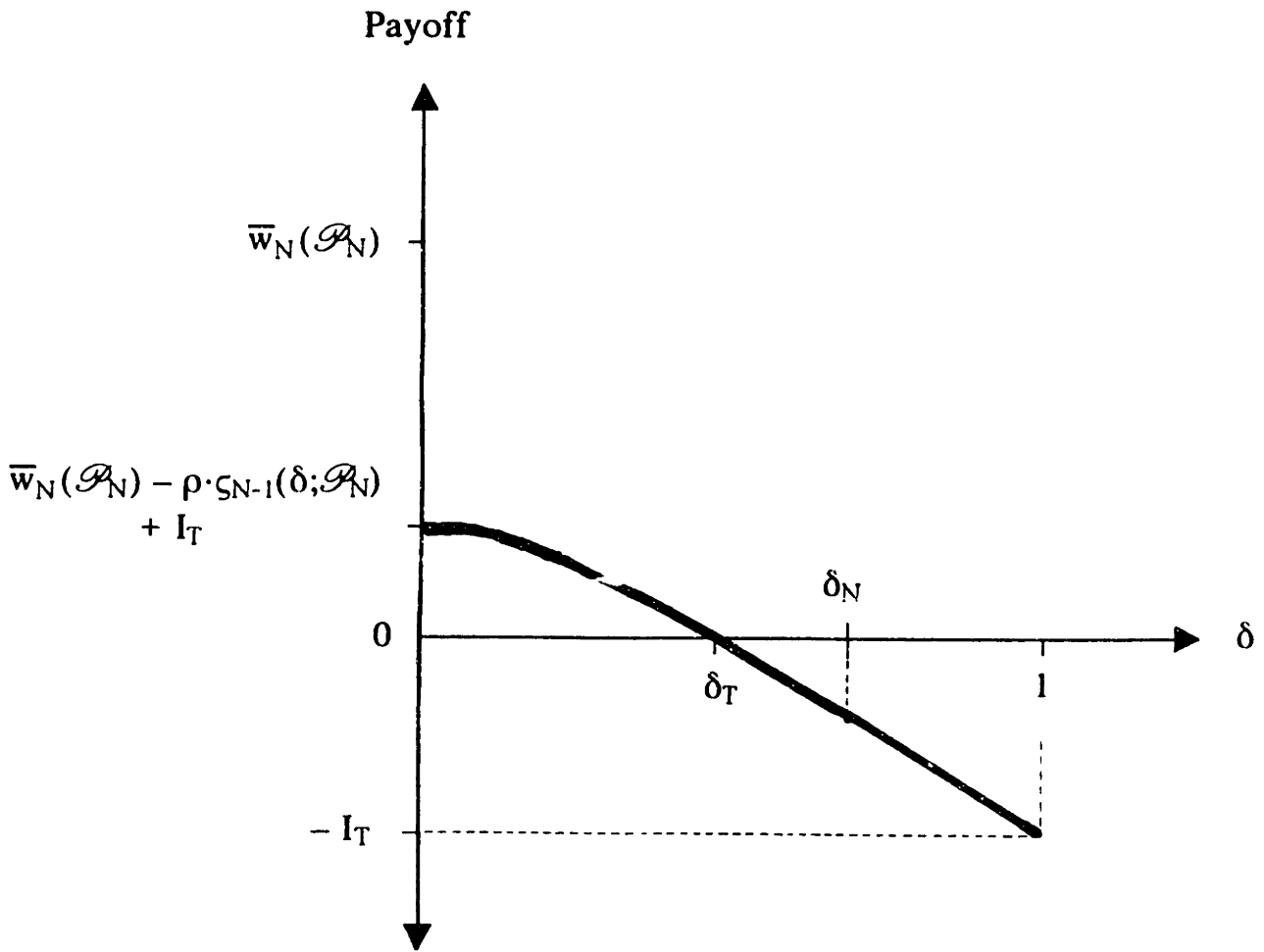


Figure 4.16 :
The TNOC's expected net present value of the project
at period N when I_T is large

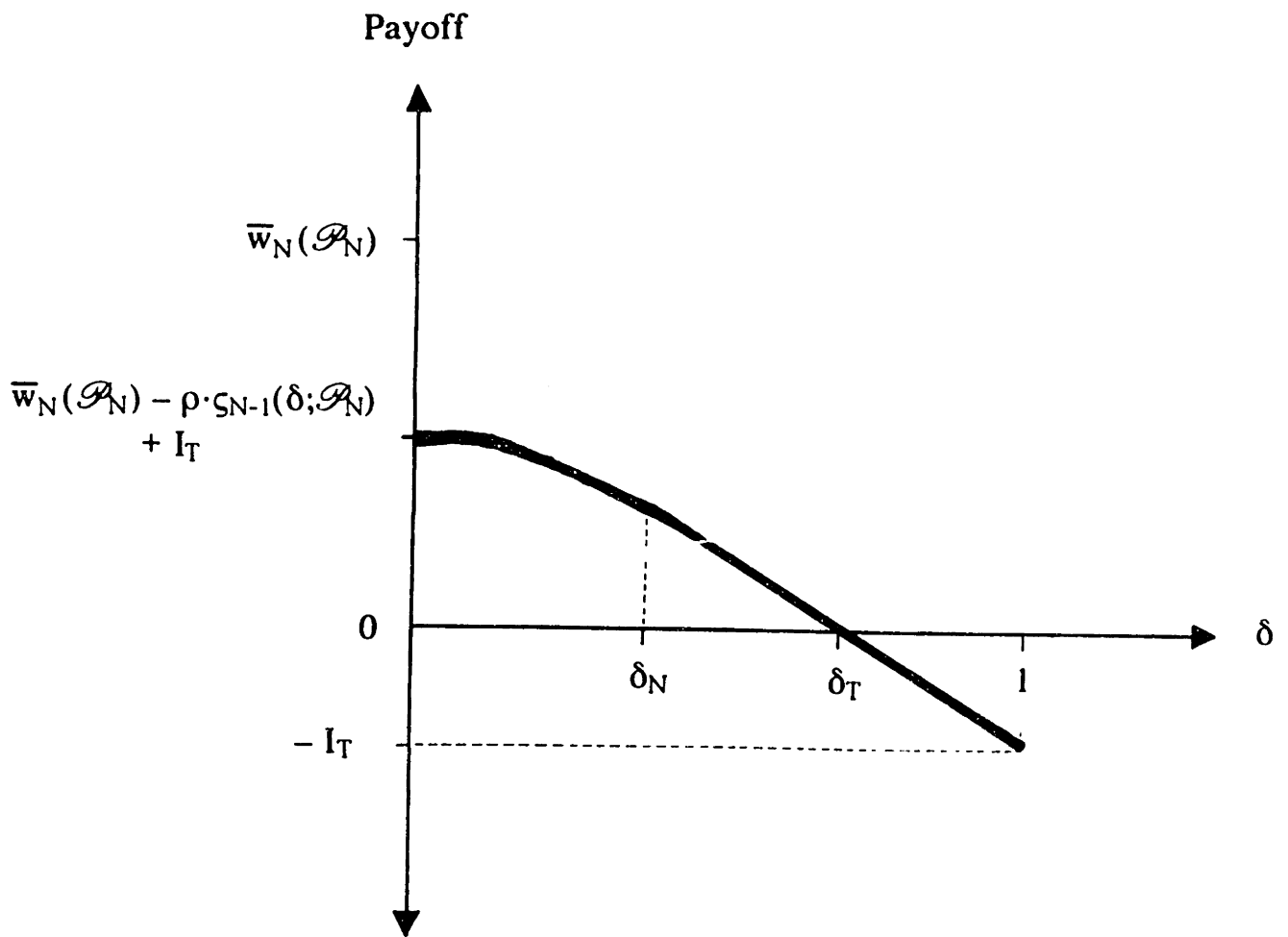


Figure 4.17 :
 The TNOC's expected net present value of the project
 at period N when I_T is small

4.7 IMPLICATIONS

This chapter explains theoretical properties in the presence of a buyout option of a petroleum investment project with a time horizon of $N \geq 3$ periods, in which certain behavioral assumptions of the host government and transnational oil company are posited. In this buyout model, both parties observe the same initial oil price p_N at time of negotiation. Although their differing perceptions about future oil price path may complicate the problem, the suggested dynamic programming approach can manage this complexity. An optimal policy for the host government regarding when to exercise the buyout option during the project's life is presented. In addition, there exists a range of tax rate δ that renders uniqueness to this optimal policy for given history of oil prices.

The severance tax rate of δ_N is introduced as the cut-off tax rate such that any tax rate greater than δ_N will prevent the host government from exercising the buyout option in the future. Furthermore, the probability that the host government will exercise the buyout option at any given period is non-increasing as δ increases. Nevertheless, it is rational for the transnational oil company to negotiate a tax rate lower than δ_N because its objective is to maximize its expected payoff from the project.

Specifically, employing the binomial lattice method, this chapter constructs an example to better understand the buyout model and, in particular, how the host government forms an optimal policy vis-à-vis the buyout option. Properties of the expected payoff function from the perspective of both the host government and transnational oil company hold in the N-pe-

riod model for $N \geq 3$ because the lower the number of periods remaining the lower the cut-off tax rate. This model also reveals that the buyout option has higher value to the host government at a low tax bracket than at higher tax rates.

CHAPTER 5

THE EXPERIMENT

5.1 INTRODUCTION

Chapters 3 and 4 develop theoretical properties of the buyout option model for a petroleum investment project of any time horizon. In practice, whether host governments and transnational oil companies behave as the theories dictate is very interesting. We shall conduct an experiment designed to test whether experimental subjects make choices of δ and contractual format that adhere to the logical implications of (E1) and (E2):

- (E1) There exists a range of tax rate δ in which a production-sharing contract with a buyout option can dominate a traditional production-sharing contract from the perspectives of both the host government and transnational oil company.
- (E2) The zone of agreement in terms of δ is larger in a production-sharing contract with a buyout option than in a traditional production-sharing contract.

We shall first show (E1) and (E2) by example. In other words, we shall examine under what conditions both the host government and transnational oil company are better off in terms of their expected payoff from the project if they enter into a production-sharing contract with a buyout option, rather than a traditional production-sharing contract. We shall then analyze whether an integrative bargain between δ and the contractual for-

mat exists in the presence of a buyout option. Experimental particulars are described in Appendices 1, 2, and 3. In addition, we shall investigate the experimental results and present implications of this experiment and some concluding remarks.

5.2 THE BARGAINING MODEL ANALYSIS

In this experiment, the instructions for the HG say that there exists no probability of expropriation from the HG's perspective. Since the HG's expectation of project outcome is uniformly distributed on $[0, 1]$, the expected payoff to the HG from a traditional production-sharing contract is

$$= .5 \delta.$$

However, the expected payoff to the HG from a production-sharing contract with a buyout option, as prescribed by Equation (8) and the uniform distribution of the project outcome, is

$$= .5 \delta + \int_{x_0(\delta)}^1 [(1-\delta) \cdot x - \psi(x)] dx,$$

or equivalently,

$$= .5 \delta + .5(1-\delta) \cdot [1 - (x_0(\delta))^2] - .75[1 - x_0(\delta) + e^{-1} - e^{-x_0(\delta)}].$$

for choice of $\psi(x) = .75(1-e^{-x})$ for $0 \leq x \leq 1$ as the mediator's buyout value function

Let $D(\delta)$ be the value of δ for the HG under a traditional production-sharing contract that yields the same expected payoff for choice of δ under

a production-sharing contract with a buyout option. A pair, δ and $D(\delta)$, is called a break-even pair of δ 's for the HG. Table 5.1 displays an array of break-even pairs for the HG. For example, $\delta = .526$ is a break-even tax rate such that at $\delta = .526$, the HG's expected payoff from a traditional production-sharing contract is the same as that from a production-sharing contract with a buyout option.

For each value of δ , the expected payoffs to the HG from both contract forms are tabulated in Table 5.2. The table informs us that if $\delta > .526$, then the HG expected payoff from a traditional production-sharing contract is equal to that from a production-sharing contract with a buyout option. This implies that if the HG is risk-neutral, for any $\delta > .526$ the HG should be indifferent between a traditional production-sharing contract and a production-sharing contract with a buyout option. Nonetheless, if $\delta < .526$, then the HG's expected payoff from a traditional production-sharing contract is less than the HG's expected payoff from a production-sharing contract with a buyout option: The HG would prefer a production-sharing contract with a buyout option if both the HG and TNOC agree upon δ that is less than $.526$. In addition, Table 5.2 tells us that in this experiment the HG will always exercise the buyout option if a negotiated $\delta < .25$.

Unlike the instructions for the HG, the instructions for the TNOC say that there exists a probability of $.15$ of expropriation in a traditional production-sharing contract, and a probability of $.05$ of expropriation in a production-sharing contract with a buyout option. Since the TNOC's expectation of the project outcome is uniformly distributed on $[0, .8]$, the ex-

Table 5.1 : Break-even δ 's for the HG

δ under a production-sharing contract with a buyout option	$D(\delta)$ under a traditional production-sharing contract
0.100	0.448
0.200	0.448
0.300	0.449
0.400	0.458
0.500	0.503
0.526	0.526
0.600	0.600
0.700	0.700
0.800	0.800
0.900	0.900
1.000	1.000

Table 5.2 :
Relationship between δ and the expected payoff
to the HG from each form of contract

δ	Expected payoff from a production-sharing contract with a buyout option	Expected payoff from a traditional production- sharing contract
0.000	0.2241	0.0000
0.100	0.2241	0.0500
0.200	0.2241	0.1000
0.250	0.2241	0.1250
0.300	0.2242	0.1500
0.400	0.2291	0.2000
0.448	0.2366	0.2241
0.449	0.2367	0.2242
0.458	0.2388	0.2291
0.500	0.2516	0.2500
0.503	0.2528	0.2516
0.526	0.2630	0.2630
0.600	0.3000	0.3000
0.700	0.3500	0.3500
0.800	0.4000	0.4000
0.900	0.4500	0.4500
1.000	0.5000	0.5000

pected payoff to the TNOC from a traditional production-sharing contract with a probability of non-expropriation of .85 is

$$\begin{aligned}
 &= .85(.4)(1-\delta) - .11 \\
 &= .23 - .34 \delta.
 \end{aligned}$$

Nonetheless, the expected payoff to the TNOC from a production-sharing contract with a buyout option and a probability of non-expropriation of .95, as prescribed by Equation (11) and the uniform distribution of the project outcome, is

$$= .95(1.25) \left[(1-\delta) \int_0^{x_o(\delta)} x \, dx + \int_{x_o(\delta)}^{.8} \psi(x) \, dx \right] - .11,$$

or equivalently,

$$\begin{aligned}
 &= .59375(1-\delta) \cdot x_o(\delta)^2 \\
 &\quad + .890625 \left[.8 - x_o(\delta) + e^{-.8} - e^{-x_o(\delta)} \right] - .11
 \end{aligned}$$

for choice of $\psi(x) = .75(1-e^{-x})$ for $0 \leq x \leq 1$ as the mediator's buyout value function.

Let $d(\delta)$ be the value of δ for the TNOC under a traditional production-sharing contract that renders the same expected payoff for choice of δ under a production-sharing contract with a buyout option. A pair, δ and $d(\delta)$, is called a break-even pair of δ 's for the TNOC. Table 5.3 exhibits break-even pairs of δ 's for the TNOC. For instance, $\delta = .352$ is a break-even tax rate such that at $\delta = .352$, the TNOC's expected payoff from a traditional production-sharing contract is the same as that from a production-sharing contract with a buyout option.

Table 5.3 : Break-even δ 's for the TNOC

δ under a production-sharing contract with a buyout option	$d(\delta)$ under a traditional production-sharing contract
0.100	0.3469
0.200	0.3469
0.250	0.3469
0.300	0.3474
0.352	0.3520
0.400	0.3643
0.500	0.4412
0.600	0.5529
0.700	0.6647
0.800	0.7765
0.900	0.8882
1.000	1.0000

The expected payoffs to the TNOC under each form of contract for a range of δ are tabulated in Table 5.4. The table reveals that if $\delta > .352$, then the TNOC's expected payoff from a production-sharing contract with a buyout option is greater than that from a traditional production-sharing contract. This implies that for any $\delta > .352$ the TNOC would prefer a production-sharing contract with a buyout option. However, if $\delta < .352$, then the TNOC's expected payoff from a production-sharing contract with a buyout option is less than that from a traditional production-sharing contract: The TNOC would not agree on a buyout option if the HG and TNOC negotiate for δ that is less than .352.

Figure 5.1 displays another important feature of this experiment: For a negotiated δ between .352 and .526, a production-sharing contract with a buyout option strictly dominates a traditional production-sharing contract from the perspectives of both the HG and TNOC. For $\delta > .526$, the HG is indifferent between a traditional production-sharing contract and a production-sharing contract with a buyout option. In other words, the TNOC would switch to a production-sharing contract with a buyout option only when the agreed-upon δ is greater than .352.

Figure 5.2 illustrates the expected payoffs to the HG and TNOC under a traditional production-sharing contract and a production-sharing contract with a buyout option as a function of δ . For a negotiated $\delta > .352$, a production-sharing contract with a buyout option yields higher expected payoffs to both the HG and TNOC, i.e., a production-sharing contract with a buyout option dominates a traditional production-sharing contract. Fig-

Table 5.4 :
Relationship between δ and the expected payoff
to the TNOC from each form of contract

δ	Expected payoff from a production- sharing contract with a buyout option	Expected payoff from a traditional production-sharing contract
0.000	0.1121	0.2300
0.100	0.1121	0.1960
0.200	0.1121	0.1620
0.250	0.1121	0.1450
0.300	0.1119	0.1280
0.347	0.1106	0.1120
0.352	0.1103	0.1103
0.364	0.1096	0.1061
0.400	0.1061	0.0940
0.441	0.0990	0.0800
0.500	0.0800	0.0600
0.553	0.0599	0.0420
0.600	0.0420	0.0260
0.665	0.0174	0.0040
0.676	0.0131	0.0000
0.700	0.0040	(0.0080)
0.711	0.0000	(0.0116)
0.777	(0.0251)	(0.0340)
0.800	(0.0340)	(0.0420)
0.888	(0.0675)	(0.0720)
0.900	(0.0720)	(0.0760)
1.000	(0.1100)	(0.1100)

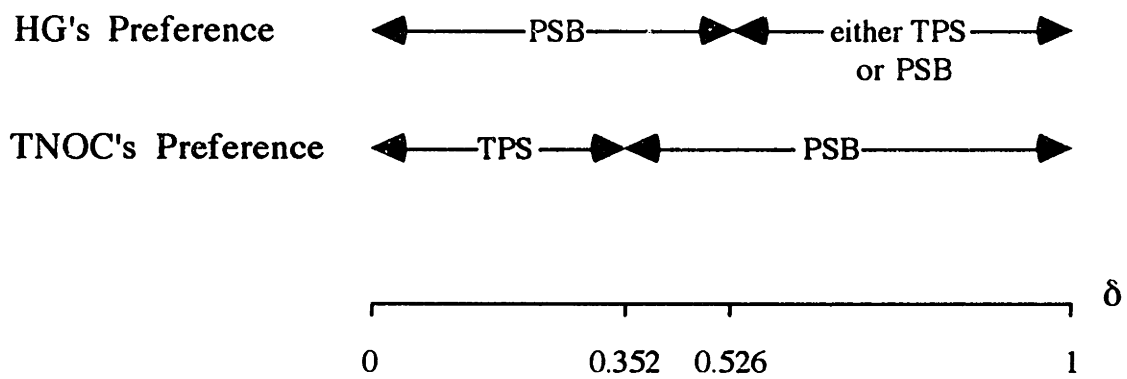


Figure 5.1 :
 The choice of contract form between
 a traditional production-sharing contract (TPS) and
 a production-sharing contract with a buyout option (PSB)

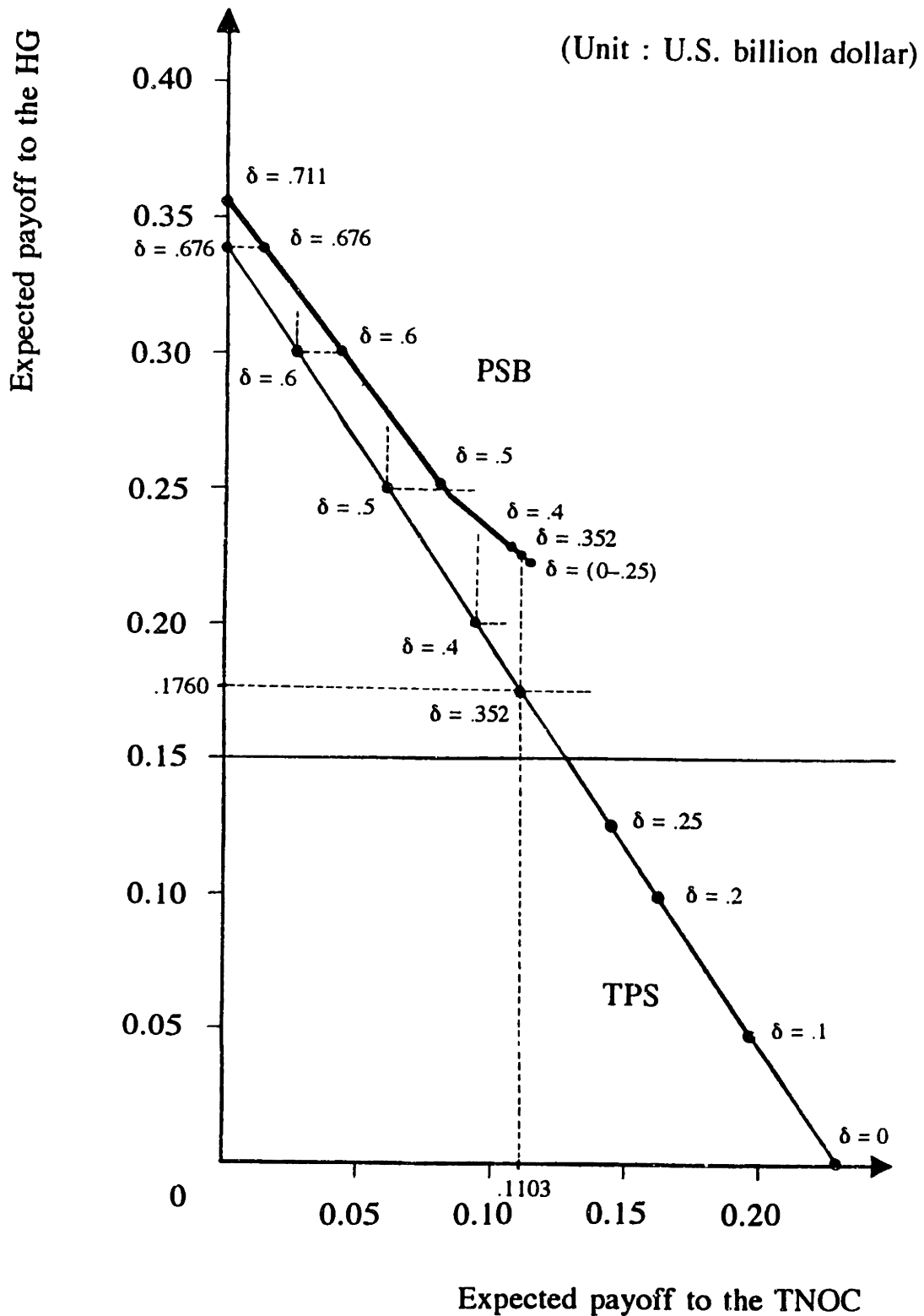


Figure 5.2 :
 The expected payoffs to the HG and TNOG under a traditional production-sharing contract (TPS) and a production-sharing contract with a buyout option (PSB)

ures 5.1 and 5.2 thus dictate that our first hypothesis—There exists a range of tax rate δ in which a production-sharing contract with a buyout option dominates a traditional production-sharing contract from the perspectives of both the host government and transnational oil company—is verified under the postulated assumptions of this experiment. In addition, that range of δ is (.352, .711) because any $\delta \geq .711$ makes this project a non-positive net-present-value investment for the TNOC.

Any point on the thick line in Figure 5.2 is Pareto-optimal in that, for a two-party negotiation on δ and the form of contract, there exist no other alternatives to make one party better off while not making the other worse off. Unless the HG's minimum expected payoff is less than .1760, a production-sharing contract with a buyout option dominates a traditional production-sharing contract. Nevertheless, if an arbitrator is introduced into this context, then the arbitrator could increase the expected payoffs to both the HG and TNOC by increasing or decreasing the agreed-upon δ , thus an increase in total expected payoff, and splitting the "extra payoff" between the two parties. The slope of the TPS and PSB lines informs the arbitrator whether to increase or decrease the negotiated δ and justifies this strategy. See Tables 5.5 and 5.6 for numbers.

When the HG and TNOC agree upon any $\delta < .352$ and a traditional production-sharing contract, the issue of a distributive bargain occurs if they try to switch to a production-sharing contract with a buyout option and negotiate for δ under this contract form. In fact, the TNOC would not

Table 5.5 :
The expected payoffs to the HG and TNOC from
a traditional production-sharing contract (TPS)

δ	Expected payoff to the HG under a TPS	Expected payoff to the TNOC under a TPS	Sum of expected payoffs under a TPS
0.000	0.0000	0.2300	0.2300
0.100	0.0500	0.1960	0.2460
0.200	0.1000	0.1620	0.2620
0.300	0.1500	0.1280	0.2780
0.400	0.2000	0.0940	0.2940
0.500	0.2500	0.0600	0.3100
0.600	0.3000	0.0260	0.3260
0.676	0.3380	0.0000	0.3380
0.700	0.3500	(0.0080)	0.3420
0.800	0.4000	(0.0420)	0.3580
0.900	0.4500	(0.0760)	0.3740
1.000	0.5000	(0.1100)	0.3900

Table 5.6 :
The expected payoffs to the HG and TNOC from
a production-sharing contract with a buyout option (PSB)

δ	Expected payoff to the HG under a PSB	Expected payoff to the TNOC under a PSB	Sum of expected payoffs under a PSB
0.000	0.2241	0.1121	0.3362
0.100	0.2241	0.1121	0.3362
0.200	0.2241	0.1121	0.3362
0.300	0.2242	0.1119	0.3361
0.400	0.2291	0.1061	0.3352
0.500	0.2516	0.0800	0.3316
0.600	0.3000	0.0420	0.3420
0.700	0.3500	0.0040	0.3540
0.711	0.3553	0.0000	0.3553
0.800	0.4000	(0.0340)	0.3660
0.900	0.4500	(0.0720)	0.3780
1.000	0.5000	(0.1100)	0.3900

accept a buyout option unless it receives an extra payoff for so doing from the HG in order to prevent it from being worse off as Table 5.4 suggests.

Graphically, the expected payoffs to the HG and TNOC under a traditional production-sharing contract are shown in Figure 5.3. In essence, a buyout option alters these expected payoff functions, and the transfigurations are depicted in Figure 5.4. The shaded area in Figure 5.5 illustrates the value to the HG of a buyout option as a function of tax rate, while the shaded area in Figure 5.6 demonstrates the value to the TNOC of a buyout option as a function of tax rate. Figure 5.7 ties together Figures 5.5 and 5.6. It is apparent from these figures that for a tax range between .352 and .711 in this bargaining model, a production-sharing contract with a buyout option dominates a traditional production-sharing contract.

Under a traditional production-sharing contract, the zone of agreement as expressed by the instructions for the HG and TNOC is $\delta \in [.3, .676]$. The lower limit of .3 is arbitrarily chosen by the HG to get immune from future political objections or accusations. Table 5.4 affirms that $\delta = .676$ yields the expected payoff of zero to the TNOC under a traditional production-sharing contract; any δ less than .676 will make this project a positive net-present-value investment for the TNOC.

However, under a production-sharing contract with a buyout option, Table 5.4 suggests that $\delta = .711$ is the upper limit of negotiable δ for the TNOC. Table 5.2 reveals that if the HG needs to maintain its expected payoff of .15 as it would receive at $\delta = .3$ under a traditional production-shar-

Expected payoff
in billion dollars

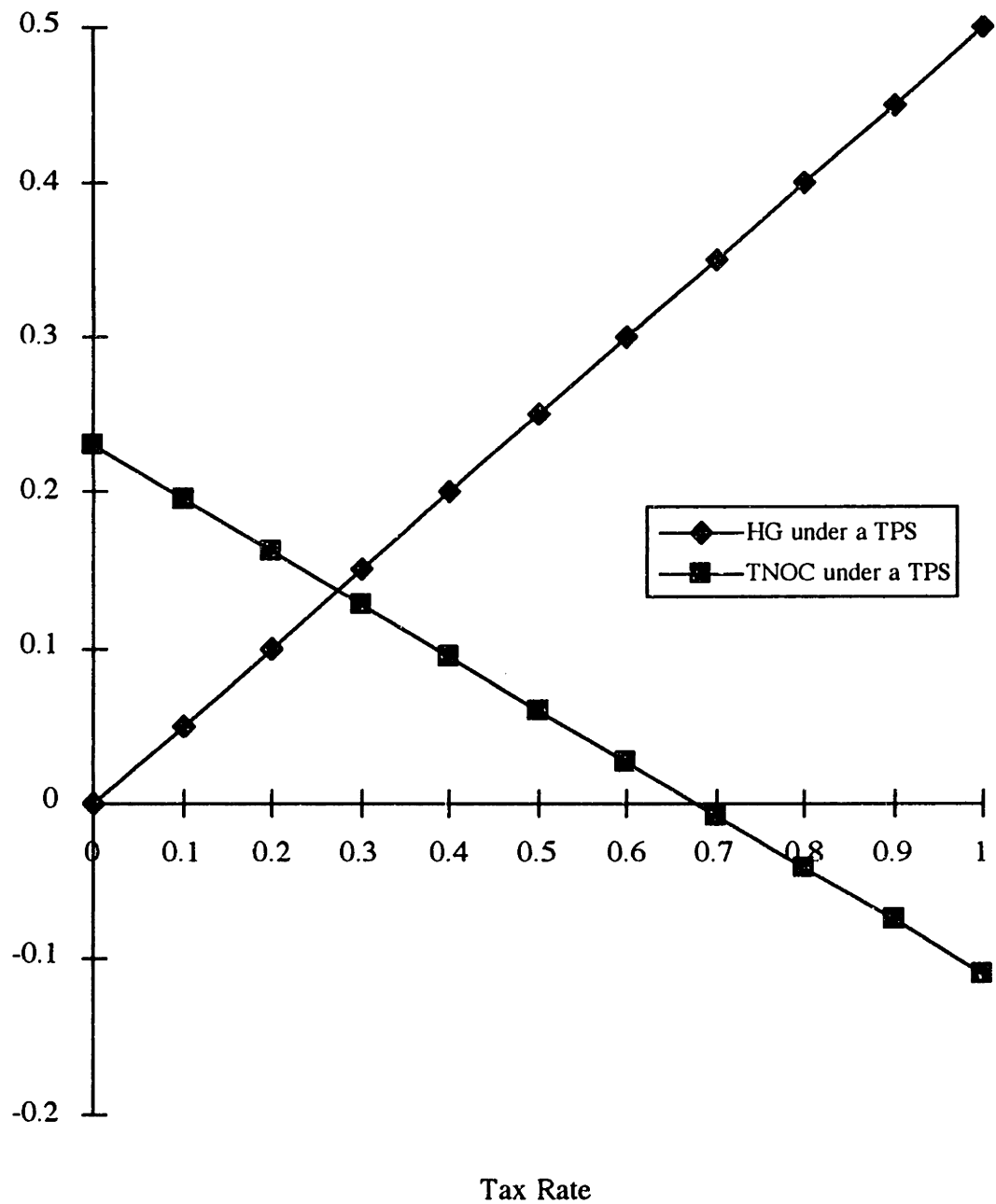


Figure 5.3 :
The expected payoffs to the HG and TNOc
under a traditional production-sharing contract (TPS)

Expected payoff
in billion dollars

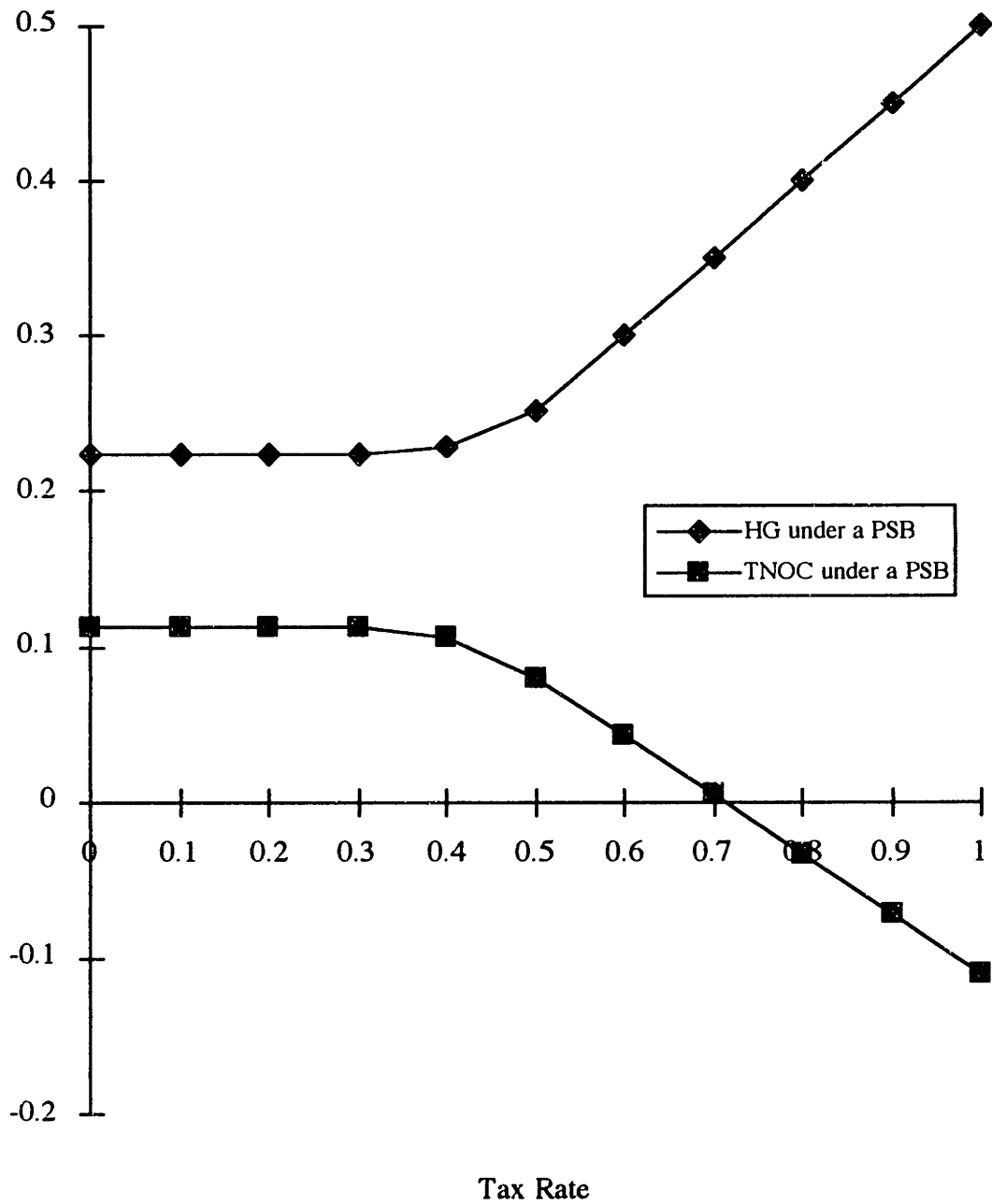


Figure 5.4 :
The expected payoffs to the HG and TNOC
under a production-sharing contract with a buyout option (PSB)

Expected payoff
in billion dollars

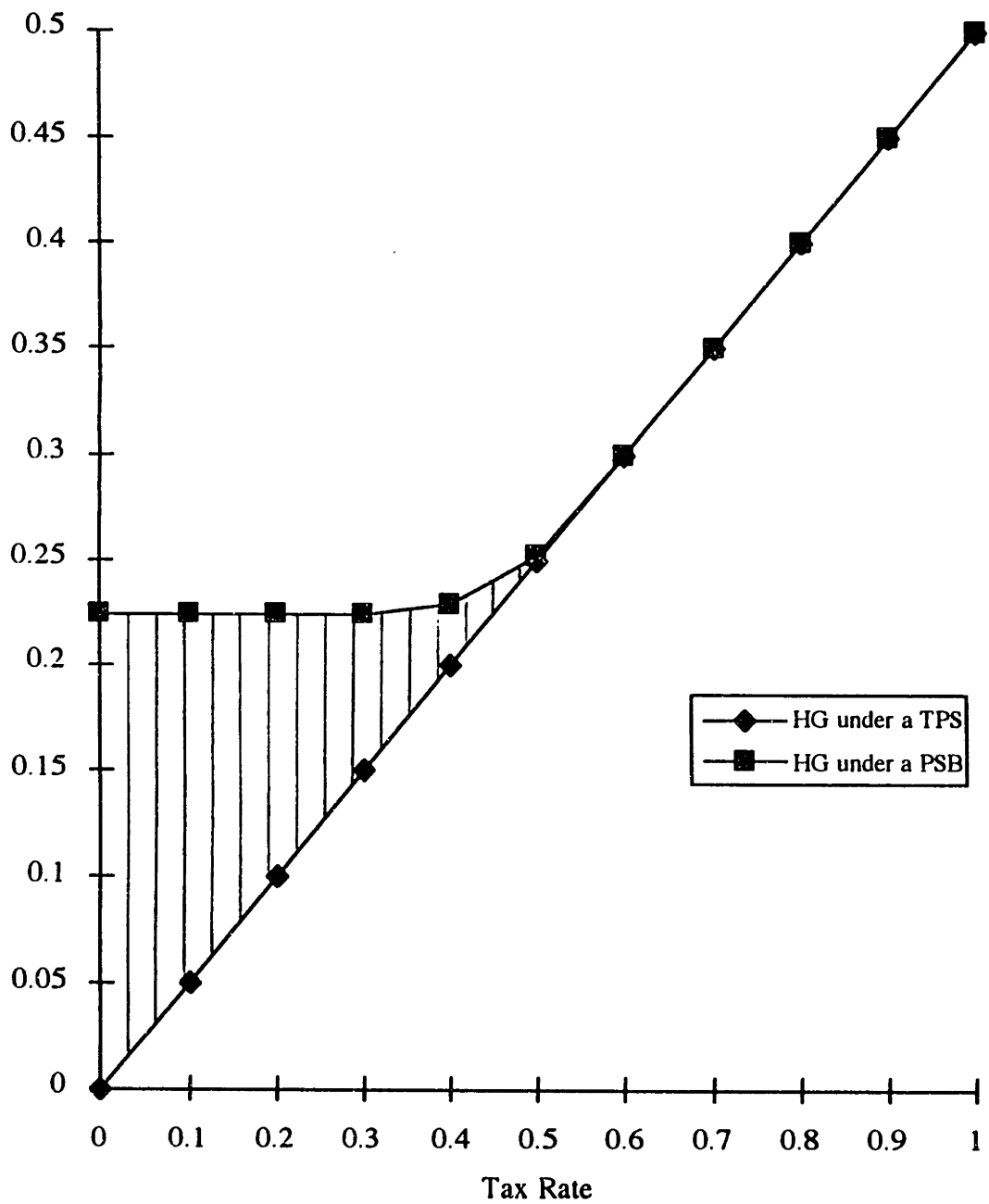


Figure 5.5 :
The value to the HG of a buyout option

Expected payoff
in billion dollars

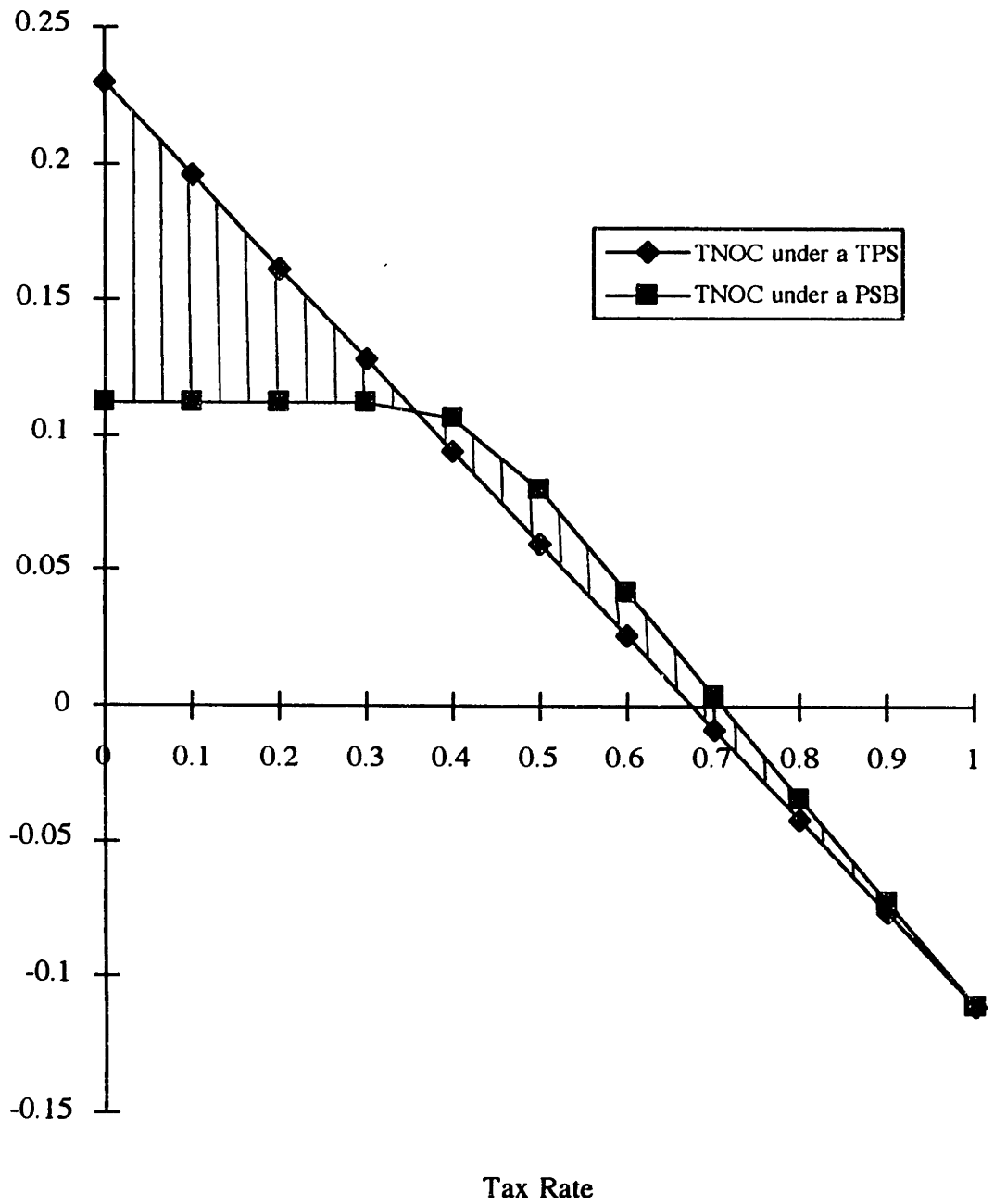


Figure 5.6 :
The value to the TNO of a buyout option

Value of Buyout Option
in billion dollars

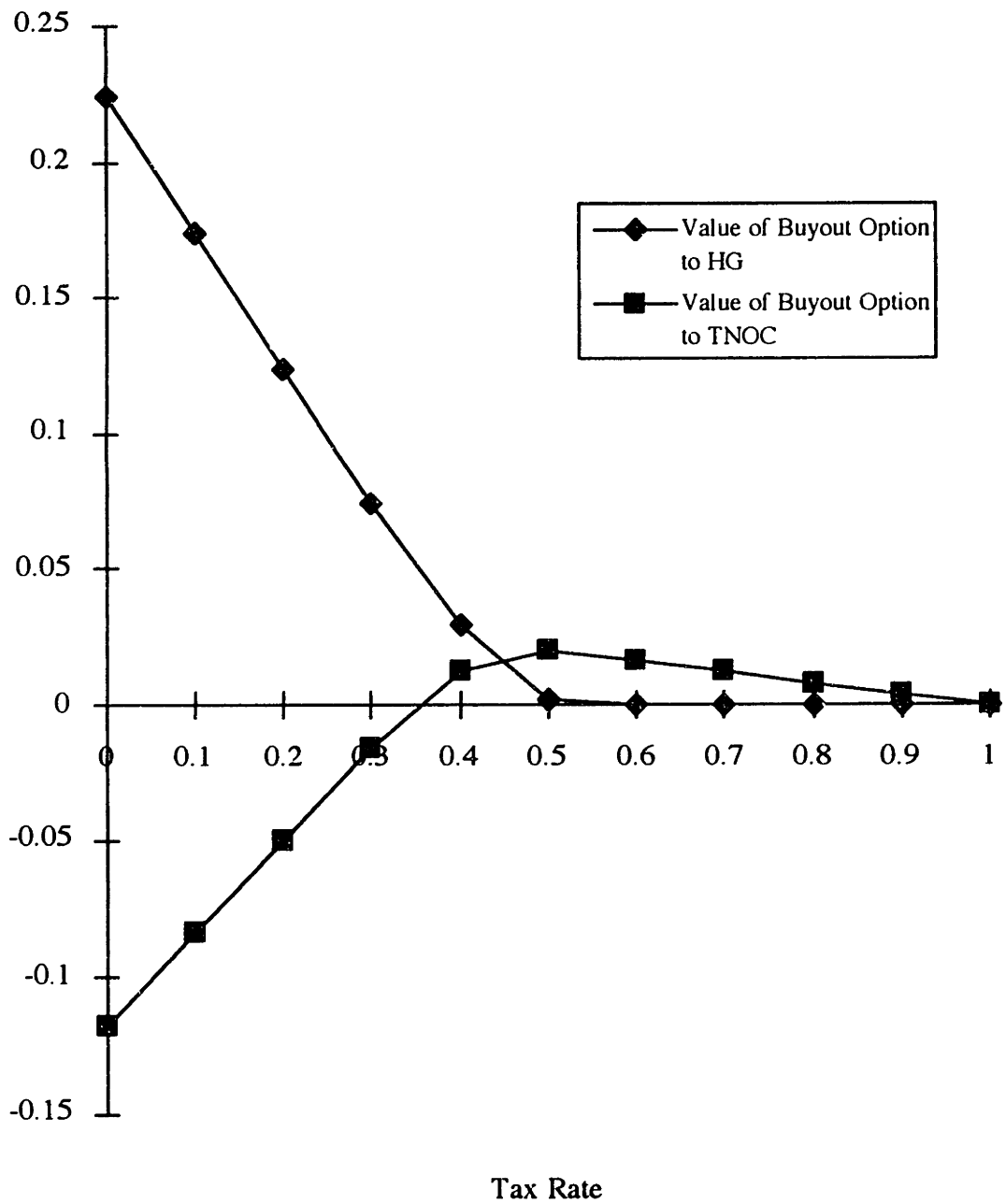


Figure 5.7 :
The value of a buyout option as a function of tax rate

ing contract then the HG is better off with a production-sharing contract with a buyout option; the lower limit of negotiable δ for the HG is 0 in this case because the HG will at least receive the expected payoff of .2241 from project buyout. Hence, the zone of agreement is expanded to $\delta \in [0, .711]$ in a production-sharing contract with a buyout option, and our second hypothesis—the zone of agreement in a production-sharing contract with a buyout option is larger than that in a traditional production-sharing contract—is verified under the particular assumptions of this experiment.

Consequently, an integrative bargain between δ and the contractual format exists in the presence of a buyout option. Theoretically, we would expect the experimental results to show that both the HG and TNOC choose a production-sharing contract with a buyout option for a negotiated $\delta > .352$. For $\delta \leq .352$, either a traditional production-sharing contract or a production-sharing contract with a buyout option will suffice because there is no dominance in contractual format in this range of δ .

5.3 THE EXPERIMENTAL RESULTS

This experiment was conducted at the Hulsizer Room of Ashdown House on M.I.T. campus on Friday, December 10, 1993 from 6 p.m. to 8:30 p.m.. Twenty M.I.T. students participated. At the beginning of the experiment, twenty copies of the instructions for the HG and TNOC and answer sheets were distributed to the experimental subjects. Each experi-

mental subject was assigned a role as either the HG or the TNOC and allowed to select his/her negotiation mate to form a negotiation team.

The objective of each negotiator was to maximize his/her expected payoff from the project. Each team had to simultaneously negotiate on two issues: (i) a tax rate and (ii) a contractual format, either a traditional production-sharing contract or a production-sharing contract with a buyout option. Although they were permitted to reach no agreement, they would receive nothing as their payoff in so doing. Pizzas and refreshments were available throughout the negotiation period.

Each team was motivated by three prizes to obtain the largest sum of their expected payoffs. In addition, as an individual, each negotiator representing the HG and TNOC was encouraged by two prizes to acquire the highest expected payoff. The results are summarized as follows:

(1) *Statistical summary.* One negotiation team was removed from a pool of samples because they agreed on a tax rate not in the specified tax range. The sample size was then reduced to eighteen negotiators or nine negotiation teams.

	MEAN	STANDARD DEVIATION
NEGOTIATED TAX RATE	0.4588	0.1502
HG'S EXPECTED PAYOFF	\$ 0.2501 x 10 ⁹	\$ 0.0607 x 10 ⁹
TNOC'S EXPECTED PAYOFF	\$ 0.0818 x 10 ⁹	\$ 0.0439 x 10 ⁹
NEGOTIATION TIME	63.7 minutes	26.2 minutes

A production-sharing contract with a buyout option was preferred by 88.89% of negotiators whereas a traditional production-sharing contract was chosen by 11.11% of negotiators as their final contractual format.

(2) *Informational Management.*

- Negotiators in seven teams did not reveal reservation tax rate or target expected payoff either trustfully or strategically.
- One TNOC announced an estimate of its investment to the HG at the beginning of the negotiation process.
- One negotiation team exchanged all information and discovered the best combined outcome; this collusion led to the largest sum of expected payoffs to both parties. In this case, the HG's expected payoff was 0.3553 whereas the TNOC's expected payoff was 0. This sum of expected payoffs is maximal in this problem setting.

(3) *Performance Satisfaction Index.* On a scale from 0 to 10, for 0 as extremely poor and 10 as extremely well, the mean of the HG performance satisfaction index is 6.33 and the mean of the TNOC performance satisfaction index is 5.33. In words, experimental subjects are, on average, contented with their negotiating performance. These indices are consistent with the fact that on average the HG would receive $0.2502 - 0.15 = 0.1002$ billion dollars over its required revenue of 0.15 billion dollars while the TNOC would obtain 0.0818 billion dollars net of its investment.

(4) *Contractual Format.* The experimental results demonstrated that for a tax range between 0.352 and 1, a production-sharing contract with a buyout option was preferred: The six negotiation teams who agreed upon tax rate ranging from 0.4 to 0.71 chose a production-sharing contract with a buyout option. Two teams chose a production-sharing contract with a buyout option and a tax rate of 0.32 and 0.3, respectively. Only one team agreed upon a traditional production-sharing contract and a tax rate of 0.3. These results are logical because in this experimental environment there is no dominance in contractual format between a production-sharing contract with a buyout option and a traditional production-sharing contract for a tax range between 0 and 0.352. The negotiated outcomes of these three teams thus cannot be improved while not making any party worse off. In addition, 88.89% of negotiators consciously recognized that they were engaged in an integrative bargain between a tax rate and a contractual format in the presence of a buyout option.

(5) *Comments.* Each negotiator was enthusiastic and concentrated on getting best possible results, either individually or as a team in case of collusion. The average negotiation time was 63.7 minutes, almost twice the average negotiation time of 33.0 minutes in the pilot tests. This situation can be explained: Consequences of negotiated outcomes motivate negotiators to be more cautious in real process of negotiation. The negotiators in the pilot tests knew that there was neither reward for good performance nor penalty for poor performance, thus negotiating on the sole basis of sufficiency.

One negotiation team colluded. They detected the slope of the PSB line as in Figure 5.2 and strategically increased their agreed-upon tax rate to 0.71 which is the highest possible rate—resulting in a maximal sum of expected payoffs—and signed a "second agreement" specifying how to split the extra payoff among them. One lesson to learn from this circumstance is that we should further investigate what the final share of each negotiator in any collusive team will be. In other words, we should also focus on "second agreement" terms designed to split a sum of payoffs in order to identify the final distribution of the project payoff.

One-third of experimental subjects agreed upon a tax rate between 0.45 and 0.55. If they had possessed perfect information, they would have negotiated a different tax rate because this tax range yields the lowest sum of expected payoffs to both parties—See Table 5.6. Since each negotiator was to maximize his/her expected payoff from the project, in reality it may not be in his/her interest to maximize the total expected payoff as a team. Nevertheless, in this experiment a "second agreement" between the two parties offers an additional payoff to each party.

5.4 CONCLUDING REMARKS

This experiment simulates the process of negotiation between host governments and transnational oil companies. Negotiating behavior and outcomes in the presence of a buyout option comply with most of the premises of our theory: (i) For a tax range between 0.352 and 1, a produc-

tion-sharing contract with a buyout option is preferred by both the host government and transnational oil company to a traditional production-sharing contract and (ii) Most of negotiators (88.89%) perceived an integrative bargain between a tax rate and a contractual format in the presence of a buyout option.

In this experiment, each negotiator tended to regard prizes as his/her real payoff and acted accordingly. In essence, the prizes should have served as an incentive tantamount to career promotion in the negotiator's organization with the one exception that prizes are distributive in case of collusion to acquire a larger sum of expected payoffs, but career promotion is not. Change of one criterion from the largest sum of expected payoffs to the largest sum of standardized z-scores¹³ motivates each negotiator and his/her counterpart to perform simultaneously well above average and thus may prevent collusion.

¹³ If x is a negotiator's expected payoff, the standardized z-score can be computed as: $z = (x - \bar{x})/s_x$. See Appendix 4 for summary of the experimental results.

CHAPTER 6

CONCLUSIONS AND FURTHER RESEARCH

6.1 CONCLUSIONS

The continuing lag in oil and gas exploration in developing countries is one of the more perplexing aspects of the international energy problem. There is universal agreement that the developing countries' allotment of worldwide exploration effort in the past has been less than would be expected on the sole basis of their geological prospects. A number of studies have documented this situation. Although the search for petroleum supplies is a systematic process, various factors that reduce returns in net present value terms to transnational oil companies limit the scope of exploration in many developing countries.

Geological promise is a necessary but not sufficient condition for attracting foreign investment. Other determinants unrelated to resource potential are economic, institutional, and political factors. For example, undue restriction of the host government's contractual arrangements governing foreign investment in petroleum exploration as well as excessive political risk can make foreign investment in the country unappealing. More importantly, political risk has been cited as a primary reason for this persisting inefficiency; thus contractual arrangements, and tax regimes to a lesser extent, tend to have the most powerful impacts on petroleum exploration. Therefore, if the geological prospects are not the problem, there

must be opportunities for productive policy actions to be taken by developing countries to attain a desired level of petroleum exploration.

A mediated buyout option is introduced into a traditional production-sharing contract as a novel contractual feature to be employed along with other instruments of political risk management. The role of innovative contract design is to mitigate political risk as perceived by transnational oil companies given a fixed probability distribution of project cash flows, thus in effect increasing the transnational oil company's expectation of project payoff and decreasing the transnational oil company's motivation to indulge in strategic mismanagement. Effective contract design alleviates costly gaming behavior between the host government and transnational oil company and enhances the overall attractiveness of the investment project to both parties. A buyout option seems promising as a device to facilitate mutually advantageous petroleum exploration deals.

The principal findings of this dissertation are theoretical, experimental, and practical. Mutual gains to both host governments and transnational oil companies can be achieved and are shown by formal analysis of properties of a production-sharing contract with a buyout option. Whether a production-sharing contract with a buyout option strictly dominates a traditional production-sharing contract depends on several factors: the perceived probabilities of expropriation in the absence of and in the presence of a buyout option, each party's assessment of the project payoff, and the mediator's function for determining the buyout value. However, a tax range under which expected payoffs from a production-sharing contract

with a buyout option are Pareto optimal from the perspectives of both the host government and transnational oil company is identifiable. Moreover, the buyout option expands the domain of agreement between both parties.

This research provides a host government with an optimal policy regarding when to exercise the buyout option and the conditions under which this buyout policy is unique. A binomial lattice price path example illustrates how the host government can construct such an optimal policy. It is shown that, in general, the buyout option has higher value to the host government at a low tax bracket than at higher tax rates and that it supplies the transnational oil company with a cut-off tax rate such that any tax rate greater than the cut-off will prevent the host government from exercising the buyout option in the future. Nevertheless, because its primary objective is to maximize its expected payoff from the project, it is rational for a transnational oil company to negotiate a tax rate lower than the cut-off. In addition, results from an experiment conducted to simulate process of negotiation between host governments and transnational oil companies reveal that their negotiating behavior and outcomes in the presence of a buyout option comply with the theories.

6.2 RECOMMENDATIONS FOR FURTHER RESEARCH

Three immediate extensions to this buyout model are: (i) the possibility of the mediator assigning a more general shape to his/her buyout value function; (ii) the possibility of the buyout value function known with certainty a priori by neither the host government nor a transnational oil

company; and (iii) the probability of expropriation as a function of tax rate and/or project payoff. The discount factor and the shape of a buyout value function could also be considered additional issues for negotiation between host governments and transnational oil companies. This course of research may hold much promise for making the buyout option more pragmatic for the management of fiscal risk in petroleum exploration and development.

Furthermore, the specific political contingency addressed in this dissertation is expropriation, but it could equally be other forms of political risk—changes in tax regimes or operating requirements, for instance. The essential point is that the contract provides a tool by which troublesome risks identified in the assessment phase can be addressed, presumably reduced, and managed during project implementation.

An option-like incentive is another contractual feature that diminishes fiscal risk perceived by transnational oil companies. A two-phase exploration and development contract, in which the transnational oil company is permitted to observe exploration results before negotiating a development contract with the host government, may allow the transnational oil company to allocate risks more efficiently and thus increase exploration activity in developing countries.

Another interesting incentive in petroleum contracts is a sliding-scale severance tax rate, in which the tax rate is a function of project cash flows: the lower the project cash flow, the lower the tax rate, and vice versa. This contractual feature may increase the expectation of project payoff

from the viewpoint of both the host government and transnational oil company, thus enhancing the overall attractiveness of the investment project.

Throughout this study we have assumed that, besides the buyout option, there is no other operating option or option-like incentive to be considered in the future. Examples of such options are (i) the option to expand or contract the scale of a project's operations or to abandon a project early when future market conditions turn out worse than initially expected; (ii) the option to wait to observe exploration results before signing a development contract as in a two-phase exploration and development contract; and (iii) the option to apply a variable tax rate according to project cash flows as in a contract with a sliding-scale tax rate. These options add not only reality to the project but also extra value and attractiveness.

Finally, many investment projects in practice are not independent but links in a chain of interrelated projects. Making an investment outlay to acquire the first project in such a sequence of contingent investments is a prerequisite for opening up the opportunity to obtain the benefits of the next investment in line. In essence, such investment opportunities are options on options or compound options. Project interdependence may have considerable strategic import since it may justify acceptance of projects with a negative net present value on the basis of their potential to open up subsequent new investment opportunities in the future. Further research is needed to develop a model that fully values these option-like incentives and compound options.

APPENDIX 1

INSTRUCTIONS FOR HOST GOVERNMENTS

CONTRACT FORMAT ONE:

A TRADITIONAL PRODUCTION-SHARING CONTRACT (TPS)

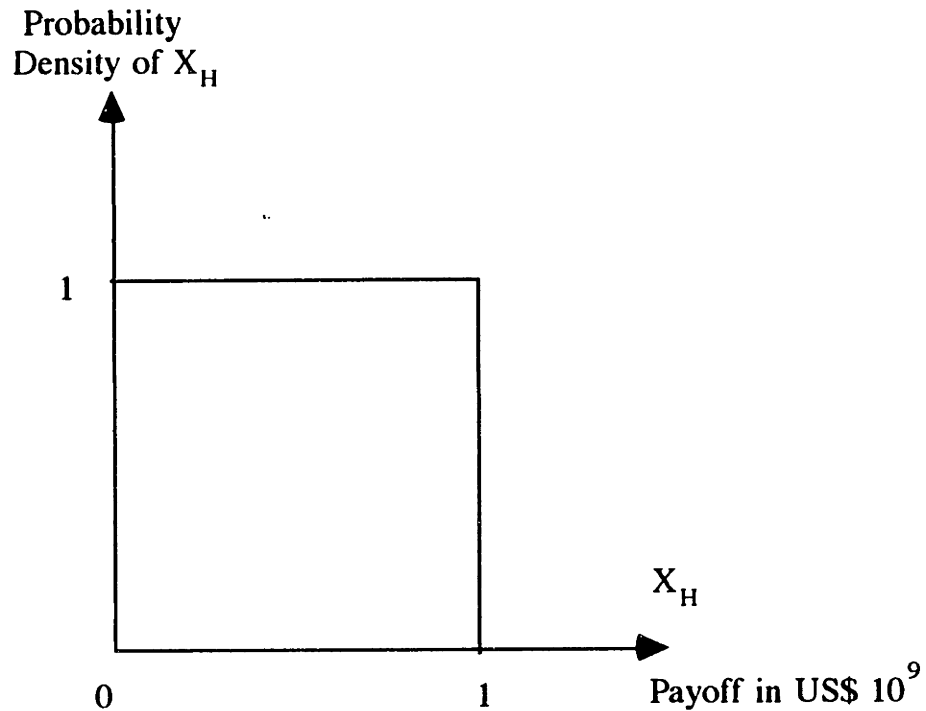
A transnational oil company and the host government of a country with considerable petroleum potential are negotiating a contract for development of a large block of acreage. The principal issue here is the fraction of revenue to be subject to a severance tax.

The petroleum investment project under consideration has a time horizon of two periods. The host government and transnational oil company negotiate in the initial period a value of δ —the tax rate that the host government will impose on the project payoff in the following period. Initial actions available to both parties are either to agree jointly to a contract specified by a choice of δ or not to consummate any contract. If no contract is concluded, the payoff is zero to each party.

Objective: Your objective is to maximize your expected payoff—or tax revenue.

Considerations:

(1) You are to scale all monetary values in this negotiation into U.S. billion dollars. Let X_H denote the project payoff in the terminal period. This payoff is uncertain. You are quite optimistic about the project's potential and suppose that X_H is uniformly distributed between 0 and 1.



(2) Your government nationalized two foreign oil companies' assets fifteen years ago. It was alleged that these transnational oil companies, along with some government high-ranking officials, conspired, to the detriment of your country, to fix local crude oil prices. However, you strongly believe that expropriation of any kind is unlikely to happen again in your country.

(3) One of your country's primary concerns is the need for security of petroleum supply. Nevertheless, the minimum expected payoff that you could agree upon without any future political objections or accusations of a "sell-out" is .15, which is ensured at $\delta = 30\%$. Therefore, the range of δ you are to negotiate with transnational oil companies is from 30% to 100%. This is not public information.

(4) You know that this project is regarded by all transnational oil companies in your country as very promising. If you do not reach any agreement on the value of δ with the transnational oil company with which you are currently negotiating, you will lose this revenue-enhancement opportunity. Moreover, your reputation for being a tough negotiator may discourage other transnational oil companies from investing in petroleum exploration and production activities in your country in the future.

CONTRACT FORMAT TWO:

A PRODUCTION-SHARING CONTRACT WITH A BUYOUT OPTION (PSB)

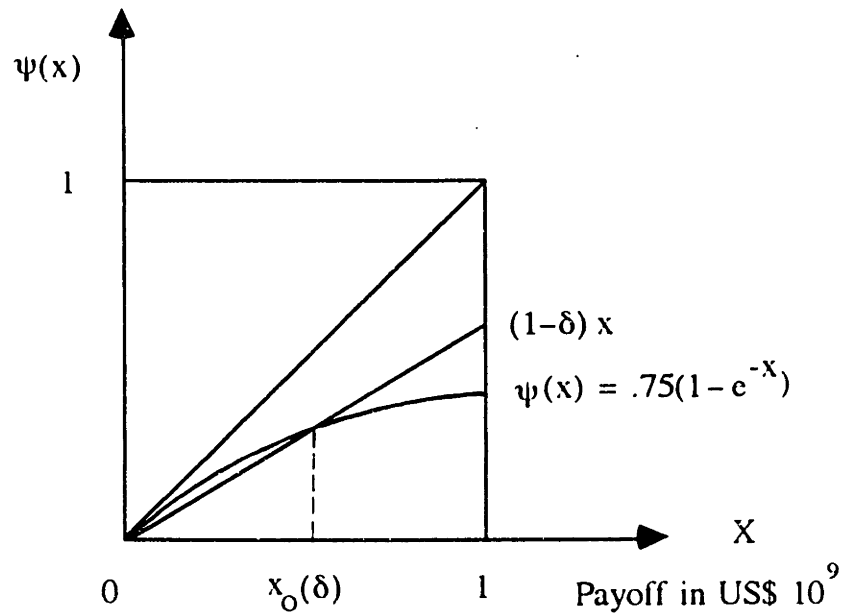
The characteristics of a buyout option can be described as follows: the host government has the right to take over the project at the beginning of next period but has to pay a monetary sum, called a buyout value (ψ), to the transnational oil company to exercise this right. The buyout value (ψ) is to be specified by a predetermined nonpartisan mediator.

The petroleum investment project under consideration has a time horizon of two periods. The host government and transnational oil company negotiate in the initial period a value of δ with a mediated buyout option in the terminal period. Initial actions available to the host government and transnational oil company are either to agree jointly to a contract specified by a choice of δ and a mediator mechanism or not to consummate any contract. If no contract is concluded, the payoff is zero to each party.

Objective: Your objective is to maximize your expected payoff—or tax revenue.

Additional Considerations:

(5) It is known to both the host government and transnational oil company that this mediator assigns a buyout value that is a function of x : $\psi(x) = .75(1-e^{-x})$ for $0 \leq x \leq 1$.



(6) It is also known to both parties that for $\psi(x) = .75(1 - e^{-x})$ and $0 \leq x \leq 1$, the host government's gain from project buyout is $(1 - \delta) \cdot x - .75(1 - e^{-x})$. For $\delta \geq .526$, this gain is negative for all x , while for $\delta < .526$, this gain may be positive or negative depending on realization of x . The following table shows the relationship between δ and the probability that the host government will buy out the project.

δ	$x_0(\delta)$	Pr. {buyout}
0.9	7.50	0.00
0.8	3.65	0.00
0.7	2.23	0.00
0.6	1.42	0.00
0.5	0.87	0.13
0.4	0.46	0.54
0.3	0.14	0.86
0.2	0.00	1.00
0.1	0.00	1.00

(7) You have demonstrated your willingness to reduce the transnational oil company's risk of being expropriated by introducing a buyout option and incorporating the clause into the contract so that the transnational oil company is guaranteed to receive fair compensation of $\psi(x)$ if you exercise the right to buy out the project. You believe that this buyout option is a breakthrough that diminishes the transnational oil company's concern about expropriation risk. Moreover, you stand behind this innovative form of contract in all circumstances.

(8) If $x - \psi(x) < \delta x$, you will not buy out the project but will receive your share of δx from the transnational oil company. However, you will exercise the right to buy out the project and pay $\psi(x)$ to the transnational oil company for compensation only when $x - \psi(x) > \delta x$. In other words, this buyout option offers you an additional opportunity to gain a positive net present value from project buyout.

(9) Keeping in mind that your required expected payoff from the project is .15 as in a TPS, you are to negotiate with transnational oil companies to acquire an expected payoff (or tax revenue) that is as large as possible—not to obtain the highest possible tax rate δ .

APPENDIX 2

INSTRUCTIONS FOR TRANSNATIONAL OIL COMPANIES

CONTRACT FORMAT ONE:

A TRADITIONAL PRODUCTION-SHARING CONTRACT (TPS)

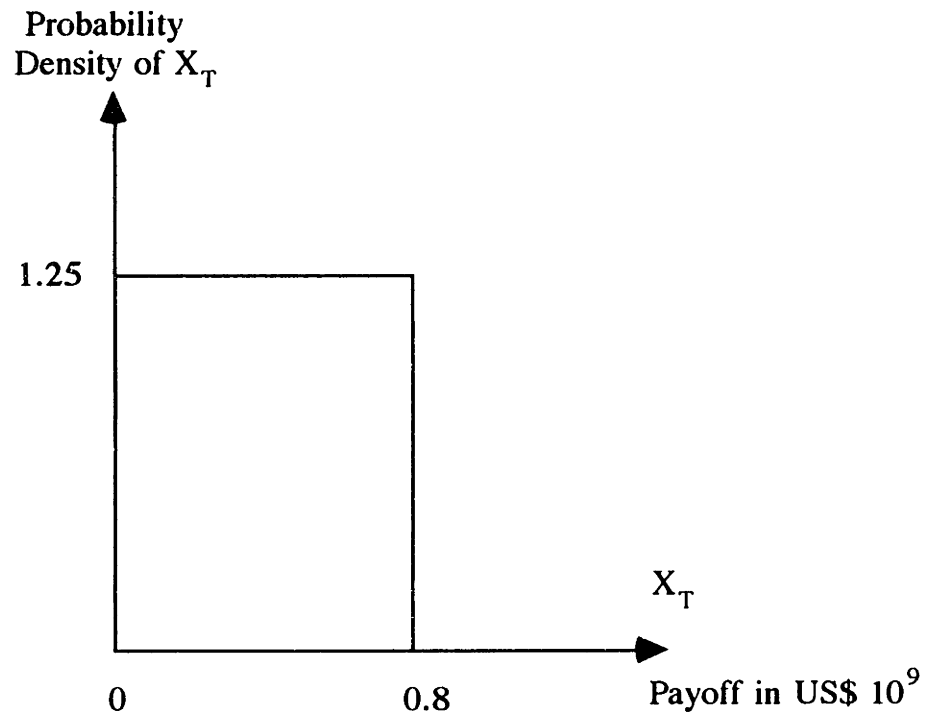
A transnational oil company and the host government of a country with considerable petroleum potential are negotiating a contract for development of a large block of acreage. The principal issue here is the fraction of revenue to be subject to a severance tax.

The petroleum investment project under consideration has a time horizon of two periods. The host government and transnational oil company negotiate in the initial period a value of δ —the tax rate that the host government will impose on the project payoff in the following period. Initial actions available to both parties are either to agree jointly to a contract specified by a choice of δ or not to consummate any contract. If no contract is concluded, the payoff is zero to each party.

Objective: Your objective is to maximize your expected payoff after tax and investment.

Considerations:

(1) You are to scale all monetary values in this negotiation into U.S. billion dollars. Your assessment of the project payoff, denoted by X_T , is uniformly distributed between 0 and 0.8. You need to make an investment of 0.11 in the initial period (the discount factor is unity, though) in exchange for a share of $(1-\delta)$ of X_T in the terminal period.



(2) Since the host government of the country in which you are considering investing in a petroleum exploration and production project expropriated two foreign oil companies' assets fifteen years ago, you feel that there exists a probability of .15 of being expropriated without any compensation.

(3) Your investment decision process takes into account this concern about expropriation risk and reveals that the maximum rate of δ that still makes the expected net present value of this investment project positive is 67.6%. Therefore, the range of δ you are to negotiate with the host government is from 0% to 67.6%. This is not public information.

(4) This project is regarded by all transnational oil companies in this country as very promising. If you do not reach any agreement on the value of δ with the host government, you will lose this positive-net-present-value investment opportunity. It is quite certain that another oil company will be able to consummate a deal with the host government.

CONTRACT FORMAT TWO:

A PRODUCTION-SHARING CONTRACT WITH A BUYOUT OPTION (PSB)

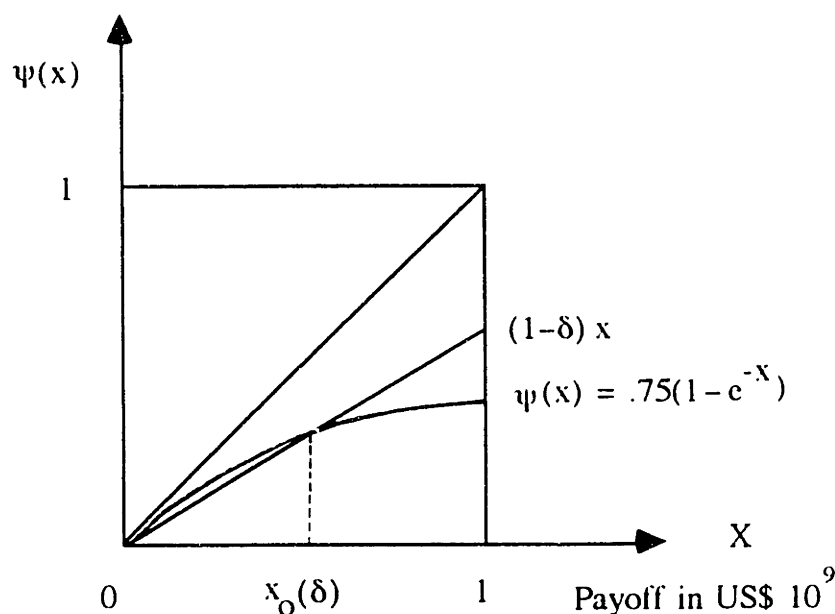
The characteristics of a buyout option can be described as follows: the host government has the right to take over the project at the beginning of next period but has to pay a monetary sum, called a buyout value (ψ), to the transnational oil company to exercise this right. The buyout value (ψ) is to be specified by a predetermined nonpartisan mediator.

The petroleum investment project under consideration has a time horizon of two periods. The host government and transnational oil company negotiate in the initial period a value of δ with a mediated buyout option in the terminal period. Initial actions available to the host government and transnational oil company are either to agree jointly to a contract specified by a choice of δ and a mediator mechanism or not to consummate any contract. If no contract is concluded, the payoff is zero to each party.

Objective: Your objective is to maximize your expected payoff after tax and investment—even though this induces the host government to buy out the project.

Additional Considerations:

(5) It is known to both the host government and transnational oil company that this mediator assigns a buyout value that is a function of x :
 $\psi(x) = .75(1 - e^{-x})$ for $0 \leq x \leq 1$.



(6) Your shrewd practice makes the host government very optimistic about the project payoff—if X_H is the host government's assessment of the project payoff in the terminal period, then X_H is uniformly distributed between 0 and 1—so the host government is willing to agree on a lesser value of δ . The host government does not seem to realize this plot.

(7) It is also known to both parties that for $\psi(x) = .75(1-e^{-x})$ and $0 \leq x \leq 1$, the host government's gain from project buyout is $(1-\delta) \cdot x - .75(1-e^{-x})$. For $\delta \geq .526$, this gain is negative for all x while for $\delta < .526$, this gain may be positive or negative depending on realization of x . The following table shows the relationship between the probability that the host government will buy out the project, the probability that the transnational oil company believes that the project buyout will occur, and δ .

δ	$x_o(\delta)$	Pr.{buyout} for the HG	Pr.{buyout} for the TNOC
0.9	7.50	0.00	0.00
0.8	3.65	0.00	0.00
0.7	2.23	0.00	0.00
0.6	1.42	0.00	0.00
0.5	0.87	0.13	0.00
0.4	0.46	0.54	0.43
0.3	0.14	0.86	0.83
0.2	0.00	1.00	1.00
0.1	0.00	1.00	1.00

(8) The host government has demonstrated its eagerness to reduce your perceived probability of being expropriated by including a buyout option clause in the contract so that you are guaranteed to receive fair compensation of $\psi(x)$ if the host government chooses to exercise its right to buy out your project. You believe that this buyout option diminishes your concern about the expropriation risk. However, you are not absolutely convinced that the host government will adhere to the terms and conditions of this innovative form of contract; you estimate that there still exists a slim chance of .05 of being expropriated without compensation. As a result of your perception of lower expropriation risk, the maximum rate of δ that still makes the expected net present value of this investment project positive increases to 71.1%.

APPENDIX 3

ANSWER SHEET FOR THE EXPERIMENT

(To be filled out during negotiations)

Check your name

Name of the host government's representative: _____()

Name of the transnational oil company's representative: _____()

SEQUENCE OF PROPOSALS

Round No.	Tax Rate (δ)	Contract Format* (TPS or PSB)	Your Expected Payoff (in US billion dollars)	Comments
1				
2				
3				
4				
5				
6				
7				
8				

(continue on back if necessary)

FINAL _____ _____ \$_____

Did you tell your rival your own reservation tax rate or target expected payoff (either trustfully or strategically)? What did you announce? At what point in the above sequence?

How well do you think you did in this negotiation?

Extremely poor Extremely well

0 1 2 3 4 5 6 7 8 9 10

* TPS denotes a traditional production-sharing contract while PSB signifies a production-sharing contract with a buyout option.

APPENDIX 4

SUMMARY OF THE EXPERIMENTAL RESULTS

Team	Tax Rate	Contract Format*	HG's Expected Payoff	Z-score ** for the HG	TNOC's Expected Payoff	Z-score for the TNOC
1	0.32	PSB	0.2245	(0.4217)	0.1115	0.6770
2	0.44	PSB	0.2349	(0.2504)	0.0992	0.3969
3	0.50	PSB	0.2516	0.0247	0.0800	(0.0402)
4	0.30	PSB	0.2242	(0.4267)	0.1119	0.6861
5	0.40	PSB	0.2291	(0.3460)	0.1061	0.5540
6	0.66	PSB	0.3300	1.3163	0.0192	(1.4245)
7	0.50	PSB	0.2516	0.0247	0.0800	(0.0402)
8	0.71	PSB	0.3553	1.7331	0.0000	(1.8617)
9	0.30	TPS	0.1500	(1.6491)	0.1280	1.0526

* PSB denotes a production-sharing contract with a buyout option while TPS signifies a traditional production-sharing contract.

** If x is a negotiator's expected payoff, the standardized z-score can be computed as: $z = (x - \bar{x})/s_x$.

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BIOGRAPHICAL NOTE

RESEARCH INTERESTS

Specifically interested in risk sharing, tax regimes, and incentive schemes in joint venture contracts between host governments and transnational corporations.

EDUCATION

Massachusetts Institute of Technology, Cambridge, Massachusetts

Ph.D. in Management Science, 1993.

Dissertation: *Political Risk Management and Its Implications in the Presence of a Buyout Option*. Analysis of political risk assessment and management in the international environment. The implications of political risk for the design of contracts. Introduction of a buyout option model for a petroleum investment project as a device to facilitate mutually advantageous petroleum exploration deals between host governments and transnational oil companies.

Activity:

1988-1989 *Secretary of the Operations Research Society of America*, MIT Student Chapter

Stanford University, Stanford, California

M.S. in Operations Research, 1987.

Chulalongkorn University, Bangkok, Thailand

B.Sc. (First Class Honors) in Statistics, 1986.

H.M. the King Gold Medal for excellence in undergraduate studies, 1986.

Activities:

1985-1986 *President of the Senior Class*

1984-1985 *President of the Junior Class*

EXPERIENCE

Army Training Command, Bangkok, Thailand

1992-1993

First Lieutenant

Commissioned in the Research and Planning Department. Transferred to the Secretariat of the Interior Security Command to examine and analyze political activities and to prepare reports for the Secretary-General.

Ministry of Transport and Communications, Bangkok, Thailand

1991-1992

Personal Secretary to the Minister

Responsible for examining and presenting for approval the works in all ministerial departments involving land transport, post, telegraph, and telephone. Primarily involved in reviewing and reevaluating the efficiency of the country's three million telephone-line expansion concessionary contract.

Senate of Thailand, Bangkok, Thailand

1990-1991

Assistant to Senator

Responsible for arranging schedules and researching particular topics concerning energy and the environment. Also responsible for investigating and summarizing bills and Council of Ministers resolutions.

Parliament of Thailand, Bangkok, Thailand

1988-1989

Parliamentary Intern

Summers

Attached to the Central Bureau to observe and evaluate the performance of the Secretariat of the Parliament, and to learn about the workings of several Senate standing committees.

HONORS

Companion of the Most Noble Order of the Crown of Thailand

Conferred by H.M. the King for dedication to government services, 1993.

Most Eligible Bachelor of 1992

Ranked by *Pooying* magazine as one of five most eligible bachelors in Thailand.

Most Promising Young Professional of 1991

Ranked by *Priew* magazine as one of five most promising young male professionals in Thailand.