ECONOMICS OF REVENUE SYSTEMS IN MALAYSIAN TIMBER CONCESSIONS

By

Awang Noor Abd. Ghani

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ABSTRACT

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Forest revenue systems in most tropical countries have failed to capture for the government much of the available stumpage value or to provide incentives for concessionaires to abide by logging regulations. Designing a forest revenue system is very important to achieve the sustainable management of natural forests and to raise government revenue.

This study addresses the economics of forest revenue systems in Peninsular Malaysia through development of microeconomic static and dynamic models based on uniform and *ad valorem* royalties. The models explicitly specify forest management objectives and assume that concessionaires maximize profits. Empirical analyses were performed using a simultaneous system of equations to estimate the optimal royalties (volume-based charge), premium (area-based charge), harvest volume, and government revenue. The analyses were based on data collected in 1990 from six concessions with different characteristics in the Permanent Forest Estate in three states of Peninsular Malaysia.

The static model specifies that the government's only objective is to maximize revenue from current harvests. Three alternative timber fees were analyzed: uniform royalty, *ad valorem* royalty, and premium. The analyses predicted that the optimal uniform and *ad valorem* royalties would induce

concessionaires to leave timber above the cutting limits, and that the premium would induce them to harvest below the cutting limits. The premium would provide the highest government revenue.

The dynamic model specifies that the government's objective function includes not only current revenue but also the future impacts of over- or under-harvesting. Two alternative fees were analyzed: uniform and *ad valorem* royalties. The analyses predicted that the optimal uniform royalty would induce concessionaires to leave timber above the cutting limits, whereas the optimal *ad valorem* royalty would induce them to harvest below the cutting limits. Compared to the static model, the dynamic uniform and *ad valorem* royalties had lower values, which resulted in larger harvests. The static and dynamic optimal royalties and premiums were found to be much higher than the actual rates.

The implications of the study are that the government must be clear about its forest management objectives, and that it must know how concessionaires will respond to alternative revenue systems. The government should carefully assess forest revenue systems under different forest management objectives to ensure that Peninsular Malaysia obtains maximum benefits from harvesting in its forests. The present royalty and premium rates can be increased substantially to raise additional revenue and to discourage concessionaires from harvesting too intensively.

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CHAPTER ONE

INTRODUCTION

1.1 General Background

Forests have played a significant role in the socioeconomic development of many tropical countries. In their productive and protective roles, tropical forests have contributed to industrial and agricultural development, regional development, conservation, job creation, and poverty eradication. If these benefits are to be fully realized and sustained for future development, forestry policies must be identified and implemented in accordance with management of forest resources based on biological and economic principles.

Unlike those in temperate countries, forests in most tropical countries are owned and administered by government (Lanly, 1982). The government formally transfers concession rights to a concessionaire[1] to harvest timber or to manage a specific area of a forest concession. A system of timber rules and procedures through a concession contract confers rights to harvest timber to concessionaires. Generally, property rights of forests in most tropical countries are not exclusive, transferable, divisible, or enforceable (Vincent & Binkley, 1991). This may be due

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[1]Throughout this dissertation, the term "concessionaire" refers to a timber operator or logger who is involved in timber harvesting and supplying logs from a concession to his own mills, to other domestic mills, or to exporters.

to various provisions in the national constitution and the forest acts in each country. Forests granted to concessionaires for timber harvest are therefore associated with property rights. Concessionaires are likely to adopt a short-term behavior when they harvest timber in the forests. This is because their concession contracts are typically shorter than the average rotation period or growing period of the main timber crop. In tropical countries where forests are managed under an uneven-aged system, governments often decide on minimum-diameter cutting limits. The cutting limits, which normally vary with respect to different species groups, are imposed to allow immature, residual trees to grow naturally so that they can be harvested in the next cutting cycle. Without logging regulations, short-term concessionaires would harvest timber when the marginal log price equaled the marginal logging cost, which would result in overharvesting, the felling of trees that are not yet financially mature.

In some countries, the government also grants long-term forest concessions in an attempt to induce concessionaires to consider the long-term consequences of their actions. A long-term forest concession refers to a lease period which is at least as long as the cutting cycle (the frequency of entry to the stand for harvesting) (35 years) or the rotation (the age of trees at harvest) (60 to 100 years) (Paris and Ruzicka, 1993). Such long-term concessionaires might also be unlikely to harvest at "sustainable" intensities because their discount rates are often high and tropical forest management is fraught with uncertainties (Vincent, 1993b). Therefore, the harvest behaviors of short- and long-term concessionaires might not differ very much. A direct role by the government in natural forest management might thus be unavoidable.

In theory, governments can capture the full stumpage value,[2] or resource rent, of a concession without affecting concessionaires' harvest decisions, through competitive auctioning. In practice, however, forest revenue systems in most tropical countries are implemented by charging timber fees--based either on timber volume (royalty) or the concession area (premium). Generally, timber fees are low and do not reflect the true stumpage value. Low timber fees are associated with inadequate mechanisms to adjust for timber scarcity and failure to offset environmental costs of logging.

The most obvious effect of this fiscal undervaluation is low revenue generation for the government and consequently large windfall profits for concessionaires (Boado, 1988; Gillis, 1980, 1988a, 1988b, 1988c; Page, Pearson, & Leland, 1976; Repetto & Gillis, 1988; Ruzicka, 1979; Vincent, 1990, 1992; Vincent, Awang Noor, & Yusuf, 1993). Other problems include rapid depletion of forest resources (Gillis, 1980), wasteful resource exploitation (Gillis, 1992; Repetto, 1988a), bias against conservation (Gillis, 1980), and illegal logging (Repetto, 1988b).

Undervaluation of the natural forests of Peninsular Malaysia has become increasingly apparent. Results from previous studies reveal that the present forest revenue system fails to capture much of the stumpage value or to provide incentives for concessionaires to abide by logging regulations (Vincent, 1990; Vincent et al., 1993). The estimated rent capture by the government does not exceed 50%, even

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[2] Stumpage value is the commercial value of timber in a standing tree. It is calculated by taking the difference between the price a mill will pay for a log, and the costs of logging and transporting the log from the forest to the mill. It is a type of scarcity rent. It provides a return to a forest owner in a competitive economy.

with tendering (Awang Noor, Vincent, & Yusuf, 1992; Vincent et al., 1993). Moreover, on average, the government rent capture was only 21.8% during the period 1966 through 1985 (Vincent, 1990). Most timber fees have remained virtually constant in most states in Peninsular Malaysia. Only five states have increased their royalties since 1972 (Vincent, 1990).

Revenue that could be used by state governments to support public-sector investments is instead captured by concessionaires at rates far exceeding true normal profits. Timber harvesting is often connected with political patronage; thus, enormous windfall profits captured by concessionaires may be distributed among various parties. Who actually collects this rent is not known.

Previous researchers have attempted to estimate the amount and distribution of stumpage value capture between the government and concessionaires, and others have focused on policy options by the government to capture more stumpage value from forests (Gillis, 1980, 1992; Gray, 1983; Sulaiman, 1977; Thompson, 1984; Vincent, 1990; Vincent et al., 1993), or on the effects of timber fees on logging behavior (Vincent et al., 1993). The studies have differed in terms of the methods employed to estimate stumpage value and the types of data used. In general, these studies have not been very explicit about government objectives in managing natural forests. Also, conflicting discussions abound in the literature on the relationship between revenue systems and the sustainability of tropical forest management (Hyde & Sedjo, 1992; Paris & Ruzicka, 1991, 1993; Vincent & Binkley, 1991; Vincent, 1993a, 1993b). It is not clear that raising government revenue and encouraging sustainable forest management are complementary objectives.

1.2 Structures of Forest Revenue Systems

Gillis (1980, 1992) and Gray (1983) described in detail the full range of forest revenue systems in tropical countries. Heaps and Helliwell (1985) provided related discussion on natural resource taxation. Some examples of the alternative structure of forest charges are as follows (based on a classification from Gillis, 1980):

I. Taxes

A. Ordinary profit taxes

-Profit tax and incentives, and withholding taxes

B. Windfall profit taxes or excess profit taxes

C. Export taxes

-Tax on logs and semiprocessed timber

D. Property taxes and custom duties

E. Production-sharing and profit-sharing arrangements

-Deduction of cost recovery, split of new production, in-kind share of government, purchased equity, free equity

II. Forest fees

A. Royalties (stumpage fees)

-Volume-based royalty (uniform, differentiated)

-*Ad valorem* royalty

B. License fees (area taxes)

C. Auction fees and bidding procedures

Forest charges can be based on income, profit, stumpage value, or timber volume. Differences between countries reflect differences in forest resources, forest management systems, socioeconomic development, socio-cultural background, institutional structure, the historical background of forest management (Gray, 1983), and, perhaps most important, differences in government objectives and the constraints that governments face.

The methods of establishing the level of forest charges under each forest revenue structure also differ from country to country. Gray (1983) noted that there are six methods of setting the level of forest charges:

1. Administratively set, fixed-rate charges
2. Value-related (*ad valorem*) charges
3. Formula-based charges
4. Negotiation-based charges
5. Open-bid and sealed-bid auctions
6. Public log markets

When forests are under government control, and there is perfect information, a perfect market, perfect tax administration, and perfect taxpayer compliance, the best method is obtained either through a competitive auction or the application of income taxes (Gillis, 1980). An auction would capture full payment of the stumpage value of standing timber, and an income tax would capture the government's normal share of other property income from timber and associated operations. Auctions provide many advantages: (a) ambiguity related to forest allocation is removed, (b) risk (information from forest inventory) is transferred to bidders, (c) rent capture is increased, and (d) incentives to lower the costs of timber harvesting are increased.

In tropical countries, however, a bidding auction (either open or sealed-bid) may be weakened due to two unfulfilled requirements: (a) full information on timber volumes, log prices, and logging costs, which is used in calculating stumpage value; and (b) the absence of bidding collusion. These requirements are often not fully satisfied due to the heterogeneity of species in tropical forests and political intervention in the timber business. Collusion is prevalent not only in tropical countries but in developed countries as well.[3]

Because of the above-mentioned problems, the most widely practiced forest revenue systems in tropical countries are royalty-based forest charges. These royalty structures are characterized by inflexible, undifferentiated, and low-level volume-based charges. They are most commonly set administratively (uniform royalties) or set proportional to log prices (*ad valorem* royalties).

1.3 Effects of Timber Fees

In general, resource-taxation analysis is particularly concerned with the efficiency and equity or distributional aspects of resource development (Heaps & Helliwell, 1985). The concept of efficiency in relation to forest revenue systems

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[3]The problem of bidding collusion is related to the behavior of bidders and market structure (Mead, 1967; Muraoka & Watson, 1983). Mead pointed out that each bidder in an imperfect market develops a plan for accomplishing his objectives. The highest bidder may not provide the highest return to the government, may not be the most efficient harvesting and marketing concessionaire, may not plan to harvest timber at the optimal time, and may practice collusion (Muraoka & Watson, 1983).

refers to the maximization of discounted stumpage value, whereas distribution refers to the allocation of stumpage value between the government and the concessionaire. The performance of alternative forest revenue systems can be measured using these two aspects.

In general, a uniform royalty causes stumpage value to be split among at least three components: government revenue, windfall profits, and timber left in the forest. Figure 1 shows the relationship between log price (P) and cumulative timber volume (V) within a given concession compartment,[4] at a particular point in time. In a typical tropical concession compartment, there are many timber species in varying diameter classes. Prices for tropical logs vary according to species, grade, and diameter class. The downward-sloping line P in Figure 1 shows the distribution of timber volume according to log price. The value of logs decreases as one moves from left to right along the horizontal axis. Potentially harvestable trees are those with diameters above the commercial minimum. But due to sustained-yield regulations, only trees above government-set minimum cutting limits are allowed to be harvested.

The marginal cost of logging (MC) is assumed to be constant within the compartment, and t is a uniform royalty. Without royalty, a profit-maximizing

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[4]A homogeneous forest stand (based on physical characteristics such as terrain and geographical area, not in terms of species composition) which is designated for management purposes, analogous to analysis areas used by the US Forest Service (Clutter, Fortson, Pienaar, Brister, & Bailey, 1983). Each compartment could be treated as an independent decision unit in timber harvesting (such as determination of cutting limits, issuance of license, etc.) and silvicultural treatment. Various names (such as working areas, management units, and cutting units) also are used in forest management textbooks.

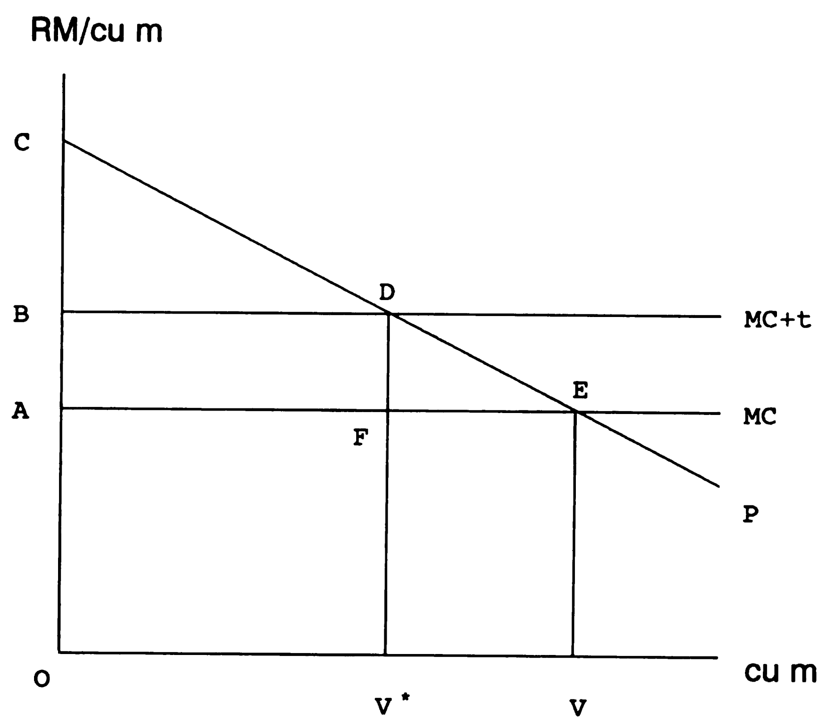

Figure 1. Uniform Royalty System and Distribution of Stumpage Value in a Concession Compartment.

concessionaire would harvest V cubic meters of timber, at a point where price equals marginal logging cost. The concessionaire would harvest V^* in the presence of royalty. The area ABDF is government revenue, the triangle BCD is the concessionaire's windfall profits, and the stumpage value of timber left in the forest is DEF. Empirical evidence has shown that the government captures only a small portion of the available stumpage value when forests are logged (Gillis, 1980; Page et al., 1976; Repetto & Gillis, 1988; Ruzicka, 1979; Vincent, 1990; Vincent et al., 1993). Most of the stumpage value is apparently captured by concessionaires. This type of royalty also results in the most timber being left in the forest.

Gillis (1980, 1988a) showed that an *ad valorem* royalty or area-based charge, on the other hand, would yield higher government revenue (the government can even capture 100% of the stumpage value) with less timber left in the forest. An income tax and a differentiated royalty also would result in higher government revenue and less timber left in the forest.

The differences in the effects of rent capture of alternative forest revenue systems are a result of concessionaires' decision on the marginal harvest. The level of royalty affects the profitability of each unit of timber harvested. For instance, for a given forest concession, an increase in the uniform royalty decreases the profitability of timber that the concessionaire extracts. Lower-priced species might offer negative profits. A rational concessionaire would prefer to leave such trees in the forest rather than extract them.

An *ad valorem* royalty (percentage based on log price) would have less effect on the concessionaire's marginal harvest decision. Whether the government revenue is greater, or windfall profits are less, depends on the magnitude of the *ad valorem* rate.

Because a premium (area-based charge) is a fixed cost (not affected by harvest level), it would be expected not to influence the harvest decision. However, without government control, concessionaires facing large premiums might be tempted to cover the fixed cost by harvesting timber below the cutting limits. An empirical analysis by Vincent et al. (1993) revealed that this practice is apparent, at least in the case of timber harvesting in Peninsular Malaysia.

1.4 Objectives of the Study

In this study, the researcher attempted to enhance the understanding of the issues discussed above. Specific objectives were:

1. To develop a theoretical microeconomic model of timber production in a typical concession and to analyze how optimal royalties and premiums are affected by forest management objectives, concessionaires' production technologies, and characteristics of the forest.

2. To examine empirically how differences in forest revenue systems affect concessionaires' harvest behavior and the achievement of the government's forest management objectives.

Knowing these theoretical and empirical relationships and their consequences will provide a better understanding of the performance of different forest revenue systems. This knowledge, in turn, may serve as a basis for developing policy options for reforming forest revenue systems, which will eventually help to ensure that forest management objectives are achieved.

1.5 Organization of the Dissertation

Forest concession policies, forest revenue systems, and forest management systems in Peninsular Malaysia are highlighted in Chapter Two. This institutional background provides the basis for developing a theoretical model of the forest revenue system. This model is developed in Chapter Three. Methods of empirical analysis used in this study are described in Chapter Four. Chapter Five contains the results of the simulation analysis and a discussion of the significance of these results. A general discussion of the results of the study is presented in Chapter Six. Policy implications that emerged from the empirical analysis also are highlighted. Finally, suggestions for further studies on forest revenue systems are offered.

CHAPTER TWO

FORESTRY AND FOREST REVENUE SYSTEMS IN PENINSULAR MALAYSIA

2.1 Introduction

The forestry sector has played an important role, not only in Malaysia's economy but also in international tropical timber trade. The forest sector developed rapidly in the 1960s and 1970s because of significant timber harvests as a result of the large-scale conversion of lowland forests to planned agricultural development. Since that time, the lowland forests have decreased in size, and timber production is now concentrated largely in hill forests. Thus, the continuing role of the forestry sector in Peninsular Malaysia's socioeconomic development will depend on the feasibility of hill forest management.

The Malaysian government is very much aware of the role of natural forests, and its policies commit it to managing these forests for the benefit of the present and future generations. Major public forest policies have been formulated and implemented to meet this ultimate goal. Some of the public forest policies that are relevant to the framework of this study are discussed in this chapter. These include the concession allocation system, the forest revenue system, and the forest management system.

2.2 General Background of Malaysia

Malaysia is located strategically at the maritime crossroads between China and India. It is divided into two geographical regions: Peninsular Malaysia and East Malaysia (Figure 2). Peninsular Malaysia comprises 11 states and the Federal Territory of Kuala Lumpur. Two other states, Sabah and Sarawak, and the Federal Territory of Labuan are situated in East Malaysia on the northern part of Borneo Island. Peninsular Malaysia, then Malaya, became independent from British Government rule on August 31, 1957. On September 13, 1963, Peninsular Malaysia, Sabah, Sarawak, and Singapore formed a federal system of government, Malaysia. However, in 1965, Singapore left Malaysia and became an independent country.

Politically, Malaysia is an elective monarchy with a constitutional parliamentary system. With regard to administration, Malaysia has a federal system of government, where the central government is responsible for certain matters such as education, defense, international trade, public works, and so forth. Legislative power is divided between the federal and state legislative assemblies, according to the Federal List and the State List, as specified in the Ninth Schedule of the Federal Malaysia Constitution. Each state has its own constitution, together with its own legislative assembly. The ruler or head of the state appoints a state Executive Council (EXCO)[5] headed by the *Menteri Besar* or Chief Minister. The EXCO is the top-level policy-making body at the state level and is empowered to carry out duties concerning the rules and regulations pertaining to matters stated in the State

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[5]EXCO members are the elected and appointed officials from the ruling party. Their function is to set rules and regulations pertaining to the State List, such as agriculture, forestry, mining, and so on.

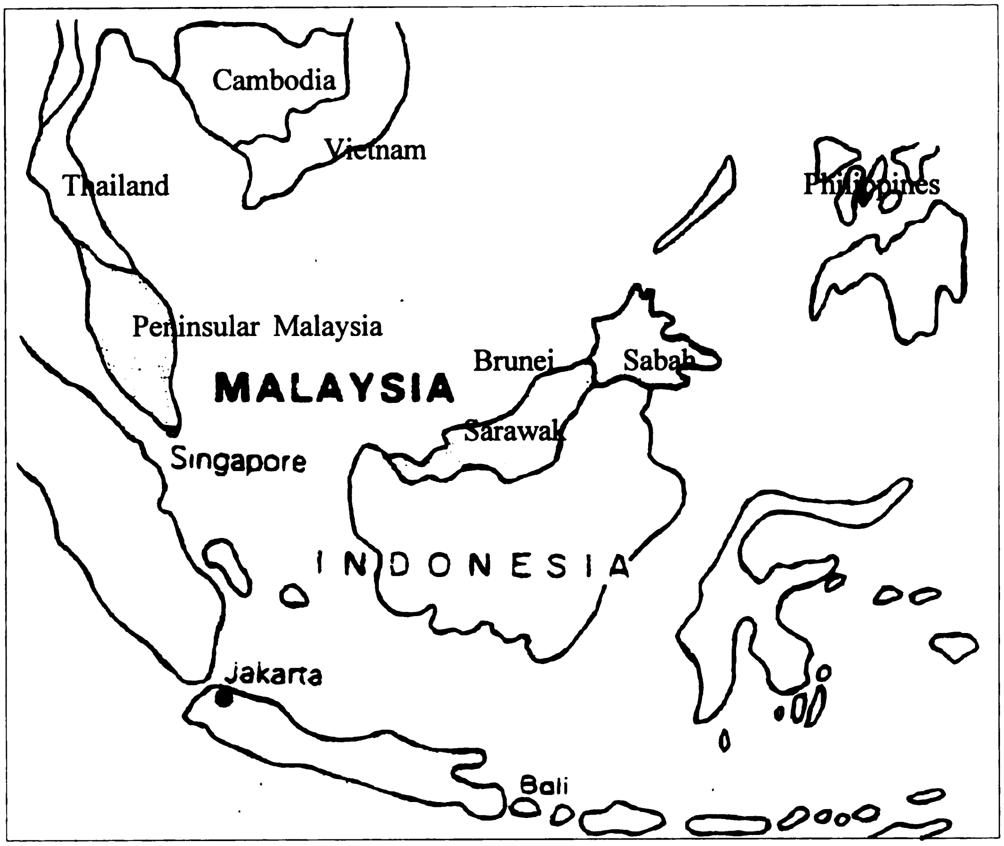

Figure 2. Map of Malaysia.

List. For instance, regulations pertaining to forestry matters, which include decisions on timber allocation, revenue collection, land development, and other matters, are made by the EXCO. The federal government provides technical assistance and formulates national policies. In any event, decisions to implement policies at the state level lie with the state itself.

From an economic perspective, Malaysia can be classified as an open economy. The country has been fortunate to have been endowed with diverse and vast natural resources such as tin, forests, oil, and natural gas. In the early stage of economic development, the Malaysian economy depended mostly on primary commodities and agricultural crops, particularly tin, timber, rubber, and oil palm. Beginning in the early 1980s, crude petroleum and natural gas became major contributors to the gross national product (GNP). The economy has changed structurally from primary- and agriculture-based exports to the export of petroleum and manufactured goods. The effects of various economic and public policies under the country's Five-year Development Plans have strengthened the resilience of the nation and contributed to its economic growth. Economic growth in Malaysia has increased significantly during the last five years (the average 1988-1992 growth in real gross domestic product (GDP) was 9.4%; it was 8.5% in 1992; Ministry of Finance, 1992). Strong economic growth in the last few years has been a result of the stimulus of growth from both domestic and external demands. A highly stable political environment and conducive investment opportunities also have helped Malaysia achieve impressive economic growth in the last few years.

2.3 Forestry in Peninsular Malaysia

The forestry sector has been one of the most important sectors in the Malaysian economy. The government has been paying greater attention to this sector in the last 20 years because of the significant role the forestry sector has played in export earnings, job creation, regional development, environmental protection, recreational opportunities, protection of wildlife, forest-based industrialization, and so forth. As a result, policies and laws related to the management and use of forest resources, forest-based industrialization, trade in timber products, and environmental protection have been formulated and enacted by the government. These include the Land Capability Classification (1965), the Protection of Wildlife Act (1972), the National Forest Policy (1978), the National Forestry Act (1984), the Wood-based Industries Act (1984), and the Industrial Master Plan (1985). In one way or another, all of these acts and policies have had significant influence on the development of the forestry sector in Peninsular Malaysia.

Forests in Peninsular Malaysia can be divided into several types--Dipterocarp, Peat Swamp, and Mangrove forests--based on their ecological and physical conditions. Dipterocarp forests are the most extensive and the most important commercially (constituting about 4.4 million hectares (ha) or 91% of the total forested land). In this forest, the family Dipterocarpaceae predominates the area, with many of the species from the genera Anisoptera, Dipterocarpaceae, Dryobalanops, Hopea, Shorea, and Parashorea. The dipterocarp forests are divided into lowland (0-300 m), hill (300-750 m), and upper hill (750-1200 m) forests.

Lowland dipterocarp forests were subject to rapid conversion during the 1960s and 1970s as a result of large-scale conversion of land for agricultural development (Vincent & Yusuf, 1991). Most timber harvesting today is carried out in hill dipterocarp forests.

To facilitate and coordinate development of the forestry sector in Peninsular Malaysia, the National Land Council (NLC) established the National Forestry Council (NFC)[6] in 1971. The NFC serves as a forum for the federal and state governments to discuss and resolve common problems and issues relating to forestry policy, administration, and management. A significant policy effect of the NFC was the formulation and acceptance of the National Forest Policy (NFP) in 1978. The policy has been accepted by all states in Peninsular Malaysia. The NFP calls for the establishment of Permanent Forest Estates (PFE),[7] sufficient in area for timber production, water supplies, environmental protection, recreation, education, research, and conservation; these are strategically located throughout the country and in accordance with the concept of rational land use. The PFEs are divided into three major categories according to their functions and objectives: protective forests (environmental amelioration such as water catchment), productive forests (timber production), and amenity forests (conservation and other services such as recreation and research). Forests intended to be converted to other uses are termed State Land Forests (SLF). The total natural forest area in Peninsular Malaysia is estimated to

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[6]The government dissolved the NFC in 1992. All forestry policies and related issues are now under the jurisdiction of the NLC.

[7]Analogous to national forests in the United States.

be 6.1 million ha, 46.5% of the total land area (Forestry Department, 1991b). Out of this area, 4.7 million ha are PFE. Production forests cover an area of 2.8 million ha. Forest plantations are becoming increasingly important in meeting future log requirements. To date, 45,368 ha of plantation forest have been established under the Compensatory Forest Plantation Project.

In 1984, another major development in forest legislation occurred in Peninsular Malaysia. The government enacted the uniform National Forestry Act of 1984 (NFA), which replaced the States Forest Enactment and Rules of 1935. The NFA was promulgated to ensure effective forest administration, use, management, harvesting, and reforestation in accordance with the principles of sustained yield management. Under the NFA, every state is required to prepare and implement forest management and working plans in the PFE. The plans describe the area to be harvested, the species to be felled, the cutting limit and allowable cut to be prescribed, penalties for poor timber harvesting practices, and so on. With this development, the management, administration, and control of forest resources have been systematically strengthened and upgraded.

Forest-based industrialization has grown rapidly during the past three decades. The tremendous growth in the forestry sector has developed it into a major contributor to foreign exchange and has established for the country a favorable image as the top producer of high quality tropical hardwood. In the 1960s and 1970s, a large proportion of the logs that were harvested were exported. The banning of logs of some popular species for export began in 1972. Since 1978, virtually all logs have been processed locally. In the mid-1980s, the government encouraged the development of wood-based processing industries. The Industrial Master Plan (IMP), launched in 1985, provides the general industrial-development objectives and strategies for sectors with promising growth potential; wood-based industries are one of such sectors. The growth strategy advocated by the IMP for wood-based industries is to focus on the manufacture of high-value-added wood products, such as furniture, joinery, and mouldings.

Forest-based industries have played a major role in regional development, foreign exchange, government revenue, and local employment. The spatial pattern of forest-based industries has been affected by such factors as proximity to timber supply, labor, agglomeration economics, and government policy. In Peninsular Malaysia, most of the forest-based industries were concentrated on the west coast during the early stage of its development. The industrial shift to a timber-producing region on the east coast began in the early 1970s due to an abundant supply of logs and available labor (Jalaluddin, 1989).

Forest-based industries grew rapidly during the period from 1961 to 1985. Domestic demand and export expansion were the main factors that contributed to the growth (Vincent, 1986; Mohd. Shahwahid, 1986).

The current and future situation of forest-based industries depends primarily on a sustained timber supply in the long run. Peninsular Malaysia is expected to face a timber shortage in the mid-1990s (Thang, 1985). The scheduled reduction in log production in Peninsular Malaysia is a major approach to maintaining a sustained yield from the natural forests. The government has taken several measures to address this situation. These include the designation of Permanent Forest Estates, which are being managed under sustained yield; practicing sustainable forest management through the Selective Management System (SMS); establishing plantations under the Compensatory Forest Plantation Project; encouraging the development of downstream processing industries; improving the timber concession policy; ensuring sufficient funds for forest development projects; and enhancing research and development.

2.4 The Forest Concession Policy

Under the federal constitution of Malaysia, forest lands are under the jurisdiction of their respective state governments. This means that forests are owned by the states, which can decide on the methods of forest allocation, development of forest lands, and other related issues such as the levels of royalties and premiums, the type of royalty payments, and so forth.

The forest allocation system can be regarded as a transfer of rights to log a particular forest concession to individuals, independent private concessionaires, private mill operators, or government-owned timber complexes. The transfer of rights is made through a contract between the government and the concessionaire. The contract specifies the rules and regulations as provided in the NFA, as well as some regulations that may be added by the respective state government. With these rights, a concessionaire is given a concession to harvest and extract timber, construct roads, or carry out any activity related to timber harvesting and forest management as specified in the contract. The states retain ownership of the concession area.

Any violation of the terms of the contract or any offense that contravenes the NFA is subject to penalty or can be prosecuted in court. However, fines imposed by the government and the terms of imprisonment under the existing NFA are inadequate to deter concessionaires from encroaching and practicing what is known as "illegal logging" (i.e., felling trees outside the demarcated boundary of the forest concession approved for timber harvesting). To further strengthen the NFA, the government has amended some provisions of the act. These include giving the army the power of arrest those involved in illegal logging, increasing imprisonment from a maximum of 3 years to 20 years, and increasing fines 50-fold (from a maximum of RM10,000 to RM500,000[8]). Other possibilities also have been considered, such as freezing concessionaires' bank accounts in addition to confiscating their property, and giving courts the power to revoke the licenses or permits of illegal concessionaires.

In both Permanent Forest Estates (PFE) and State Land Forests (SLF), Section 16 of the NFA clearly specifies that timber rights may be transferred by state authority in three ways: (a) tendering, (b) negotiation, and (c) other processes (depending on a particular case, such as grant or status). A taxonomy of forest allocation systems in Peninsular Malaysia is depicted in Figure 3.

A short-term concession contract is allocated by two mechanisms--tender and negotiation. The duration of the contract is normally from 1 to 3 years. Each concession area averages 400 ha (Kumar, 1986). The terms of the contract include definition of the felling area, description of forest products, period of harvesting,

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[8]US$1.00=RM2.57 in 1993.

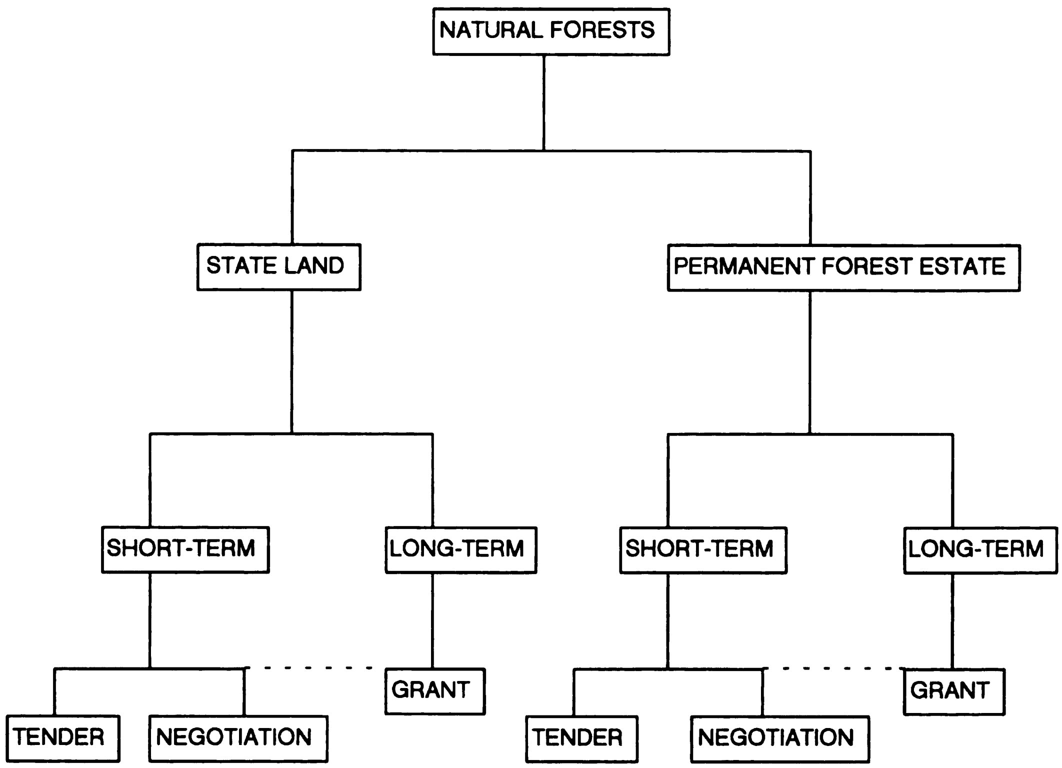

Figure 3. Taxonomy of the Forest Allocation System.

payments due, location of checking stations for log scaling, and a list of species not to be felled. Other harvesting regulations are prescribed in the guidelines of the Selective Management System (SMS)[9] (see section 2.6). The management of natural forests logged under short-term contracts is the responsibility of the State Forest Office (SFO).

Tendering (auctioning) is a mechanism to allocate concessions in State Land Forests that have been demarcated for agricultural development. However, in some states this mechanism is extended to allocate concessions in Permanent Forest Estate. There are two types of tenders: open tender (open bid) and closed tender (sealed bid). Closed tenders are limited to *bumiputera*,[10] whereas open tenders are conducted for any parties. In both mechanisms of forest allocation, the concession is normally awarded to the highest bidder.[11]

Under the negotiation mechanism, an applicant (individual, independent concessionaire, or wood-based manufacturer) must meet certain requirements when submitting an application to the SFO. Under regular and normal procedures, the decision is made by the EXCO. A successful applicant will be notified by the SFO and sign an agreement with the state that specifies the rights of the concessionaire and the state, and outlines the regulations governing the harvesting operation. The

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[9]The guidelines and regulations of the SMS apply only to Permanent Forest Estates.

[10]Malays and other indigenous groups; Chinese, Indians, and others are not considered *bumiputera*.

[11]Sometimes the successful concessionaire who obtains concession rights is called the "concession holder" or "license holder." In this study, the terms "concessionaire," "concession holder," and "license holder" are used interchangeably.

applicant is issued a logging permit (for a concession in a Permanent Forest Reserve) or a license (for a concession in a State Land Forest) that is valid for a specified short duration.

A long-term concession contract or "long-term agreement" is granted to private wood-based manufacturers (contract period of 3 to 30 years) or to government-owned timber complexes (known as integrated timber complexes--ITC; contract period of 15 to 60 years). The objectives of granting a long-term concession contract are to ensure a long-term timber supply for wood-based industrial activity and to maximize the use of timber resources.

One important term of reference specified in the concession contract is that forest management activities should be carried out by the concessionaire with direct supervision from the SFO. For instance, the ITCs have their own management section, which is responsible for forest management activities such as forest inventory, preparation of management and working plans, forest rehabilitation, and research and development (Abd. Latif & Nik Mohd. Shah, 1984; Ahmad Zainal, 1984; Sheikh Ibrahim & Shaharuddin, 1984). The ITCs can be reimbursed for the amount they have spent on forest management and development activities. In these long-term concession areas, forest allocations are controlled by a separate permit, which differs from the permit issued for a short-term contract. In some cases, the ITCs also are permitted to tender out concession areas to independent private concessionaires.

The loss of virgin forests as a result of agricultural expansion has reduced forest areas available for logging. This has reduced log supplies and, consequently, has tempted concessionaires to engage in illegal logging, i.e. to harvest timber outside of or adjacent to the concession area or to harvest timber below the cutting limits. This situation has prompted the government to review the forest concession policy. The government is studying proposals to grant forest concessions only to concessionaires who have processing mills or to appoint concessionaires to harvest timber in a designated concession for a period of 5 years. In some states, other proposals have been considered; for instance, existing concessionaires might be required to log only a small area annually, thus extending the concession period[12] and introducing new criteria governing the issuance of licenses.

2.5 The Forest Revenue System

A broad structure and level of fees on timber harvesting is employed in Peninsular Malaysia. The methods of payment are related to the mechanisms of the forest allocation system. In practice, the systems typically comprise a mix of volume-based charges ("royalties," "silvicultural cesses," and "tributes") and area-based charges ("premiums"). In some states, government revenue collected from these timber fees has been substantial and has been a significant source of public funds.[13]

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[12]For instance, if a concessionaire had been promised a forest concession of 10,000 ha per year, the concessionaire would be allowed to harvest 1,000 ha per year, and the concessionaire would continue to harvest 1,000 ha every year until the 10-year contract expired. The SFO may suggest to the state authority that the contract period be extended (perhaps from 10 to 20 years, depending on the situation), provided that the concessionaire reduces the yearly harvest.

[13]Only royalties, premiums, charges on minor forest products, compensation, and fines are channelled to the public fund, whereas the collection of silvicultural cesses is used solely for forest management and development activities.

Table 1 shows total government revenue collection, according to method of payment. The increase in government revenue was directly related to an increase in log production. As can be seen in Table 1, royalty was the major contributor to total forest revenue (on average, contributing 50%). The average contributions from premium and silvicultural cess were 27% and 13%, respectively. Revenue from minor forest products (such as bamboo, rattan, poles, resin, and so on) was not substantial (about 6%).

Because area- and volume-based revenue systems were both analyzed in this study, they require further explanation. The area-based forest charge is known as a premium; it is a charge levied for the right to harvest a specific concession area granted under a permit or a license. The premium is assessed per hectare, based on the total area of the forest concession as shown in the permit or license. There are two types of premiums, tendered and standard. The tendered premium is the competitive bid price, appraised per hectare, for concessions that are allocated by a tendering mechanism. Conceptually, this fee is independent of harvest volume, and it may reflect the true total willingness of the concessionaire to pay in exchange for the concession right. Thus, the tendered premium would be expected to vary with respect to the productivity of the forest concession, location, accessibility, characteristics of the concessionaire, price of logs, and other costs associated with timber harvesting.

The standard premium applies to all concessions; the rate is set by the EXCO or the SFO (the rates are shown in Table 2). Thus, the standard premium varies according to forest type, administrative structure of the forest where the concession

Table 1. Total Government Revenue Collection, Peninsular Malaysia, (1971-89) (RM[1] '000)

Year	Premium	Royalty	Silvicultural Cess	Other[2]	Total
1971	972	47,810	-	1,301	50,083
1972	12,896	58,169	-	2,022	73,087
1973	20,883	60,960	4,855	4,428	91,126
1974	16,089	60,063	5,316	3,940	85,408
1975	25,998	54,090	4,871	3,513	88,472
1976	36,528	73,111	6,824	4,705	121,168
1977	NA	NA	15,166	NA	NA
1978	38,000	78,000	21,000	7,000	144,000
1979	42,572	75,892	22,705	42,991	184,160
1980	43,547	89,146	21,844	19,588	174,125
1981	62,678	80,531	21,658	9,135	174,002
1982	48,349	98,132	20,668	6,856	174,005
1983	97,996	97,470	22,651	11,588	229,705
1984	69,210	88,129	20,302	8,145	185,786
1985	65,630	76,630	16,696	9,802	168,758
1986	73,660	84,790	20,308	9,647	188,405
1987	67,676	102,174	24,484	31,132	225,466
1988	113,042	116,017	28,262	17,847	275,168
1989	115,451	120,490	31,237	18,025	285,203

NA = Not available.

[1]RM Ringgit Malaysia (Malaysian currency, US$1=RM2.57 in 1993).

[2]Including the collection of minor forest products, compensation, and fines.

Source: Forestry Department (1979, 1986, 1991a).

Table 2. Premium Rates for Forest Concessions, Peninsular Malaysia, 1989 (Selected States)

State	Concession area	Rate
Pahang	Long-term agreement areas under Amanah Saham Pahang (ASPA)	RM250.00/ha/yr
	Other long-term agreements	
	i. Virgin forests	RM1000.00/ha/yr
	ii. Logged over forests	Assessed by SFO
	Areas granted under special allocation/other areas	Assessed by SFO
	Tendered areas	Based on tendered price
	Areas granted for land clearance	Charged at a premium between 15 and 30 percent of royalty collection
Terengganu	Long term agreements	RM100.00-300.00/ha/yr
	Forest reserved and state land forests	Based on tendered price
	Peat swamp and mangrove forests	Based on tendered price
Kelantan	Forest reserved/state land forests, and long term agreements	
	i. Virgin forests	RM150.00/ha/yr
	ii. Logged over forests	RM75.00/ha/yr
	Peat swamp forests	
	i. Virgin forests	RM40.00/ha/yr
	ii. Logged over forests	RM20.00/ha/yr
	Mangrove forests	
	i. Virgin forests	RM50.00/ha/yr
	ii. Logged over forests	RM25.00/ha/yr

Table 2. (cont'd).

State	Concession area	Rate
Selangor	Forest reserved (inland)	
	a. Virgin	
	i. Long term agreements	RM600.00/ha/yr
	ii. Areas given to timber complexes	RM600.00/ha/yr
	iii. *Bumiputera* areas	RM600.00/ha/yr
	iv. Tendered areas	Based on tendered price
	b. Logged over	RM300/ha/yr
	State land forests	
	i. Virgin	RM600.00/ha/yr
	ii. Logged over	RM250.00-300.00/ha/yr
	iii. Land development	RM250.00-300.00/ha/yr
	iv. Areas given to timber complexes	RM250.00-300.00/ha/yr
	Peatswamp forests	
	i. Virgin	RM150.00/ha/yr
	ii. Logged over	RM75.00/ha/yr
	Mangrove forests	
	i. Virgin	RM200.00/ha/yr
	ii. Logged over	RM100.00/ha/yr

Source: Forestry Department (1991a).

is located, condition and status of forest, length of agreement, and type of concession contract. The rate can be reviewed from time to time by the EXCO or SFO in the respective state. The basis for establishing the rate varies. In the state of Selangor, for example, the rate is sometimes calculated based on inventory data (Sulaiman, 1977); it is fixed at 20% of the merchantable timber value. More recently, one state has tripled its premiums, and another has proposed increasing premiums 5- to 15-fold (depending on the site) (Awang Noor & Vincent, 1993).

Volume-based timber fees include royalty, silvicultural cess, and tribute. Royalties are calculated and charged based on the actual volume of logs extracted from the forest. The rates for selected species and states are shown in Table 3. The rates vary by species, but they are uniform within each state. For a given species, royalties are not differentiated according to stumpage value. The royalty is independent of diameter class, quality of logs, terrain, location of forest, and type of forest concession. Thus, royalties in Peninsular Malaysia are closer to uniform royalties[14] than to differentiated royalties. The basis for setting royalty rates was originally 10% of the market price of logs.[15] As can be seen in Table 3, royalties tend to be higher for heavy hardwood and lower for lesser-known species (grouped under the category of other species). Even though log prices vary substantially, the rates do not reflect these differences. In general, Kelantan charges the lowest

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[14]This is equivalent to the specific uniform royalty used by Gillis (1980, 1988a).

[15]In this sense, the rate can be considered as *ad valorem*. However, the rates are fixed by the EXCO, and in practice they do not reflect the prices of logs.

Table 3. Royalty Rates for Logs, Peninsular Malaysia, 1978-1989 (Selected States and Species, RM/m³)

State	Species	1978	1985	1989
Pahang	Cengal	14.00	19.00	19.00
	Balau	10.00	14.00	14.00
	Kapur	8.00	13.00	13.00
	Keruing	5.50	13.00	13.00
	DRM[1]	5.50	16.00	16.00
	Jelutong	4.00	14.00	14.00
	Sepetir	4.00	11.00	11.00
	Other LHW[2]	4.00	6.00	6.00
Terengganu	Cengal	14.00	18.00	18.00
	Balau	7.00	9.00	12.00
	Kapur	7.00	9.00	12.00
	Keruing	7.00	9.00	12.00
	DRM[1]	11.00	15.00	15.00
	Jelutong	8.00	11.00	12.00
	Sepetir	5.50	8.00	10.00
	Other LHW[2]	5.50	8.00	8.00
Kelantan	Cengal	14.00	18.00	18.00
	Balau	8.00	11.00	11.00
	Kapur	8.00	11.00	11.00
	Keruing	5.50	8.00	8.00
	DRM[1]	5.50	8.00	8.00
	Jelutong	4.00	8.00	8.00
	Sepetir	4.00	6.00	6.00
	Other LHW[2]	4.00	6.00	6.00
Selangor	Cengal	14.00	20.00	20.00
	Balau	10.00	25.00	25.00
	Kapur	8.00	12.00	13.00
	Keruing	7.00	11.00	13.00
	DRM[1]	7.00	18.00	18.00
	Jelutong	4.00	16.00	16.00
	Sepetir	4.00	12.00	12.00
	Other LHW[2]	4.00	8.00	8.00

[1]DRM = Dark Red Meranti (see Table 11 for species listed in this group).

[2]LHW = Light Hardwood (see Table 11 for species listed in this group).

Source: Forestry Department (1979, 1986, 1991a).

royalty, whereas Perak has the highest royalty.[16] For a particular single species, the highest royalty rate is RM30 per m^3, whereas the lowest rate is RM5.30 per m^3. The royalty rates have not shown any significant increase during the past several years and have not actually corresponded to the price trend for logs.

Another volume-based charge, known as silvicultural cess, has been collected in all states since 1973; the revenues are to be used solely for forest rehabilitation and development ("Forest Resource," 1979). Specific flat rates are charged on each cubic meter of timber extracted, but these rates vary among states, from RM0.60 to RM2.80 per m^3. The tribute is a special payment made by integrated timber complexes (ITC) in certain states. The tribute rates vary among states.[17]

2.6 The Forest Management System

The stated objectives of forest management in Peninsular Malaysia are to ensure sustainability of forest resources, obtain maximum social and economic benefits, and safeguard environmental stability ("Forest Resource," 1979; Salleh, 1983). The implementation of forest management with regard to Permanent Forest Estates is specifically stated in the National Forest Policy as follows (Forestry Department, 1978):

> "The Permanent Forest Estate should be managed to provide optimum production of all forms of forest produce and other benefits for the welfare of the community.

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[16]Based on statistics published by the Forestry Department (1991a). The royalty rates for Perak are not shown in the table.

[17]Cess and tribute are not explicitly specified in the theoretical and empirical models. "Royalty" in these empirical analyses implicitly includes these fees.

> The Director-General of Forestry is responsible to the Federal Government for the proper and efficient management of the Nation's Permanent Forest Estate, which is achieved by providing State Governments, through their respective State Directors of Forestry, with technical advice, assistance and training facilities. In the interest of the community and the Nation, State Governments may accept technical and professional advice given by the Director General of Forestry for implementation.
>
> If there should be a need in the future for harvesting Amenity and Protective Forests, the State Government may make such decision upon the advice of the Director of Forestry.
>
> State Governments shall ensure that the Permanent Forest Estate is adequately protected from encroachment or damage." (p. 20)

Forest management and harvesting practices vary with regard to the status of forest lands. In State Land Forests (Conversion Forests), clear felling is practiced and there is no minimum-diameter cutting limit. Timber with a diameter as low as 27 cm dbh (diameter at breast height) is commonly sold in the market. Selective felling is implemented in production forests of the Permanent Forest Estates. Strict rules and regulations are imposed on timber harvesting. The cutting cycle is determined first. Then the minimum-diameter cutting limits are decided.[18] Only trees above the minimum-diameter cutting limits may be harvested.

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[18]This differs from forest management in even-aged forests with single species, in which a forest owner only decides when to harvest. Most problems associated with even-aged forest management involve determining optimal rotation and subsequently to estimate optimal harvest volume. Optimal rotation varies with respect to factor ownership, and economic and other policy variables. The optimal rotation length has its roots in the Faustman formula. There is extensive literature on this subject (for examples, Heaps & Helliwell, 1985; Hyde, 1980; Johansson & Lofgren, 1985; Neher, 1990; Newman, Gilbert, & Hyde, 1985; Synder & Bhattacharyya, 1990). The effect of forest taxation on optimal rotation has also been studied extensively (Chang, 1982; Klemperer, 1976a, 1976b; Ollikainen, 1990).

Increasing the cutting limits affects the amount of stumpage value, and hence the distribution of resource rent and efficient harvest level. The economics of cutting regimes have been analyzed by Mohd. Shahwahid (1985) and Vincent et al. (1993). However, the methods used in their studies were different. The findings suggest that the cutting limits are not economically justified under the current SMS because of low rates of return relative to the opportunity cost of capital (if nontimber benefits are not taken into account). Higher cutting limits are economically justified if nontimber benefits are considered.

It should be noted that forest management in the natural lowland and natural hill dipterocarp forests is entirely different because of variations in forest structures and the ability of seedlings to regenerate after harvest. The management system developed for natural lowland forests rich in meranti (a group of *Shorea* spp.) is known as the Malayan Uniform System (MUS). This management system has been found to be very effective in regenerating such forests (Tang, 1987). The cutting cycle under the MUS is 70 years.

The current management practice in the natural hill forests of Permanent Forest Estates is based on the Selective Management System (SMS). This system attempts to prescribe cutting regimes that yield an economically viable harvest volume while leaving sufficient residual trees of advanced regeneration to ensure future harvests at intervals of 30 years (Tang, 1987; Thang, 1986). The SMS is designed to optimize the management objectives of economic and better harvesting practices, sustainability of the forest and timber supply, and minimum forest development costs under prevailing socioeconomic conditions.

In practice, the SMS is implemented by setting minimum-diameter cutting limits for dipterocarp and nondipterocarp by analyzing data from pre-felling (pre-F) inventories. Cutting limits typically are no lower than 50 cm dbh for dipterocarp and 45 cm dbh for nondipterocarp timber species. Minimum residual stocking is also required, which should be not less than 32 marketable trees of good quality in diameter class 30 to 45 cm or its equivalent per ha.

To endow the next harvest with a greater proportion of dipterocarp than nondipterocarp species groups, the difference in cutting limits prescribed between the two groups should be at least 5 cm for any one compartment. The SFO attempts to choose the cutting regime that best balances current timber production and protection of advanced regeneration. There is no standard set of cutting limits because the choice depends on particular forest conditions.

The Forest Department carries out the following activities in implementing the SMS: (a) boundary clearing before harvesting,[19] (b) pre-felling (pre-F) inventory, (c) tree marking (all commercial trees that are larger than the prescribed cutting limits, (d) enforcement during and after harvesting, (e) post-felling (post-F) inventory, and (f) prescribed silvicultural treatments. The types of silvicultural treatments performed are climber cutting, poisoning of defective and unwanted trees, and enrichment planting.

All logging operations in a concession (managed under the SMS or the MUS) are under the general supervision of the SFO. Logging must be carried out during

[19]This activity is not very destructive as it involves the cutting of undergrowth and small trees, not larger timber species. The purpose of boundary clearing is to distinguish the felling area from other adjacent compartments.

the period when the permit or license is valid. Normally, a concessionaire submits an application for permission to terminate the logging operations when almost all of the sound marked trees have been harvested. However, in some cases, concessionaires will leave marked trees because they are difficult to extract and are likely to be defective (for instance, hollow trunks). The government allows concessionaires to leave as many as 20% marked trees. Concessionaires are subject to fines if they do not continue logging. They can also be fined for felling unmarked trees (trees that are below the cutting limits) or felling trees in other compartments (timber trespass or illegal felling).

A recent management practice in the implementation of the SMS is to incorporate volume control into the area-control approach ("Perlaksanaan," 1993; Alias, 1993). Under this approach, a periodic harvest schedule will be determined, based on joint considerations of area, volume, and silvicultural conditions of the forest stands. This will ensure that concessionaires harvest an allowable timber volume from forest concessions, as prescribed in the pre-F inventory. A 100% tree marking for trees above the cutting limits will be undertaken to further confirm the harvest volume extracted. Strict enforcement of log flow from the forest will be conducted at checking stations, where concessionaires' harvest volume will be compared with the estimated timber volume from pre-F and tree-marking data. Through this practice the Forest Department hopes that illegal logging will be eliminated and that a substantial increase in government revenue can be expected.

CHAPTER THREE

MICROECONOMIC MODELS OF FOREST REVENUE SYSTEMS

3.1 Introduction

In this chapter, static and dynamic microeconomic models of optimal forest revenue systems for Malaysian forests are described and developed. The models differ in terms of the nature of the government's objective function, whether it is to maximize short-run revenue only (the static model) or to maximize revenue and future forestry benefits jointly (the dynamic model). The revenue system consists solely of a royalty (uniform and *ad valorem*), although some implications for the premium are examined. The models assume that concessionaires act according to neoclassical production theory, as firms that maximize profits, taking forest revenue policies as given. Other assumptions underlying the two models are the same. In each model, the optimal royalty is derived for three types of logging technologies: Cobb-Douglas, Leontief, and Linear. Comparative static analysis is carried out to examine the direction of changes in production function parameters and characteristics of forest concessions and their effect on the optimal royalty.

The main hypothesis is that alternative forest revenue systems have significant effects on concessionaires' harvest behavior and government revenue, and that in designing an optimal forest revenue system to achieve specified government objectives, these effects must be taken into account.

3.2 The General Approach

Generally, two approaches can be taken to study log production: the household production model and the timber production model. The application of each approach depends on the behavior of the household and the firm. The household production model is appropriate when forests are privately owned, particularly when nontimber outputs are valued by the owner (Binkley, 1987). The household production model treats the landowner as a utility-maximizing consumer of nontimber forest outputs and consumptive goods. The timber production model is best used when logging firms operate under a defined market structure whereby production behavior is described as a solution to profit maximization. In this approach, three methods can be used: primal (direct), dual (indirect), and statistical analysis (Cardellichio & Kirjasniemi, 1987).

The primal and dual approaches are based on the neoclassical production theory. Based on this theory, production behavior is described which incorporates information on both economic behavior and available technology. A system of output supply and input demand functions are then derived. The statistical analysis approach, however, uses arbitrary output supply and input demand functions without explicit consideration of the underlying technology. A calibrated model falls in the first two categories.

Functional relationship of output supply or input demand functions can be estimated econometrically or using the "calibration" method. The application of each method depends on data availability. Cross sectional or time series data, which can be gathered from published reports or through sample survey, will permit the use of econometric method to estimate parameter values. If data are lacking or unavailable, the calibration method can be used.

This study employed a direct approach based on timber production of profit-maximizing behavior of a firm in a competitive economy using a Constant Elasticity of Substitution (CES) production function. This approach is appropriate because forest concessions in Peninsular Malaysia are owned by the government. Timber harvesting is carried out by concessionaires, subject to government regulation. The concessionaire is thus considered as a profit-maximizing firm in the short run. The government, not the concessionaires, is responsible for forest management activities following logging.

The timber production system involves both human and natural components. The human component comprises the government and concessionaires. Through decisions made by the government and concessionaires about timber production, the natural systems are affected. The focus of this study is not the influence of human decisions on natural systems, but rather the interaction between the revenue system and timber production. These two systems (forest revenue and timber production systems) are interrelated because of the roles played by the government and the concessionaire. The two systems are governed and controlled by the National Forestry Act, which facilitates the administration and development of the forestry sector in Peninsular Malaysia. The concessionaire employs labor and fixed capital (for examples, roads and equipment) in timber production. The concessionaire obtains timber right--a designated forest concession--through a concession contract. The logging industry is assumed to be perfectly competitive.[20] It is therefore assumed that the concessionaire takes log prices, the wage rate, the price of capital, and royalties as given. The concessionaire attempts to maximize profits subject to these prices and the production technology employed. If capital is fixed and labor is the only other factor, the concessionaire's decision is to determine the level of labor that will maximize profits.

The government, on the other hand, either attempts to maximize forest revenue in the short-run, or adopts a long-run objective of current forest revenue together with other forest management objectives, subject to the concessionaire maximizing profits. These objectives are consistent with the stated objectives of forest management in Peninsular Malaysia (section 2.6). The economic benefits could be viewed as the short-run objective, and the sustainability of forest resources is the long-run objective. The government views the forest revenue system as a policy instrument to influence the concessionaire's harvest behavior to achieve forest management objectives. Determining the optimal level of royalty can be viewed as a process that simultaneously determines the optimal labor input and the optimal royalty.

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[20]The degree of "competitiveness" of the logging industry is difficult to determine because there has been no single study carried out on this subject. However, the number of concessionaires could be used as an indicator. In 1993, there are about 1,200 concessionaires in Peninsular Malaysia (Dan, 1993). This indicates that the logging industry is competitive.

3.3 Assumptions of the Model

In formulating the static and dynamic models, the following conditions were assumed:

1. The logging industry exhibits perfect market competition. The concessionaire behaves as a price taker--to take log prices, royalties, and factor inputs (price of labor and capital) as given--when he determines an optimal policy. Timber fees levied by the government are assumed to have no effect on log prices.

2. The concessionaire is small relative to the industry. The harvest decision made by one concessionaire does not affect the decisions of other concessionaires.

3. Log prices vary among diameter classes and by species group. Variations in log prices are a result of differences in the quality of logs and how mills perceive the value of each species in the marketplace.

4. The concessionaire behaves rationally with respect to output and input prices and timber harvesting. This behavior is facilitated by accessible, relevant, and free information, as well as minimal transaction costs.

5. Forest concessions are managed by the Forestry Department, not the concessionaire, under the Selective Management System (SMS) with 25- to 30-year cutting cycles. The length of the cutting cycle and the cutting limits are taken as given and are assumed to be optimal.

6. The government is responsible for forest management activities. A nominal forest development fee is charged to the concessionaire, but this fee is assumed to be negligible and contained within the royalty.

3.4 The Static Model of Forest Revenue Systems

3.4.1 Model Structure

The static model developed here is based on the competing interests of two principal agents in the short run--the government and the concessionaire. The government owns, manages, and controls the forests, whereas the concessionaire is directly involved in harvesting timber from a particular forest concession. The concessionaire is treated as a single firm producing an intermediate good--logs. A contract to harvest timber in a particular compartment is made through a short-term agreement. This agreement establishes the royalty to be paid for timber harvested and extracted, and the premium is due based on the total area logged. In practice, the logging operation in a concession compartment normally is carried out within a year. Thus, the concessionaire is characterized by short-term harvest behavior, and this behavior is reflected by the short-run profit function.

Basically, the choice variable for the government is the timber royalty, with the forest revenue systems being obtained as functions of the choice variable (labor input) from the concessionaire's profit-maximization problem. Therefore, the basic tenet of the static model is that the government is attempting to maximize forest revenue subject to the production technology of the concessionaire, who is attempting to maximize profits.

3.4.2 The Concessionaire's Behavior

The concessionaire harvests timber from a given forest concession within a given contract period and sells the logs at competitive prices in the market. The concessionaire employs labor L and fixed capital K. The area of forest to be harvested is fixed by the contract; thus, there is no allocation of land over a period of harvest.

The concessionaire's log production function is defined on a per-hectare basis and is taken as Constant Elasticity of Substitution (CES). The CES production function was chosen for this study because it allows the analysis of a number of other more specialized production functions--Cobb-Douglas, Leontief, and Linear (Silberberg, 1978; Varian, 1984). The CES production function was first introduced by Arrow, Chenery, Minhas, and Solow (1961). Moreover, Sato (1975b) pointed out that this and the Cobb-Douglas nonlinear types of functions are frequently used in the field of economic analysis. Detailed explanations about characteristics, economic justifications, and types of CES functions have been provided by Arrow et al. (1961), McFadden (1963), Sato (1975a, 1975b), and Yacui (1965).

Formally, the general CES production function for the concessionaire is written as

$$V = A[\gamma L^{-\rho} + (1-\gamma)K^{-\rho}]^{-\frac{1}{\rho}} \tag{1}$$

where V is timber output per hectare, L is labor input, and K is fixed capital input. The parameter A is the "efficiency parameter," the parameter γ is the "distribution parameter" ($0 < \gamma < 1$), and the parameter ρ is the "substitution parameter." A change in A changes output by the same proportion for any given set of inputs. The value of parameter A, at least, would vary from site to site. The parameter γ

indicates that for any given value of ρ, the distribution of revenue between factors is determined by the extent to which the technology is labor intensive (γ is large) or capital intensive (γ is small). A change in ρ changes the elasticity of substitution. It is assumed that $\rho \geq -1$. If $\rho = -1$, the function is Linear; if $\rho = 0$, it is Cobb-Douglas; and if $\rho \Rightarrow \infty$, it is Leontief. The production function has the following properties:

The marginal product of labor is positive:

$V_L > 0$,[21]

but it exhibits diminishing returns:

$V_{LL} < 0$.[22]

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[21]This is obtained by differentiating the CES function with respect to L,

$$\frac{\partial V}{\partial L} = V_L = A(-\frac{1}{\rho})[\gamma L^{-\rho} + (1-\gamma)K^{-\rho}]^{-\frac{1}{\rho}-1}[-\rho\gamma L^{-\rho-1}]$$

$$= A\gamma[\gamma L^{-}\rho + (1-\gamma)K^{-\rho}]^{-\frac{1}{\rho}-1}[L^{-\rho-1}]$$

$$= A\gamma[\gamma L^{-\rho} + (1-\gamma)K^{-\rho}]^{-\frac{1}{\rho}(1+\rho)}[L^{-(1+\rho)}]$$

$$= \frac{\gamma}{A^{\rho}}V^{(1+\rho)}L^{-(1+\rho)} \Rightarrow \frac{\gamma}{A^{\rho}}(\frac{V}{L})^{1+\rho} > 0.$$

[22]The partial derivative of V_L with respect to L is

$$\frac{\partial(V_L)}{\partial L} = V_{LL} = \frac{\partial\{\frac{\gamma}{A^{\rho}}(\frac{V}{L})^{1+\rho}\}}{\partial L}$$

$$= \frac{\gamma}{A^{\rho}}(1+\rho)(\frac{V}{L})^{\rho}(\frac{LV_L - V}{L^2}) < 0,$$

This production function also exhibits homogeneity of degree one (Arrow et al., 1961).

Harvest behavior of the concessionaire is derived from a short-run profit function that treats labor L as the input to be chosen. Thus, the objective function of the concessionaire can be written as:

$$\underset{L}{Max}\ \pi = (1-\sigma)\int_0^{V^*} P(V)dv - wL(1+\delta) - rK(1+\delta) - t(1-\sigma)V - m \tag{2}$$

where $P(V)$ is timber value distribution, w wage rate, r price of capital, t uniform royalty rate, m premium rate, δ normal profit margin, and σ logging damage. Note that V is the actual harvest volume of timber felled by the concessionaire, but due to logging damage, only a portion of this timber, $(1-\sigma)$, is actually extracted and sold. It should be pointed out that uncertainties and risks are not treated explicitly, but they are implicitly embodied in total factor costs through the inclusion of normal profit margins, $1 + \delta$.[23]

Equation 2 comprises three components:

1. Total revenue $= (1-\sigma) \int_0^{V^*} P(V)dv$
2. Total factor costs $= wL(1+\delta)+rK(1+\delta)$
3. Total timber fees $= t(1-\sigma)V+m$

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because $LV_L - V < 0$ by the Euler theorem (under constant returns to scale).

[23]Neher (1990) pointed out that it is not easy to know how to incorporate uncertainty. Normally, the treatment of uncertainty in modeling frameworks is employed in the expected-value and expected-utility approaches.

The first component, total revenue, is the integral of the timber value distribution. The timber value distribution is a descriptive relationship between log prices and timber volume. It indicates the price of each incremental cubic meter of timber that is harvested within the forest concession. The timber value distribution would be a step function if it were plotted out for an actual compartment. For simplicity, $P(V)$ is modeled by a linear function, as in Figure 1:

$$P(V) = \alpha - \beta V \tag{3}$$

where α is a constant (measures the price of highest-valued timber species) and β is the slope of the timber value distribution (measures how steeply prices fall off as less valuable timber is extracted). The timber value distribution slopes downward due to differences in species, diameter, and grade. Although $P(V)$ is downward sloping, it is not a demand function. This functional relationship is consistent with figures in Page et al. (1976), Ruzicka (1979), Awang Noor et al. (1992), and Vincent et al. (1993).

The second component, total factor costs, is the payment for labor and fixed capital inputs. These include a normal profit margin, δ, which is what the concessionaire receives for his management effort. The profit margin is net of payments of corporate income taxes. Only normal profits are earned by all concessionaires if the government captures all the stumpage value.

The last component, total timber fees paid by the concessionaire, is part of the concessionaire's total costs. Royalty is charged at a uniform[24] rate t for each species on each cubic meter of timber extracted from the concession area. V is multiplied by $1-\sigma$ to adjust for logging damage during timber harvesting. A premium rate m is charged, based on per hectare area logged.[25]

To maximize profit, Equation 2 is differentiated with respect to L and equated to zero:[26]

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[24]There are basically three royalty structures for logs: specific royalties, per tree royalties, and *ad valorem* royalties (Gillis, 1992). In the case of specific royalties, there are two forms--uniform specific royalties and differentiated specific royalties. In this study, the uniform royalty refers to uniform specific royalties used in Gillis (1988a, 1992) or to uniform fixed royalties used by Hyde & Sedjo (1992).

[25]As explained in Chapter Two, the model considers a forest revenue system that comprises a mix of volume-based and area-based charges. Even though silvicultural cess and tribute are not explicitly specified, these charges are implicitly included in t.

[26]The second-order condition for profit-maximizing behavior requires that $\partial^2\pi/\partial L^2 < 0$; that is, the profit function must be strictly concave in the neighborhood of the optimal level of labor use. Thus, by taking the partial derivative of V_L we have

$$\frac{\partial^2\pi}{\partial L^2} = (1-\sigma)[V_L(-\beta V_L)+(\alpha-\beta V)V_{LL}]-t(1-\sigma)V_{LL} < 0,$$

which can simply be written as

$$(\alpha-\beta V-t)V_{LL}-\beta(V_L)^2 < 0,$$

which holds because $V_L > 0$, $V_{LL} < 0$. The concessionaire would not harvest at a point where $\alpha-\beta V-t < 0$, as this implies that the royalty, t, exceeds the log price, $\alpha-\beta V$.

$$\frac{\partial \pi}{\partial L} = (1-\sigma)(\alpha-\beta V-t)V_L - w(1+\delta) = 0 \tag{4}$$

This equation can be rearranged to yield the standard result that the net marginal value product of labor ($NMVP_L$) equals the marginal factor cost of labor (MFC_L):

$$(1-\sigma)(\alpha-\beta V-t)V_L = w(1+\delta) \tag{5}$$

The left-hand side of the equation represents the net revenue from hiring one more unit of labor: incremental harvest (V_L), times price (α-βV) minus royalty (t), adjusted for logging damage (1-σ). On the right-hand side is the marginal cost of labor (including overhead costs, i.e. normal profit) (MFC_L). Therefore, the concessionaire will employ labor input until the net marginal value product of the **L^*th** unit of labor equals its factor cost. This condition is presented in Figure 4.

The horizontal axis represents the labor used in harvesting logs within a given concession compartment. In this case, capital is fixed at level K. V_L is, as discussed earlier, a concave function ($V_L > 0$, $V_{LL} < 0$). MFC_L does not vary with labor input L and is drawn horizontally.

In the absence of royalty, the concessionaire will harvest logs when the gross marginal value product of labor equals the alternative wage rate of labor, including overhead costs, *ceteris paribus*. The optimal labor input is at **L^1**.

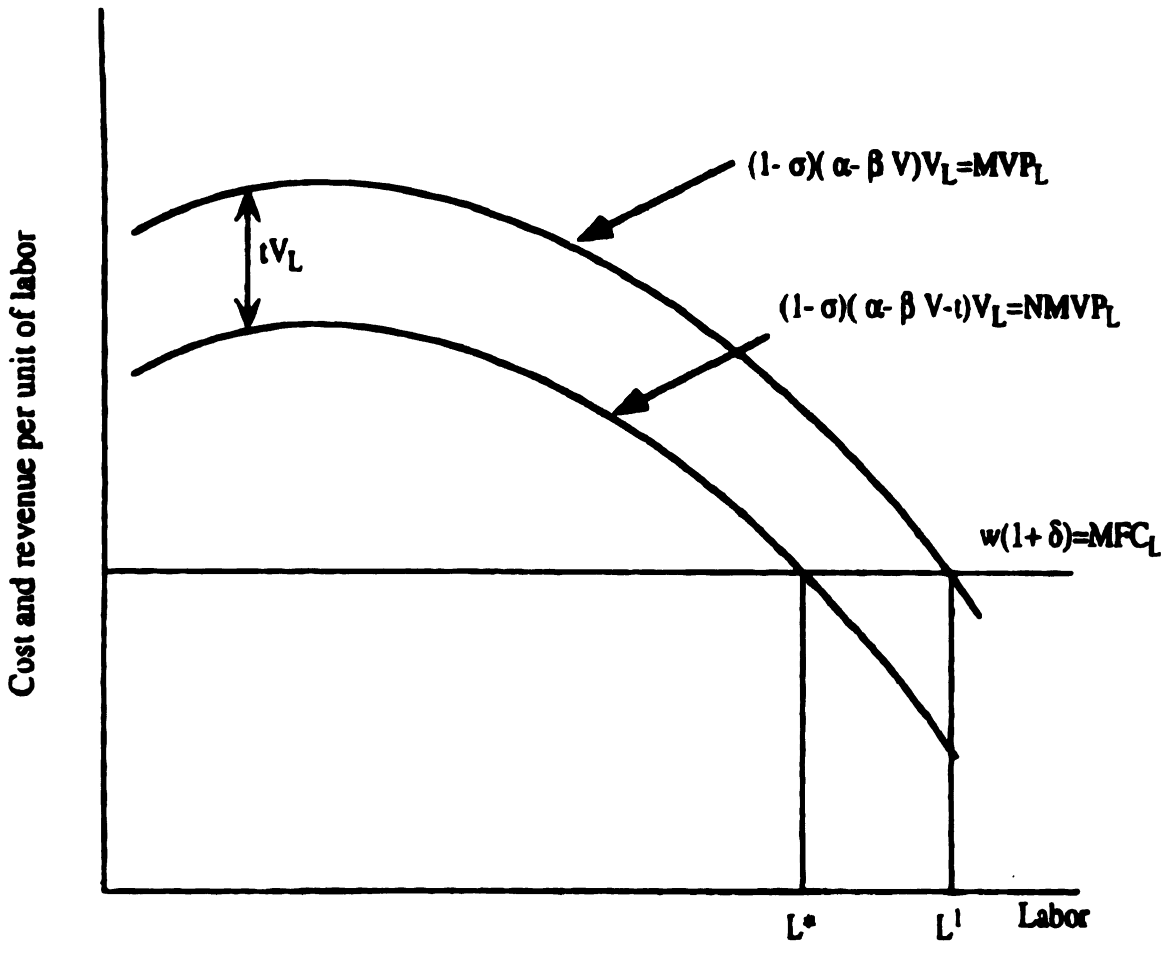

Figure 4. The determination of Optimal Labor Input.

The net marginal value product curve is drawn below the marginal value product of labor because the concessionaire has to pay *t* ringgit[27] per unit of timber harvested. The vertical distance between the MVP_L and the $NMVP_L$ shows the amount of royalty paid for an incremental unit of timber harvested. This will induce the concessionaire to reduce output below the level where the gross marginal value product of labor equals its alternative wage rate. As a result, the concessionaire has to reduce the amount of labor used in timber production, and thus the level of harvest. The optimal labor input is now at **L***.

The optimal labor input **L*** is found by solving the first order condition of Equation 4:

$$L^* = V\left[\frac{A^{\rho}w(1+\delta)}{\gamma(1-\sigma)(\alpha-\beta V-t)}\right]^{-\frac{1}{1+\rho}} \tag{6}$$

where (1/1+ρ) is the elasticity of substitution. Equation 6 can be simplified as

$$L^* = \frac{V}{A^{\rho\theta}}[k(\alpha-\beta V-t)]^{\theta} \tag{7}$$

where

k = $\gamma(1-\sigma)/w(1+\delta)$, and

θ = $1/(1+\rho)$.

Equation 7 indicates that the optimal labor input in timber production, and thus the optimal harvest, will depend on output and input prices and the technology used.

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[27]Malaysian currency (abbreviated as RM for Malaysian Ringgit).

This equation is treated as a constraint in formulating the objective function of the government.

3.4.3 The Government's Behavior

The government employs a single criterion or objective--to choose the royalty that will maximize forest revenue R in any specific time period. This objective function is subject to solution of the first-order condition of the concessionaire (Equation 7). Formally, the static objective function can be written as

$$\underset{t}{Max}\ R = t(1-\sigma)V+m-c(1-\sigma)V \tag{8}$$

subject to $\partial\pi/\delta L = 0$. The equation indicates that the government attempts to maximize forest revenue collection from a given hectare of a forest concession (the first two terms), and c ringgits must be spent for royalty collection. These costs are the payment to forestry staff at checking stations, where royalties are assessed. Note that the per-hectare premium, m, is not treated as a choice variable; more on this is provided below.

The first-order condition for maximizing forest revenue is obtained by differentiating Equation 8 with respect to t, and setting the resulting derivative equals to zero:

$$\frac{\partial R}{\partial t} = (1-\sigma)V+t(1-\sigma)V_L\frac{\partial L^*}{\partial t}-c(1-\sigma)V_L\frac{\partial L^*}{\partial t} = 0 \tag{9}$$

For an interior solution, $t > 0$. To interpret the first-order condition more easily, Equation 9 is rearranged as

$$V^{*} = -(t-c)V_{L}\frac{\partial L^{*}}{\partial t} \tag{10}$$

The left-hand side of Equation 10 represents increased revenue on timber currently harvested if the government raises the royalty. The right-hand side is the opportunity cost of net marginal forest revenue from timber that the higher royalty causes the concessionaire to leave in the forest. Referring to Figure 4, an increase in royalty causes labor input to fall ($\partial L^{*}/\partial t < 0$), which also causes harvest to fall ($V_L > 0$). A decrease in harvest level will lead to a lower net revenue received from each cubic meter of timber left in the forest (t-c). Thus, at the optimal level of royalty, the marginal increase in revenue from current timber harvest and the marginal loss in net forest revenue are equal. In other words, maximization of government revenue requires simultaneous determination of the labor input and the royalty rate. So for every L^{*}, one can choose the optimal t. This result is similar to the one worked out by Hyde and Sedjo (1992, p. 349), which was corrected by Vincent (1993b).

The optimal royalty can be obtained by solving the first-order condition of Equation 10. But Equation 10 cannot explicitly be solved for t because V_L and $\partial L^{*}/\partial t$ also are functions of t. V_L is obtained from Equation 5,

$$V_L = \frac{w(1+\delta)}{(1-\sigma)(\alpha-\beta V-t)} \tag{11}$$

and $\partial L^{*}/\partial t$ is obtained by differentiating Equation 7 partially with respect to t, using the chain rule,

$$\frac{\partial L^{*}}{\partial t} = \frac{-\frac{1}{A^{\rho\theta}}\theta k V}{g^{1-\theta}-\frac{1}{A^{\rho\theta}}gV_L+\frac{1}{A^{\rho\theta}}\theta k\beta VV_L} \tag{12}$$

where g is given by $k(\alpha\text{-}\beta V\text{-}t)$.

Substituting V_L and $\partial L^{*}/\partial t$ in Equation 10, yields a general formula for the optimal royalty, t^{*}:

$$t^{*} = \frac{g^{1-\theta}}{A^{\rho\theta}\theta kV_L}-\frac{1}{\theta}(\alpha-\beta V-t)+\frac{1}{A^{\rho\theta}}\beta V+c \tag{13}$$

When combined with Equations 1 and 7, it forms a system of three simultaneous equations that can be used to predict optimal values of the three unknown variables, t^{*}, L^{*}, and V^{*}.

Equation 13 can be converted to optimal-level-of-royalty formulas for three types of production technologies, Cobb-Douglas, Leontief, and Linear, by inserting the appropriate values of θ:

Cobb-Douglas (θ=1):

$$t^*_{S,CD} = [\alpha - \gamma(\alpha - c)] + (2\gamma - 1)\beta V^* \tag{14}$$

Leontief (θ=0):

$$t^*_{S,LF} = [\alpha - \frac{w(1+\delta)}{(1-\sigma)}] - \beta V^* \tag{15}$$

Linear (θ=∞):

$$t^*_{S,LN} = c + \beta V^* \tag{16}$$

where the subscript S refers to the static objective, and the subscripts CD, LF, and LN correspond to the Cobb-Douglas, Leontief, and Linear production technologies, respectively.

In general, therefore, the optimal level of royalty is influenced by output and input prices, logging damage, and the characteristics of a forest concession. The extent to which these factors affect the optimal level of royalty depends on the nature of the production function of the logging industry.

Note that for the Cobb-Douglas technology, the relationship between the optimal royalty, t^*, and the optimal harvest volume, V^*, is seen to depend on the distribution parameter in the production function, γ. If $\gamma > ½$, t^* is positively related to V^* (that is, a higher royalty rate is associated with a larger harvest); if $\gamma < ½$, t^* is negatively related to V^* (that is, a lower royalty rate is associated with a lower harvest); and if $\gamma = \frac{1}{2}$, the royalty rate is independent of the volume of harvest. In the extreme, the optimal royalty in the Cobb-Douglas technology is exactly equal to the optimal royalty in the Linear technology when $\gamma = 1$ (labor is the only input).

In addition to royalty, the government can collect revenue by levying a premium. This can range from zero to a maximum value that limits concessionaire profits to normal levels: $\pi = 0$ in Equation 2. If m is so high that $\pi < 0$, the concessionaire would not operate. Once the optimal royalty is determined, Equation 2 can be used to determine m as a residual.[28] As the premium is not chosen directly, it is not necessarily an optimal value. The premium is thus the difference between total revenue and the sum of fixed costs, variable costs, and royalty payments. The premium can be regarded as the maximum amount that the concessionaire would be willing to pay in order to obtain concession rights, given the optimal royalty. If no royalty is levied, this is the total stumpage value of the compartment.

3.5 The Dynamic Model of Forest Revenue Systems

3.5.1 Conceptual Framework and Model Structure

The conventional timber harvest objective in a long term context is to harvest forests to maximize the sum of discounted stumpage value from present and future

[28]It should be pointed out that the premium may not provide the best solution due to input assumptions used in the model. It is expected that if royalties are raised and volume of harvest reduces then residual damage would increase at a rate higher than the proportional decline in timber harvest. The effects of logging damage and revenue collection costs on premium are not taken into account since they are assumed fixed with respect to different harvest levels.

timber harvests (Hyde, 1980; Heaps and Helliwell, 1985; Johansson & Lofgren, 1985; Sedjo & Lyon, 1990; Neher, 1990). The classical economic problem is to determine the optimal rotation length (i.e. when a forest stand should be harvested). This concept is mainly applied in even-aged forests, in which all trees are harvested at the same time. Dipterocarp forests in Peninsular Malaysia are, however, managed as uneven-aged stands. The long term aspects of forest management are the timing of harvests (the cutting cycle) and the selection of minimum-diameter cutting limits, which determine the size of current harvests and affect future ones through impacts on stand composition.

The implementation of minimum-diameter cutting limits for particular species groups, given a fixed cutting cycle, results in some portion of timber with positive stumpage in the current period being left in the forest as advanced regeneration to restore the forest. It follows that a long-run formulation of the government's objective function should not be restricted to revenue maximization alone but should also include the opportunity cost of deviations from the minimum cutting limits. The static model assumes that the government's only objective is to maximize forest revenue without considering the long-term impacts of the present harvest level. This revenue-driven objective fails to reflect sustainable management of natural forests for long-term, socially optimal behavior.

To model this, an additional term that reflects the opportunity cost of harvest deviations from the prescribed level must be included in the government's objective function. The inclusion of this term might even signify a long-term interest in managing natural forests for multiple benefits. Over- or under-harvesting might affect the sustainability of multiple benefits following harvesting. Therefore, the basic purpose of the dynamic model is to analyze optimal royalties that are optimal for long-term forest management objectives.

3.5.2 The Concessionaire's Behavior

In this model, concessionaires are assumed to continue to behave in a short-run manner due to the structure of concession contracts, which are shorter than the cutting cycle. Because of this and the fact that forests are owned by the government, concessionaires would not expect to capture stumpage value from future harvests. Therefore, the objective function of the concessionaire in the dynamic model remains the same as in the static model.[29] Equation 7 is used as a constraint in formulating the objective function of the government.

3.5.3 The Government's Behavior

The objective function of the government must accommodate a long-term forest management objective and may be expressed as follows:

$$\underset{t}{Max}\ R = t(1-\sigma)V+m-c(1-\sigma)V-\mu(V^{SY}-V)^2, \tag{17}$$

subject to the optimal level of labor input (Equation 7). This objective function is similar to the expression in Equation 8, but with one extra term; $\mu(V^{SY}-V)^2$, which is

[29]Vincent (1993b) pointed out that if the owner (government) makes the optimal decisions and the concessionaire abides by them, the stumpage value of timber harvested today is the financially optimal amount, regardless of whether the concession is short term or long term.

a loss function giving the opportunity cost to the government of harvest deviations (either under- or over-harvesting) from the SMS prescriptions. Since the term is an opportunity cost, it must be subtracted in Equation 17, which implies that the government maximizes forest revenue net of forgone future benefits.

V^{SY} is the prescribed harvest level to implement a sustained-yield management regime that maximizes the sum of discounted stumpage value (and perhaps other values, as noted in section 3.5.1) from present and future harvests. It should be recognized that V^{SY} is the policy instrument for long-term, multiple benefits even though these benefits are not explicitly specified. The difference, V^{SY}-V, exists due to logging behavior by the concessionaire in response to timber fees levied by the government, market conditions, and other factors. The larger the difference, V^{SY}-V, the larger the deviation of the harvest from the prescribed level. In practice, there are two possibilities that relate to the concessionaire's harvest behavior in a concession compartment, i.e., whether $V > V^{SY}$ or $V < V^{SY}$.

If $V > V^{SY}$, i.e. if the actual harvest is greater than the prescribed harvest level, the concessionaire harvests too much timber by harvesting below the cutting limits. Vincent et al. (1993) confirmed that this actually happens under the present forest management system in Peninsular Malaysia. The discrepancy creates a dynamic cost because fewer residual trees are left to grow until the next harvest. If $V < V^{SY}$, i.e. if the actual harvest is less than the prescribed harvest level, this implies too little harvest--timber is left in the forest above the cutting limits. The discrepancy also creates a dynamic cost because the timber left to grow until the next harvest is overmature. Therefore, any deviation (negative or positive) of the actual timber harvest level V from the prescribed harvest level V^{SY} generates losses, which reduce the government's objective function. To show this in Equation 17, the expression V^{SY}-V, can be made arbitrarily squared and subtracted, so that all deviations, whether positive or negative, yield a loss. This specification also indicates that the government is more concerned with great deviations than with small ones. Because V^{SY}-V is squared, the cost rises exponentially as the deviation increases.

The deviations must be valued by a shadow price, μ, in order to be compared to revenue effects. Because μ multiplies by $(V^{SY}-V)^2$, it is the per squared-unit cost of deviations. If only timber values are important, it can be regarded as the reduction in discounted forest values due to overmature timber left in the forest (if $V < V^{SY}$) or immature timber harvested in the current cutting cycle (if $V > V^{SY}$). μ is analogous to shadow price of a resource in optimal control theory (Chiang, 1992; Dorfman, 1969; Neher, 1990).

The first-order condition for maximization is:

$$\frac{\partial R}{\partial t} = (1-\sigma)V+t(1-\sigma)V_L\frac{\partial L^*}{\partial t}-c(1-\sigma)V_L\frac{\partial L^*}{\partial t}+2\mu(V^{SY}-V)V_L\frac{\partial L^*}{\partial t} = 0 \tag{18}$$

At the optimum, the first-order condition for maximization indicates that

$$V^* = -[(t-c)+\frac{2\mu(V^{SY}-V)}{(1-\sigma)}]V_L\frac{\partial L^*}{\partial t} \tag{19}$$

Compared to Equation 10, the right-hand side of Equation 19 has one extra term, the opportunity cost for deviations from the SMS prescriptions. Thus, it is expected that the harvest level in the dynamic model is greater than the harvest in the static model if the harvest in the static model is less than V^{SY} (not enough timber is harvested from the standpoint of the dynamic objective), and less otherwise.

To obtain the optimal level of royalty, the same procedure is followed as in the static case. Substituting V_L (Equation 11) and $\partial L^*/\partial t$ (Equation 12) in Equation 19 and obtaining the general expression for t,

$$t = \frac{g^{1-\theta}}{\frac{1}{A^{\rho\theta}}\theta k V_L} - \frac{1}{\theta}(\alpha - \beta V - t) + \frac{1}{A^{\rho\theta}}\beta V + c - \frac{2\mu(V^{SY}-V)}{(1-\sigma)} \tag{20}$$

Equation 20 can be used to derive the optimal royalty, t^*, for three types of production technologies:

Cobb-Douglas (θ=1):

$$t^*_{D,CD} = \{\alpha - \gamma[\alpha - c + \frac{2\mu V^{SY}}{(1-\sigma)}]\} + [(2\gamma - 1)\beta + \frac{2\gamma\mu}{(1-\sigma)}]V^* \tag{21}$$

Leontief (θ=0):

$$t^*_{D,LF} = [\alpha - \frac{w(1+\delta)}{(1-\sigma)}] - \beta V^* \tag{22}$$

Linear (θ=∞):

$$t^*_{D,LN} = c+\beta V^* - \frac{2\mu(V^{SY}-V^*)}{(1-\sigma)} \tag{23}$$

where the subscript D refers to the dynamic royalty, and the subscripts CD, LF, and LN correspond to the Cobb-Douglas, Leontief, and Linear production technologies, respectively. As before, the (not necessarily optimal) premium m can be obtained as a residual by using the zero-profit condition. Compared to the static royalties, the dynamic royalties of the Cobb-Douglas and Linear production technologies are either less or greater than the static royalties, depending on the size of the deviation from the SMS prescriptions. In the case of the Leontief technology, the static and dynamic royalties are the same. These results are summarized in the following equations:

a) $t^*_{D,CD} < t^*_{S,CD}$,[30] if $V^{SY} > V^*$;

$t^*_{D,CD} > t^*_{S,CD}$, if $V^{SY} < V^*$;

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[30]Rewriting Equation 21, one has

$$t^*_{D,CD} = [\alpha-\gamma(\alpha-c)]+(2\gamma-1)\beta V^* - \frac{2\gamma\mu}{(1-\sigma)}(V^{SY}-V^*)$$

The first two terms on the right-hand side represent the static royalty in Equation 14. Hence,

$$t^*_{D,CD} = t^*_{S,CD} - \frac{2\gamma\mu}{(1-\sigma)}(V^{SY}-V^*)$$

It is obvious that the optimal dynamic royalty ($t^*_{D,CD}$) relative to the static royalty ($t^*_{S,CD}$) depends on the size of V^{SY}-V^*.

b) $t^{*}_{D,LF} = t^{*}_{S,LF}$,[31]

c) $t^{*}_{D,LN} < t^{*}_{S,LN}$,[32] if $V^{SY} > V^{*}$;

$t^{*}_{D,LN} > t^{*}_{S,LN}$, if $V^{SY} > V^{*}$.

Based on these results, the levels of premiums in the dynamic model of the Cobb-Douglas and Linear production technologies are likely to be higher or lower than the level of premium in the static model. When the dynamic royalty is lower than the static royalty, the dynamic premium is higher than the static premium. This is because the lower royalty induces a larger harvest, with a higher aggregate stumpage value. The reverse is true when the dynamic royalty is higher than the static royalty. The optimal static premium equals value of ***m*** when t=0, but this does not apply for the dynamic premium because the concessionaire has no incentive to recognize V^{SY} in the absence of t. The static and dynamic premiums for the Leontief technology would be the same.

3.6 Deriving Optimal *Ad Valorem* Royalty

The government also can levy timber fees based on a flat rate or *ad valorem* royalty. In this study, the royalty base is the market value of timber harvested, and

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[31]This is obvious from Equations 15 and 22.

[32]Similarly, from Equations 16 and 23, one can write

$$t^{*}_{D,LN} = t^{*}_{S,LN} - \frac{2\mu(V^{SY} - V^{*})}{(1-\sigma)}$$

Thus, it is obvious that the optimal dynamic royalty relative to the static royalty depends on the size of V^{SY}-V^{*}.

royalty, t, is levied on an *ad valorem* basis (that is, percentage of log price).[33] To derive an optimal *ad valorem* royalty, the conditions and assumptions as specified in the case of uniform royalty remain unchanged. The only difference is the specification of the concessionaire's and government's objective functions. Therefore, the same approach as was employed in the static and dynamic uniform royalties can be used to derive optimal *ad valorem* royalties. Because the concessionaire pays a royalty based on a percentage of log price, $(1-t)P(V)$, the concessionaire's revenue net of royalty payments is therefore:

$$(1-\sigma)(1-t)\int_0^{V^*} P(V)dv$$

As in the case of uniform royalty, the concessionaire's static and dynamic objective functions are assumed to be the same (that is, maximize profits). Therefore, the concessionaire's static and dynamic objective functions are expressed as follows:

$$\underset{L}{Max}\ \pi = (1-\sigma)(1-t)\int_0^{V^*} P(V)dv - wL(1+\delta) - rK(1+\delta) - m \tag{24}$$

The total government revenue from *ad valorem* royalty is then equal to the integral of timber value distribution times the royalty rate:

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[33] *Ad valorem* royalty can also be defined as percentage charges on net revenues (Hyde & Sedjo, 1992). However, Gillis (1980, 1988a) and most tropical country governments have defined *ad valorem* royalty as the charge on log price.

$$(1-\sigma)t\int_0^{V^*} P(V)dv$$

The integral is multiplied by 1-σ, to adjust for logging damage.

As in the case of uniform royalty, the structure of the problem for the government is to maximize revenue (static objective) or to maximize revenue and future benefits with sustained logging practices (dynamic objective). The static objective of the government is written as:

$$\underset{t}{Max}\ R = (1-\sigma)t\int_0^{V^*} P(V)dv + m - c(1-\sigma)V, \tag{25}$$

and the dynamic objective function is given by:

$$\underset{t}{Max}\ R = (1-\sigma)t\int_0^{V^*} P(V)dv + m - c(1-\sigma)V - \mu(V^{SY}-V)^2 \tag{26}$$

A more detailed derivation is provided in Appendix A. The optimal static and dynamic *ad valorem* royalties for the Cobb-Douglas production technology are given below.

a. Static *ad valorem* royalty

$$t^*_{S,CD} = \frac{z+\gamma c V^*}{z+\gamma(\alpha-\beta V^*)} \tag{27}$$

where

$$z = [\alpha V^* - \frac{\beta}{2}(V^*)^2][1 - \gamma + \frac{\gamma \beta V^*}{(\alpha - \beta V^*)}]$$

b. Dynamic *ad valorem* royalty

$$t^*_{D,CD} = \frac{z + [c - \frac{2\mu}{(1-\sigma)}(V^{SY} - V^*)]\gamma V^*}{z + \gamma V^*(\alpha - \beta V^*)} \tag{28}$$

3.7 Summary

The static and dynamic microeconomic models of optimal forest revenue systems for the uniform royalty were described and developed in this chapter. The same derivations were also employed to determine the static and dynamic microeconomic models for the *ad valorem* royalty. From these models, the residual static premium, which is not necessarily optimal, can be developed.

Given these optimal royalties, comparative statics can also be investigated. The purpose is to study the effect of changes in certain parameters on the equilibrium (optimal) level of decision variables when certain assumptions change, holding other variables or parameters constant. The analysis considers the direction of the changes on the equilibrium value rather than the magnitude of the changes. Two parameters were considered because of their importance in the forest revenue system--one representing technology, γ, and the other representing forest characteristics, β. Appendix B provides detailed results for the uniform royalty.

CHAPTER FOUR

EMPIRICAL ANALYSIS: METHODS

4.1 Introduction

The theoretical models formulated in Chapter Three are applied to data on Peninsular Malaysia in this chapter. The main purpose is to determine optimal royalties and to examine how differences in forest revenue systems affect concessionaire's behavior given a specific forest managment objective.

For this purpose, production behavior is modeled using the Cobb-Douglas function. This function provides a more suitable representation of the production function of the logging industry than does either the linear function, which assumes that labor and capital are perfect substitutes, or the Leontief function, which assumes they cannot substitute at all for each other. The analysis provides quantitative estimates of the optimal royalty and the effects of changes in exogenous variables and parameters on the optimal royalty, harvest volume, and government revenue.

The chapter begins with a brief description of the full model. The research sites and the methods for estimating key functions and parameters are described in the remainder of the chapter. Results of sensitivity analysis are presented in Chapter Five.

4.2 The Empirical Model

The empirical model is based on equations derived in Chapter Three. Five models are developed, depending on government objectives and the structure of the royalty systems. The models are:

Model I:	Static Model: Uniform Royalty
Model II:	Dynamic Model: Uniform Royalty
Model III:	Static Model: *Ad Valorem* Royalty
Model IV:	Dynamic Model: *Ad Valorem* Royalty
Model V:	Static Model: Premium

Models I through IV comprise six simultaneous equations. The equations are:

1. Production function
2. Labor demand function
3. Profit function
4. Government revenue function
5. Optimal royalty equation
6. Premium equation

Model V is a special case when the royalty is zero (t=0). The optimal royalty equation is therefore excluded from this model. Table 4 summarizes the definitions of all variables and parameters, which are the same as in Chapter Three. Tables 5 through 9 list the model equations.

With reference to Tables 5 through 9, the models differ in terms of the structure of Equations 2, 3, 4, and 6. Equation 1 is the same in all models. Equations 2, 3, 4, and 6 are the same in Models I and II, but they are different

Table 4. Definitions of Variables and Parameters

Symbol	Definition
Endogenous	
V	Volume of timber felled
L	Labor input
π	Profit
R	Government revenue
t	Royalty
m	Premium
Exogenous	
α	Intercept of the timber value distribution
β	Slope of the timber value distribution
σ	Logging damage
μ	Cost of harvest deviation (shadow price)
A	Efficiency parameter
K	Capital
V^{SY}	Prescribed harvest volume
c	Royalty collection costs
Parameter	
γ	Labor share
δ	Profit margin
w	Wage rate
r	Interest rate

Table 5. Structure of Model I

1. Production function

$$V = AL^{\gamma}K^{1-\gamma}$$

2. Labor demand function

$$L = V[\frac{\gamma(1-\sigma)}{w(1+\delta)}(\alpha-\beta V-t)]$$

3. Profit function

$$\pi = (1-\sigma)(\alpha V-\frac{\beta}{2}V^2)-wL(1+\delta)-rK(1+\delta)-t(1-\sigma)V-m$$

4. Government revenue function

$$R = t(1-\sigma)V+m-c(1-\sigma)V$$

5. Optimal royalty equation

$$t = \alpha-\gamma(\alpha-c)+(2\gamma-1)\beta V$$

6. Premium equation

$$m = (1-\sigma)(\alpha V-\frac{\beta}{2}V^2)-wL(1+\delta)-rK(1+\delta)-t(1-\sigma)V$$

Table 6. Structure of Model II

1. Production function

$$V = AL^{\gamma}K^{1-\gamma}$$

2. Labor demand function

$$L = V[\frac{\gamma(1-\sigma)}{w(1+\delta)}(\alpha-\beta V-t)]$$

3. Profit function

$$\pi = (1-\sigma)(\alpha V-\frac{\beta}{2}V^2)-wL(1+\delta)-rK(1+\delta)-t(1-\sigma)V-m$$

4. Government revenue function

$$R = t(1-\sigma)V+m-c(1-\sigma)V$$

5. Optimal royalty equation

$$t = \alpha-\gamma[\alpha-c+\frac{2\mu V^{SY}}{(1-\sigma)}]+[(2\gamma-1)\beta+\frac{2\gamma\mu}{(1-\sigma)}]V$$

6. Premium equation

$$m = (1-\sigma)(\alpha V-\frac{\beta}{2}V^2)-wL(1+\delta)-rK(1+\delta)-t(1-\sigma)V$$

Table 7. Structure of Model III

1. Production function

$$V = AL^{\gamma}K^{1-\gamma}$$

2. Labor demand function

$$L = V[\frac{\gamma(1-\sigma)}{w(1+\delta)}(1-t)(\alpha-\beta V)]$$

3. Profit function

$$\pi = (1-\sigma)(1-t)(\alpha V-\frac{\beta}{2}V^2)-wL(1+\delta)-rK(1+\delta)-m$$

4. Government revenue function

$$R = (1-\sigma)t(\alpha V-\frac{\beta}{2}V^2)+m-c(1-\sigma)V$$

5. Optimal royalty equation

$$t = \frac{(\alpha V-\frac{\beta}{2}V^2)[1-\gamma+\frac{\gamma\beta V}{(\alpha-\beta V)}]+\gamma cV}{(\alpha V-\frac{\beta}{2}V^2)[1-\gamma+\frac{\gamma\beta V}{(\alpha-\beta V)}]+\gamma(\alpha-\beta V)}$$

6. Premium equation

$$m =(1-\sigma)(1-t)(\alpha V-\frac{\beta}{2}V^2)-wL(1+\delta)-rK(1+\delta)$$

Table 8. Structure of Model IV

1. Production function

$$V = AL^{\gamma}K^{1-\gamma}$$

2. Labor demand function

$$L = V[\frac{\gamma(1-\sigma)}{w(1+\delta)}(1-t)(\alpha-\beta V)]$$

3. Profit function

$$\pi = (1-\sigma)(1-t)(\alpha V-\frac{\beta}{2}V^2)-wL(1+\delta)-rK(1+\delta)-m$$

4. Government revenue function

$$R = (1-\sigma)t(\alpha V-\frac{\beta}{2}V^2)+m-c(1-\sigma)V$$

5. Optimal royalty equation

$$t = \frac{(\alpha V-\frac{\beta}{2}V^2)[1-\gamma+\frac{\gamma\beta V}{(\alpha-\beta V)}]+[c-\frac{2\mu}{(1-\sigma)}(V^{SY}-V)]\gamma V}{(\alpha V-\frac{\beta}{2}V^2)[1-\gamma+\frac{\gamma\beta V}{(\alpha-\beta V)}]+\gamma V(\alpha-\beta V)}$$

6. Premium equation

$$m = (1-\sigma)(1-t)(\alpha V-\frac{\beta}{2}V^2)-wL(1+\delta)-rK(1+\delta)$$

Table 9. Structure of Model V

1. Production function

$$V = AL^{\gamma}K^{1-\gamma}$$

2. Labor demand function

$$L = V[\frac{\gamma(1-\sigma)}{w(1+\delta)}(\alpha-\beta V)]$$

3. Profit function

$$\pi = (1-\sigma)(\alpha V - \frac{\beta}{2}V^{2}) - wL(1+\delta) - rK(1+\delta) - m$$

4. Government revenue function

$$R = m - c(1-\sigma)V$$

5. Premium equation

$$m = (1-\sigma)(\alpha V - \frac{\beta}{2}V^{2}) - wL(1+\delta) - rK(1+\delta)$$

compared to Models III and IV. The optimal royalty equation (Equation 5) differs in every model.

The equations specified for each model show how endogenous variables are determined in the model. Parameters and exogenous variables are assumed to be independent of one another. Therefore, any new value can be assigned to any one of them without affecting the values of the others. This is an important criterion for sensitivity analysis, whereby the value of an exogenous variable or parameter is increased individually in order to obtain new values for the endogenous variables. The values of endogenous variables after the change can be used to calculate elasticities for the royalty, harvest volume, and government revenue.

The endogenous variables were arranged such that they appeared on the left side of the equations. Except in Model V, all six equations were solved simultaneously. In Model V, the five equations (excluding the optimal royalty equation) were solved under the constraint that the royalty is zero. Data source, estimation, and computational procedures for all variables and parameters are discussed in the following sections.

4.3 Research Sites

4.3.1 General Remarks

Data for this study were drawn primarily from a concession-level study on forest revenue systems in Peninsular Malaysia by Awang Noor et al. (1992). That study was carried out in eight concession compartments in three east-coast states of Peninsular Malaysia (Pahang, Terengganu, and Kelantan). Since eight concession compartments were used in that study, there are eight data sets that could have been used in this study. However, only six data sets were actually used. The reason for excluding the other two is given in the next section.

For each compartment, the database consists of timber volumes before and after logging, which were aggregated by species group, diameter class, and average log prices. Other available information includes the average logging costs within each state, logging damage, logging fines, and profit margin. In addition to this database, other information was also collected from published reports and other sources. This information includes interest rate, wage rate of logging workers, and the government cost of collecting royalty.

Further details on data and data sources are contained in the remainder of this section and also in section 4.4.

4.3.2 Location and Characteristics

The research sites were located in four concessions in virgin hill forests in Permanent Forest Reserves in three east-coast states (Pahang, Terengganu, and Kelantan) of Peninsular Malaysia (Figure 5). These states accounted for 63% of the timber harvest in Peninsular Malaysia in 1989. Their forests are broadly similar in terms of forest types and productivity. However, the forest revenue systems vary among the three states due to state autonomy over forestry matters. Timber fees are characterized as follows (refer to section 2.5 for details of the Forest Revenue System):

Pahang: high royalty, high premium.

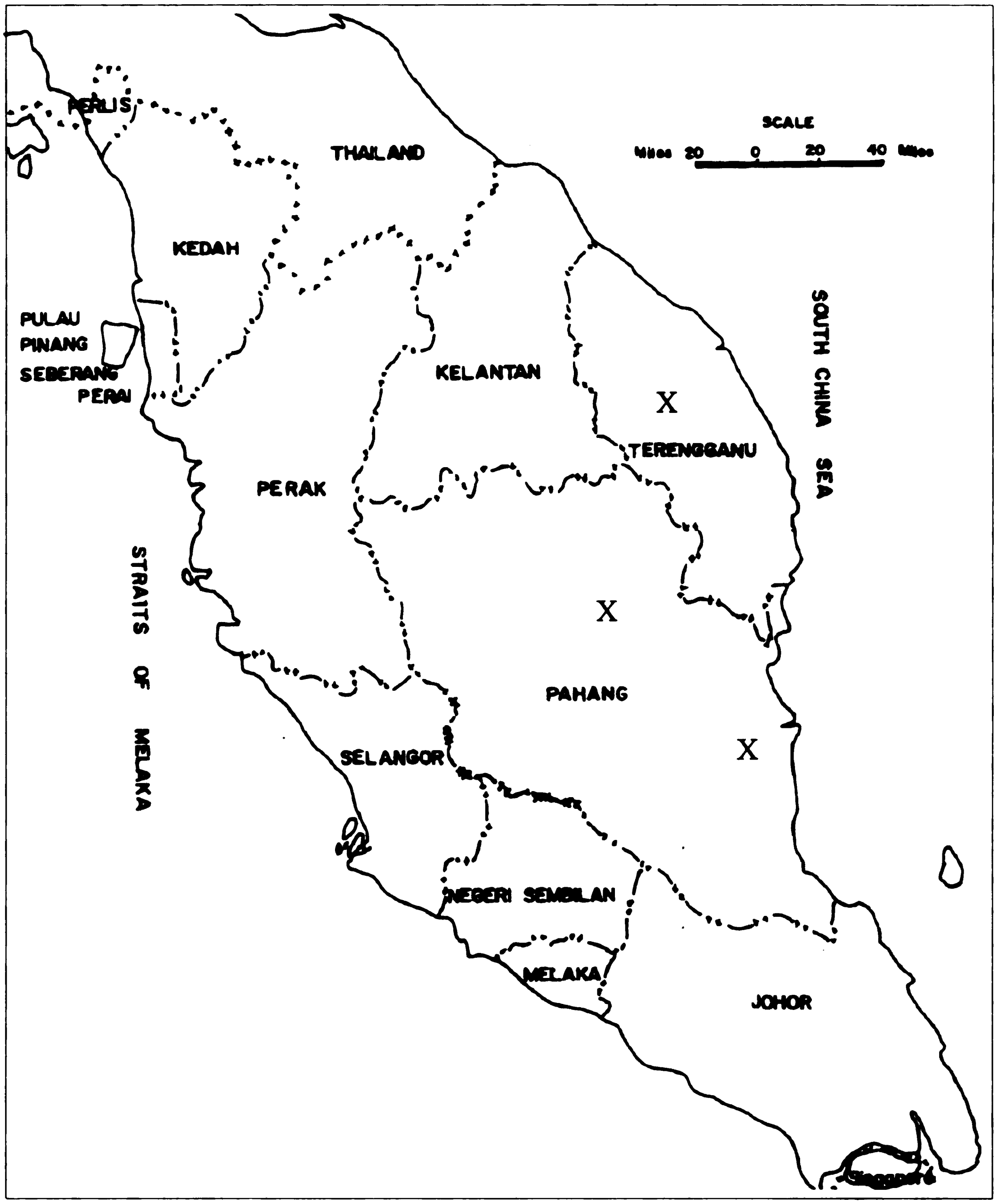


Figure 5. Location of the Research Sites.

Terengganu: moderate royalty, moderate premium.

Kelantan: low royalty, low premium.

The characteristics of the research sites are shown in Table 10. Each research site is denoted by a three-symbol abbreviation. The first symbol (P, T) is the first letter of the state where the site was located. The second symbol (1 or 2), applies only to Pahang, and distinguishes the concessions within a state. The third symbol distinguishes the compartments within a concession (a or b). Sites K1a and K1b were excluded from the empirical analysis due to inconsistencies between pre-F and post-F data (thus, they are not shown in the table). Compartment size ranged from 239 ha to 401 ha. These differences meant that harvesting activities took longer to complete in some compartments than others. The duration of logging ranged from 6 months (P2b) to 17 months (T1a). The average volume of timber extracted per hectare over the life of the concession, based on volumes recorded at checking stations, ranged from approximately 35 m^3 to nearly 70 m^3. Regarding the forest revenue system, premiums were higher in Pahang than those in Terengganu. It should be noted that the premiums for P2a and P2b, which were sites in tendered compartments, exclude the tender price, which is reported lower in the table. Average royalties are expressed both per hectare and per m^3. They varied among sites because of variations in stocking and species composition. Silvicultural cess and tributes are set at fixed rate per m^3. The rate of silvicultural cess is the same in all sites. In Terengganu, concessionares are not required to pay the tribute.

The minimum-diameter cutting limits varied little across sites--limits were 60-65 cm for dipterocarps and 50-55 cm for nondipterocarps. Standing timber volumes

Table 10. Characteristics of the Research Sites

Characteristic	State					
	Pahang				Terengganu	
	P1a	P1b	P2a	P2b	T1a	T1b
Area (ha)	288	239	285	269	401	401
Dates of logging	Nov. 89 - June 90	Nov. 89 - June 90	Jan. 90 - July 90	Oct. 88 - Mar. 89	Mar. 88 - July 89	Feb. 88 - Apr. 89
Average extracted volume (m^3/ha)	65.96	52.93	35.40	59.90	56.86	68.89
Premium (RM/ha)	500.00	500.00	500.00	500.00	300.00	300.00
Average royalty:						
per hectare (RM/ha)	752.94	728.50	698.04	740.41	945.59	964.70
per cubic meter (RM/m^3)	11.42	13.76	19.72	12.36	16.63	13.80
Cess (RM/m^3)	2.80	2.80	2.80	2.80	2.80	2.80
Tribute (RM/m^3)	1.86	1.86	1.86	1.86	n.a	n.a
Tender price (RM/ha)	n.a	n.a	2526.50	930.00	n.a	n.a
Cutting limits: (cm)						
Dipterocarps	60	60	60	60	65	65
Nondipterocarps	50	50	50	50	55	50
Mean volume (m^3/ha, $\geq$ 30 cm dbh)						
a. Pre-F inventory:						
Dipterocarps	41.53 (44%)	83.60 (68%)	30.20 (30%)	37.15 (35%)	78.79 (69%)	76.37 (70%)
Nondipterocarps	48.17 (50%)	39.28 (32%)	69.38 (70%)	67.94 (65%)	34.62 (31%)	32.46 (30%)
Conifer	5.43 (6%)					
b. Post-F inventory:						
Dipterocarps	10.66 (22%)	15.74 (26%)	3.57 (7%)	5.34 (10%)	16.70 (25%)	11.81 (23%)
Nondipterocarps	38.39 (78%)	45.34 (74%)	50.58 (93%)	49.55 (90%)	50.88 (75%)	39.74 (77%)

n.a = Not applicable.

before and after logging varied substantially among sites. Timber volumes before and after logging were based on pre-F and post-F inventories, respectively. (See section 4.4.1.2 for explanation of pre-F inventory). The post-F inventories were carried out in a 50-ha block within each compartment. The selection of a 50-ha block was based on the judgement that it was the minimum size that would be representative of the terrain and initial forest composition of an average compartment. A local timber inventory consulting firm was hired to carry out the inventory. The sampling framework and the information collected are essentially identical to those in the pre-F inventory. Thus, in each block there were 50 sampling plots. The post-F inventories covered one-fourth to one-eight of the area covered by the pre-F inventories. Therefore, the pre-F and post-F data are not exactly comparable.

Timber volume in the table is defined as the volume of trees having a diameter at breast height (dbh) of at least 30 cm. The highest pre-F timber volume was 122.88 m^3/ha in P1b. Most of the sites are very well stocked, having pre-F volumes between approximately 95 m^3/ha and nearly 123 m^3/ha. There were also substantial differences in species composition. In three of the sites (P1b, T1a, T1b), dipterocarps accounted for two-thirds or more of the pre-F timber volume.

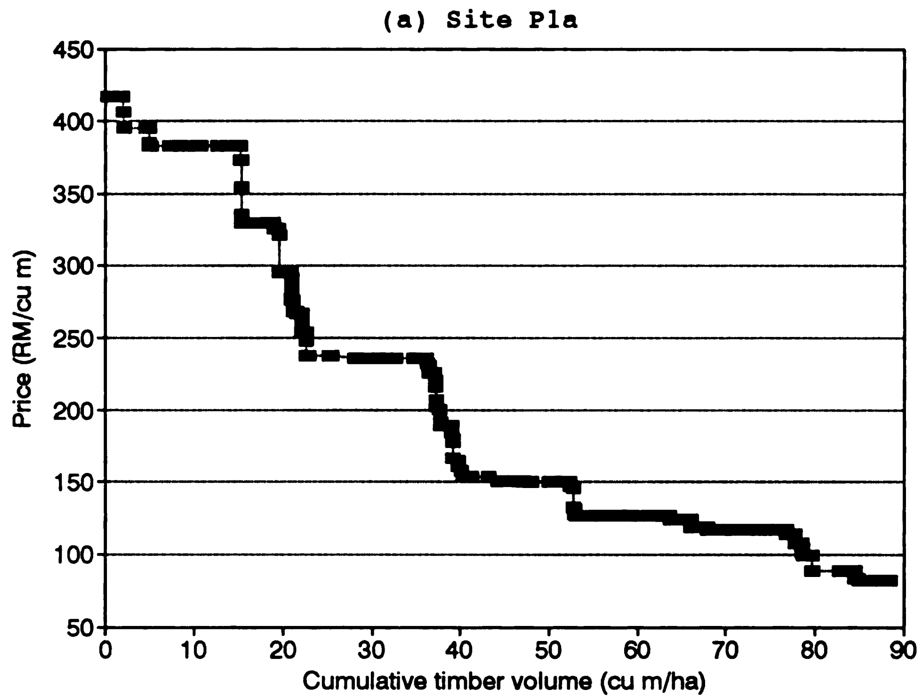
4.4 Data and Estimation

4.4.1 Timber Value Distribution (TVD)

4.4.1.1 Model specification. The relationship between log prices and cumulative timber volume within a forest concession can be graphed as a step function (Page et al., 1976; Ruzicka, 1979; Vincent et al., 1993). This is because log prices vary due to differences in species, grade, and log diameter. The timber value distribution patterns for the compartments are plotted and shown in Figure 6.

The horizontal axis represents the cumulative timber volume across all species groups. To calculate cumulative timber volume, each species group disaggregated by diameter class was ordered from highest to lowest, according to the magnitude of the average log price. Then the cumulative timber volume was obtained by adding the volume of timber in a given group to the timber volume for all the more valuable groups. The vertical axis indicates log price for a given, incremental species/diameter group. Each species/diameter group defines a step, with the width being the volume in the group and the height the log price.

The model requires that these step functions be represented by single equations. Two functional forms of timber value distribution (TVD) were considered: linear and semilog equations. The functional forms of the equations are written as follows:



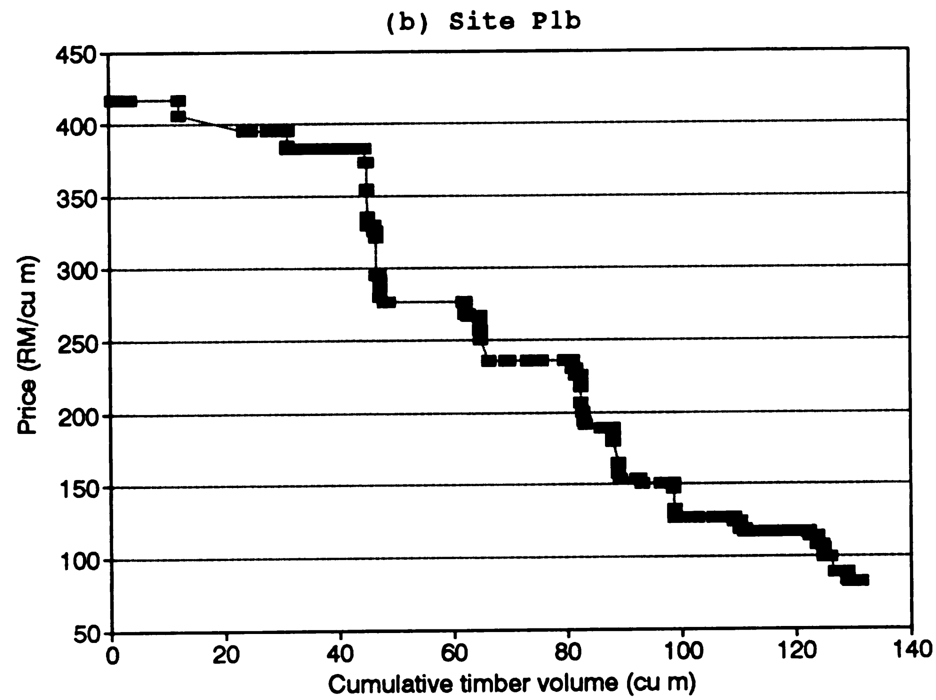
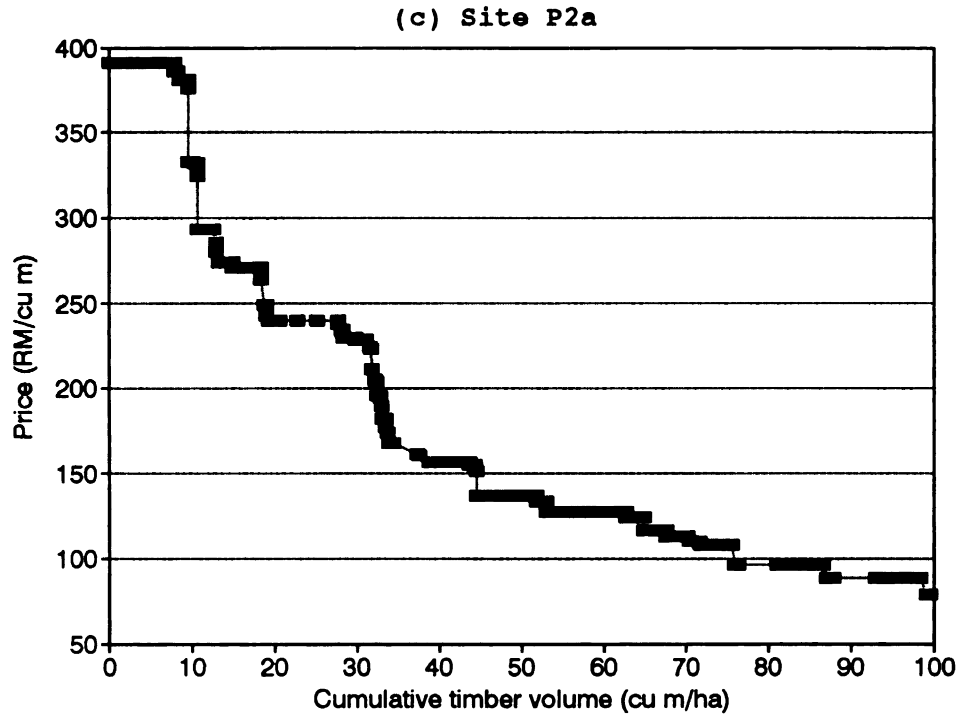


Figure 6. Timber Value Distribution.



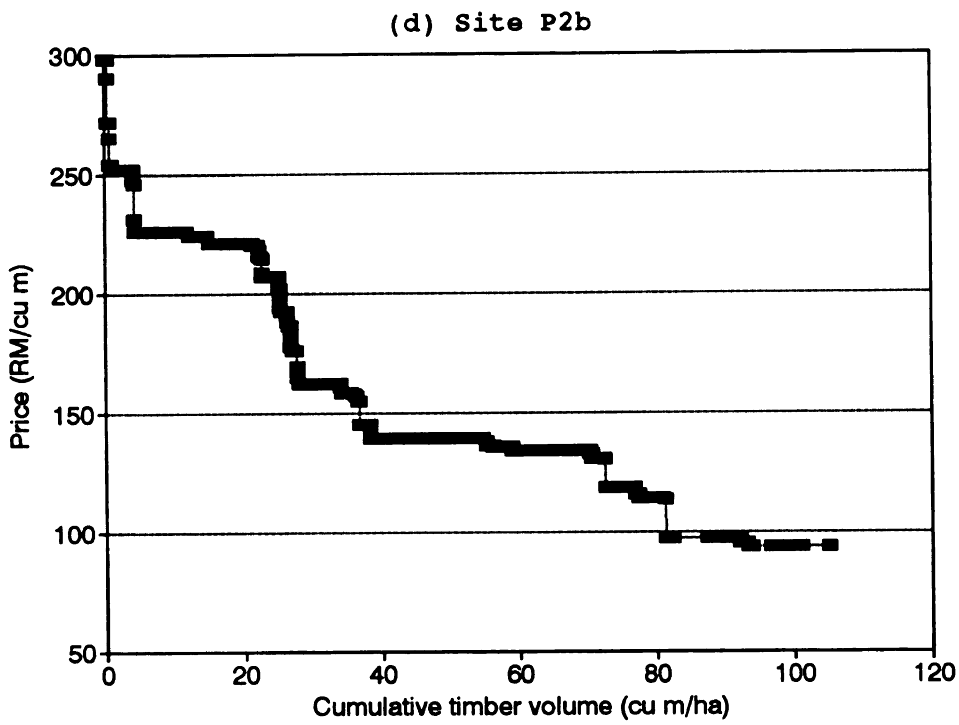
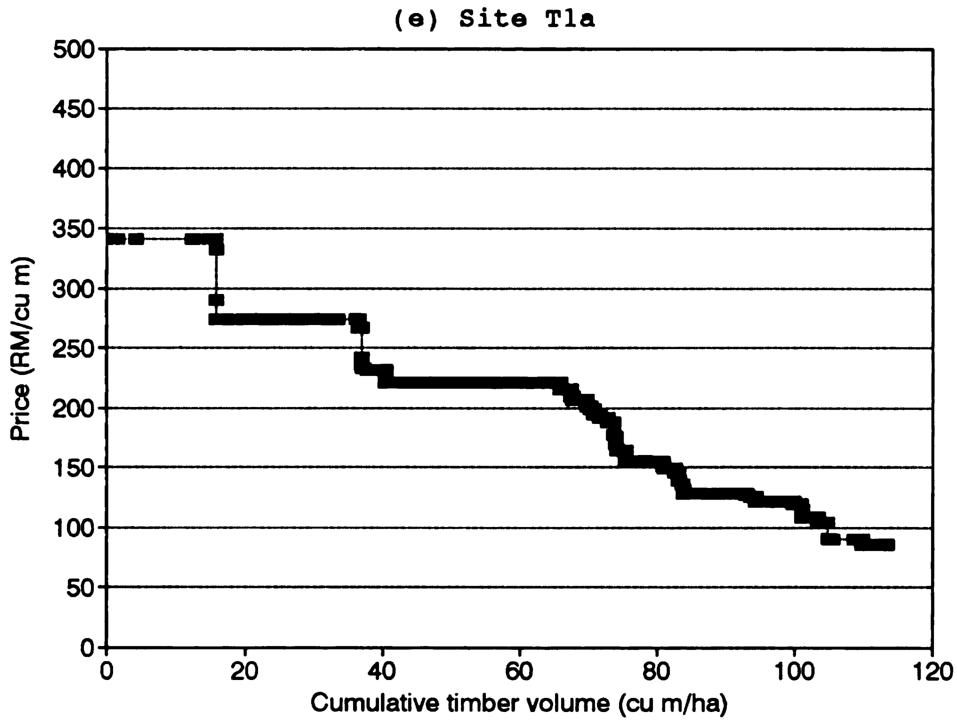


Figure 6. (cont'd).



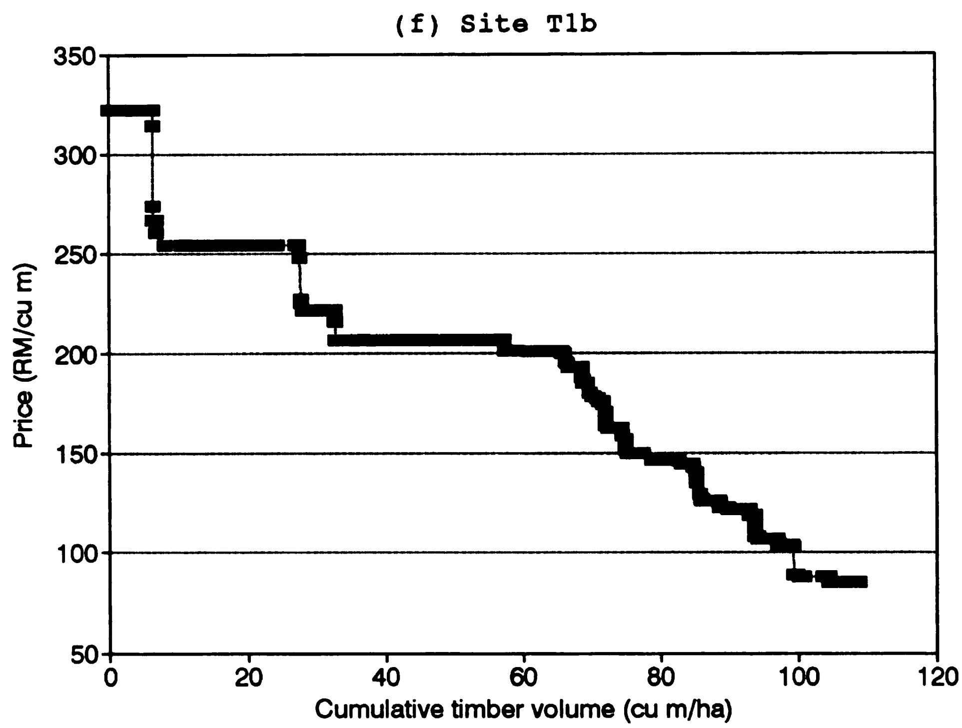


Figure 6. (cont'd).

Linear:

$$P_{ij} = \alpha + \beta V_{ij} + \epsilon_{ij}$$

Semilog:

$$P_{ij} = e^{\alpha + \beta V_{ij}} + \epsilon_{ij}$$

where

P = the price of logs,

V = cumulative timber volume,

ϵ = error term,

α and β are parameters to be estimated, i is species group, and j is diameter class.

Data required for estimating timber value distribution are timber volumes and log prices. They are discussed below.

4.4.1.2 Timber volumes. This study used pre-F inventory data on timber volumes before logging for each site. These data were provided by the SFOs. As discussed in Chapter Two, pre-F inventories are normally carried out by the SFO for an individual compartment 1 to 2 years before it is logged. This inventory is required under the SMS in the Permanent Forest Reserves. The inventory is based on a 10-percent systematic linear sampling method. The inventory records stocking (number of trees) per diameter class (as classes, in 5 to 15 cm increments) by individual species. The inventory also records information on log quality, crown status, and presence of climbers. The Forestry Department uses formulas based on volume tables to estimate timber volumes from these data. These data then were aggregated to correspond to species groups in Table 11 and timber volumes by species group and diameter class were calculated. These groups correspond to the ones used to report monthly log prices for Peninsular Malaysia in *MASKAYU*, a monthly timber bulletin published by the Malaysian Timber Industry Board (MTIB).

4.4.1.3 Log Prices. Data on log prices were gathered from *MASKAYU*. Average domestic log prices paid by mills (in Malaysian ringgit) per cubic meter are reported for 21 individual species and species groups and three regions--East Coast, Central and West Coast. The states of Pahang and Terengganu are in the East Coast region. These prices are mean reported log prices provided by mills and the logger's association in each region. The reported log prices are normally gathered through direct information provided by mills or via telephone call.[34] Only selected mills are included in providing this information.

The data pertain to logs with diameters of 55 cm and above. The average East Coast log prices for the months when logging actually occurred were used. These prices are provided in Table 12. Reduction factors were used to adjust log prices by diameter class (Table 13). For instance, a factor of 0.3 for dbh 30 to 45 cm indicates that price per cubic meter is only 70% of the full value.

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[34]These data are collected through MTIB regional offices, which compile the information into a monthly report called 'Area Timber Price' and send it to MTIB Headquarters. These log prices are then published in *MASKAYU*.

Table 11. List of Species Groups Used in the Analysis

Species Group	Dipterocarps/ Nondipterocarps[1]	Symbol	Species (Common Name)
HEAVY HARDWOOD (HHW)			
Balau	DIP	BL	Balau and Sengkawang Air
Cengal	DIP	CGL	Cengal
Merbau	NONDIP	MRB	Merbau
Red Balau	DIP	RB	Damar Laut Merah, Membantu
Other Heavy Hardwoods	DIP/NONDIP	OHHW	Giam, Resak, etc.
MEDIUM HARDWOOD (MHW)			
Kapur	DIP	KPR	Kapur and Keladan
Kempas	DIP	KPS	Kempas
Keruing	DIP	KRG	All Keruings
Mengkulang	NONDIP	MK	Mengkulang
Other Medium Hardwoods	NONDIP	OMHW	Keledang, Punah, Simpoh, etc.
LIGHT HARDWOOD (LHW)			
Dark Red Meranti	DIP	DRM	Seraya, Meranti Bukit, etc.
Jelutong	NONDIP	JLG	Jelutong
Light Red Meranti	DIP	LRM	Meranti Rambai Daun, Meranti Batu, Meranti Tembaga, Meranti Kepong, etc.
Mersawa	DIP	MA	All Mersawas
Nyatoh	NONDIP	NY	Nyatoh
Red Meranti	DIP	RM	Gerutu, Gerutu Pasir, etc.[2]
Sepetir	NONDIP	SP	Sepetir
White Meranti	DIP	WM	Meranti Bakau, Meranti Belang, Meranti Bumbung, Meranti Jerit, etc.
Yellow Meranti	DIP	YM	Damar Hitam, Damar Katup, etc.
Other Light Hardwoods	NONDIP	OLHW	Penarahan, Machang, Kembang Semangkuk, Bintanggor, Kedondong, etc.
CONIFER			
Damar Minyak/Kuari	NA	DM	Damar Minyak/Kuari

NA = Not applicable. Damar Minyak and Kuari are conifers.

[1] These two groups are important for determining the cutting limits. Cutting limits for dipterocarps are slightly higher than those for nondipterocarps.

[2] Some of the species are listed under LRM.

Table 12. Average Nominal Log Prices[1] by Species and Site (RM/m^3)

Species	State				
	Pahang			Terengganu	
	P1a and P1b	P2a	P2b	T1a	T1b
HEAVY HARDWOOD (HHW)					
Balau	277	280	254	231	222
Cengal	417	405	364	341	322
Merbau	330	333	299	274	267
Red Balau	254	258	221	199	192
Other Heavy Hardwoods	119	113	136	130	127
MEDIUM HARDWOOD (MHW)					
Kapor	227	240	215	200	195
Kempas	151	157	162	149	147
Keruing	236	240	221	207	201
Mengkulang	295	293	224	209	200
Other Medium Hardwoods	127	127	139	128	126

Table 12. (cont'd).

Species	State				
	Pahang			Terengganu	
	P1a and P1b	P2a	P2b	T1a	T1b
LIGHT HARDWOOD (LHW)					
Dark Red Meranti	395	386	272	274	254
Jelutong	238	229	252	242	222
Light Red Meranti	383	391	226	221	207
Mersawa	267	271	207	201	193
Nyatoh	226	230	207	194	185
Red Meranti	271	267	200	199	183
Sepetir	154	155	186	164	163
White Meranti	257	249	199	195	179
Yellow Meranti	189	182	165	155	150
Other Light Hardwoods	117	137	134	122	122
CONIFER					
Damar Minyak	150				

[1]Average log prices for the months when logging actually occurred. Refer to Table 10 for dates of logging on each site.

Table 13. Price Reduction Factors

DBH Class (cm)	Reduction Factor
30 - 45	0.300
45 - 50	0.150
50 - 55	0.025
55 and above	0.000

The information in Table 13 was obtained from the MTIB (Ahmad, 1990). These prices were expressed in nominal terms for two reasons: the logging within each site typically occurred in periods of one year or less, with 29 months as the longest period in one site, and inflation was low during this period.[35]

Although log prices in Pahang were generally close to the East Coast averages, log prices in Terengganu were often 10% to 13% lower. This is because the state of Pahang is relatively close to many timber manufacturing plants located in Selangor. Thus, logs in Pahang would be offered at higher prices because of lower transportation costs.

4.4.1.4 Method of estimation. The linear equation was estimated by the Ordinary Least Squares (OLS) method and the semilog equation by the Nonlinear Least Squares (NLS) method. The results are shown in Tables 14 and 15. The results indicate that both models were consistent with a negative slope of the timber value distribution curve. All of the coefficients were highly significant at the .001

[35]The percentage annual increases of consumer price index (CPI) for 1989-1991 were between 2.9% to 4.7%.

Table 14. OLS Results for the Timber Value Distribution

Site	Estimate α	Estimate β	N	R^2	Adjusted R^2
P1a	380.449* (2.1200)	-3.6048* (0.0340)	1320	.8948	.8948
P1b	474.536* (2.7473)	-3.2935* (0.0297)	1111	.9175	.9174
P2a	327.588* (3.1609)	-3.3437* (0.0596)	671	.8244	.8241
P2b	236.946* (1.3377)	-1.6621* (0.0237)	704	.8755	.8753
T1a	336.458* (1.7308)	-2.2214* (0.0206)	594	.9516	.9516
T1b	298.053* (1.3327)	-1.9295* (0.0160)	737	.9516	.9516

Figures in parentheses indicate standard errors.

* Significant at the .001 level.

Table 15. NLS Results for the Timber Value Distribution

Site	Estimate α	Estimate β	N	R^2	Adjusted R^2
P1a	6.0904* (0.00485)	-0.0184* (0.00012)	1320	.9445	.9445
P1b	6.3496* (0.0093)	-0.0138* (0.00014)	1111	.8911	.8910
P2a	5.9867* (0.0059)	-0.0203* (0.00016)	671	.9538	.9538
P2b	5.5370* (0.0049)	-0.0107* (0.00011)	704	.9264	.9263
T1a	5.9384* (0.0089)	-0.0114* (0.00013)	594	.9199	.9198
T1b	5.7679* (0.0072)	-0.0104* (0.00010)	737	.9162	.9160

Figures in parentheses indicate standard errors.

* Significant at the .001 level.

level, and the coefficients of determination (R^2) were very high. The relative values of R^2 between the two models in each site did not show any large differences.

Semilog and linear models each give better fits in three cases. Shortcomings of the semilog function are that it implies an infinite timber volume and an infinitely high maximum log price, and that deriving the theoretical model using the semilog function is difficult. Hence, the linear function was used in the analysis.

4.4.2 Calibrating the Production Function Parameters

A Cobb-Douglas production function can be econometrically estimated either from time-series or cross-sectional data by the Ordinary Least Squares (OLS) technique (Greene, 1990; Kmenta, 1986). The data required for estimation are outputs (might be measured by value added) and labor and capital inputs for each firm across region or yearly data of all industries across a region. In Peninsular Malaysia, time-series or cross-sectional data on timber production in relation to input requirements were not available for the logging industry. Thus, the functional relationship of the Cobb-Douglas production function cannot be estimated econometrically.

Kmenta (1986) suggests that faced with this problem, one can choose parameter values using the "calibration" method instead of estimating them econometrically. In this study, the approach is to use an exogenous estimate of the labor share to calibrate the production function to data for the endogenous variables (labor and capital). The calibration procedure used in this study is described below.

The short-run total costs (TC) per hectare for the concessionaire in timber production must equal total variable costs (TVC) plus total fixed costs (TFC). Variable costs include such items as labor and fuel; fixed costs include such items as road construction and payments for machinery. The relationship between total costs and total variable and total fixed costs is given as:

$$\text{TC} = \text{TVC} + \text{TFC}.$$

The short-run variable and fixed costs can be represented as follows:

$$\text{TVC} = wL, \text{ and TFC} = rK.$$

If the short-run average total costs (ATC) are defined as total costs per unit of output, then

$$\text{TC} = \text{ATC} * V.$$

Given estimates of ATC and V, total costs can be calculated from the preceding equation. If the share between TVC and TFC is known, the amount of TVC and TFC can be estimated from the total costs (TC). Moreover, if the values of w and r are known, the amount of labor input L and fixed level of capital K can be estimated using the following relationships:

$$L = \text{TVC}/w,$$

$$K = \text{TFC}/r.$$

Given this information, the parameters of the Cobb-Douglas production function can easily be determined. The Cobb-Douglas production function has a labor share parameter (γ) and an efficiency parameter (A). The labor factor share is estimated as follows:

$$\gamma = \frac{wL}{wL+rK} = \frac{TVC}{TC}$$

Once the factor share is determined, the efficiency parameter can be determined by inserting V, L, K, and γ into the Cobb-Douglas production function:

$$A = \frac{V}{L^{\gamma}K^{1-\gamma}}$$

Data required for calibrating those production function parameters include timber volumes, average logging cost, wage rate, interest rate, and labor share. Data on timber volumes are the same as described in section 4.4.1.2. Actual harvest volumes were adjusted for logging damage, based on checking station records.

The average logging costs for each state were RM63.83/m^3 in Pahang and RM60.83/m^3 in Terengganu. The estimate in Pahang was based on a previous study (Apong, 1989), and in Terengganu it was estimated from information provided by a concessionaire. It was assumed that the average logging costs were constant within the state. The estimates of average logging costs were in nominal terms and included a normal, post-tax profit margin (δ). The pre-tax profit margin was estimated to be 22%, based on information provided by logging contractors. It was assumed that the corporate income tax was 40%. Thus, the estimated post-tax profit margin was 13.2%. The average post-tax logging costs, *exclusive* of profit margins, were MR56.39/m^3 in Pahang and MR53.74/m^3 in Terengganu.

Wage differentials in the logging industry vary according to type of occupation, skill level, nature of work, and region. The wage paid is based on a monthly payment or a piece-rate, depending on the nature of work done by the workers. In this study, the wage rate for felling activities was used to reflect the average wage rate of all categories of workers in the logging industry. The wage rate was set equal to RM30.00 per man-day in all states (Ku Azmi, 1993; Shaharuddin, 1993).

The interest rates should necessarily reflect the cost of capital to the logging industry. In this study, prime or base lending rates (BLR) were readily available and could be used as a general measure of the cost of capital. However, in practice, the actual interest rates charged by commercial banks and finance companies are normally 2% higher than the reported prime lending rates. Information obtained from commercial banks and finance companies indicates that the market interest rates range from 10% to 12%. In this study, the interest rate was set at 12%.

The labor share was calculated using logging cost data for 1979 to 1981 reported by Chung (1984). The calculated value of γ was 0.53, and it was treated as constant for all states. Using all the information described above, the estimates of TC, TVC, TFC, L, K, and A were obtained and are shown in Table 16.

The estimates presented in Table 16 represent only two major costs (labor, L and capital, K), because the production function assumes that harvest is a function of L and K only. K can be thought of as the sum of all fixed factors (e.g., road construction and overhead, as well as equipment), while L can be thought of as all variable factors. Timber management costs are not included because the government is responsible for forest management activities.

If one had used an econometric approach to estimate the relationship among labor (*L*), capital (*K*), and harvest (*V*) at the individual concessionaire level, the vales of the factor shares (γ, $1-\gamma$) and the efficiency parameter (*A*) might have differed. Uncertainty of these values is evaluated through sensitivity analysis.

4.4.3 Logging Damage

Logging damage can be in the form of physical damage to the trees (seedlings and saplings and advanced growth) or to the environment (soil, water, nutrient, habitat for wildlife, so on). In this study, logging damage referred to all dead or damaged, standing or down, trees above the cutting limits.

The parameter of logging damage was calculated using the following formula:

$\sigma = V_D/V * 100$, where σ is the percentage of logging damage, V is actual harvest volumes, and V_D is volume of timber damaged. The actual harvest volume (V) was based on checking station records. Checking stations record information on the actual volume of timber extracted from the forest. The values of σ for each site are provided in Table 17.

4.4.4 Other Variables and Parameters

Information on logging fines and volume of timber above the cutting limits left in the forest was used to estimate μ. The fine is based on RM400 per tree. This fine is also applied to trees harvested below the cutting limits. If one assumes that

Table 16. Estimates of Cost Values and Production Function Parameters

Site	Total Costs (TC) (RM/ha)	Total Variable Costs (TVC) (RM/ha)	Total Fixed Costs (TFC) (RM/ha)	Labor (*L*)	Capital (*K*) (RM/ha)	Efficiency Parameter (*A*)
P1a	3,648.19	1,933.54	1,714.65	64	14,289	0.0832
P1b	2,976.48	1,577.53	1,398.94	53	11,658	0.0832
P2a	2,010.29	1,065.45	944.84	36	7,874	0.0832
P2b	3,326.84	1,763.23	1,563.62	59	13,030	0.0832
T1a	3,389.98	1,796.69	1,593.29	60	13,277	0.0793
T1b	3,979.23	2,108.99	1,870.24	70	15,585	0.0793

Table 17. Logging Damage

Site	Volume (m^3/ha)	Percent
P1a	1.93	2.84
P1b	2.46	4.44
P2a	2.01	3.48
P2b	2.01	3.13
T1a	3.26	5.42
T1b	0.68	0.96

a loss function giving the opportunity cost of deviations from the SMS prescriptions ($\mu(V^{SY}-V)^2$) equals the total fine per hectare for timber above the cutting limits left in the forest, then:

$$400 * n = \mu(V^{SY}-V)^2,$$

where n is the total number of unfelled trees above the cutting limits, then μ can simply be estimated using the following formula:

$$\mu = \frac{400 * n}{(V^{SY}-V)^2}.$$

The numerator is the total fine per hectare for timber left in the forest: logging fine (RM400.00 per tree), times the number of trees above the cutting limit (n), left in the forest per hectare. The denominator is the square of the total volume of timber above the cutting limit left in the forest. This residual volume was calculated from the post-F inventory, as was n. The values of μ were estimated separately for each site.

The cost of royalty collection (c) was estimated at MR3.20/m^3 in Pahang and MR3.10/m^3 in Terengganu. The estimated values were based on 5% of tree-marking and post-F inventory costs of the total logging costs plus the cost at the checking station. Information on the proportion of tree-marking and post-F inventory costs was based on concessionaires' estimates, and the cost at the checking station was calculated from data provided by the Forestry Department.

The values for each variable are provided in Appendix C. These values were used to solve all empirical models shown in Tables 5 through 9. The models were solved using the SIML command of the econometric computer program, PC-TSP Version 4.2A (Hall, 1991). The simulation results for all five models are included in Appendix D. The results are discussed in the next chapter.

CHAPTER FIVE

EMPIRICAL ANALYSIS: RESULTS

5.1 Introduction

The results of the five models outlined in Chapter Four are presented in this chapter. First, the results of model validation are presented. Then the simulation results for four key endogenous variables (royalties, premiums, government revenues, and harvest levels) are presented.

5.2 Model Validation

Model validation refers to a procedure in which the performance and the structure of the model are compared empirically and theoretically to the real world situation (Isaac & Michael, 1982; Robinson & Frey, 1983). Validity tests indicate whether a model provides accurate and acceptable predictions of the behavior of the system being simulated (Hiller & Lieberman, 1980). Model validation is also required because of uncertainty in assumptions and data used, and omissions of some variables in model structure (Hufschmidt, James, Meister, Bower, & Dixon, 1983; Meerschaert, 1993; Robinson & Frey, 1983). The main objective of model validation is therefore to determine whether the model provides a sufficiently accurate representation of reality to be used in examining the potential effects of optimal royalties.

The calibration approach employed in this study implies that, on an equation-by-equation basis, the model replicates real-world behavior perfectly. Comparing predicted values to actual values is therefore not a meaningful way of validating a calibrated model. An appropriate approach is to evaluate whether the individual equations provide reasonable representations of behavior, and to conduct sensivity analysis. As noted in Chapter Four, the use of the Cobb-Douglas production function provides a reasonable representation of concessionaires' harvest behavior. The fact that the models did not predict actual harvest well is not surprising and of little consequence to the results. In the real world, concessionaires face minimum diameter cutting limits, which the model ignores, as the focus was on revenue system alone as a means of regulating harvest behavior. If the cutting limit had been included in the model, then the predicted harvest would have been approximately near to actual harvest.

A sensitivity analysis was carried out to investigate the impacts of uncertainty about data. As explained in chapter four, some of the parameters used are known with certainty, while others are not. Sensitivity analysis enables one to examine the extent to which uncertainty about the data affects confidence in model output. Meerschaert (1993) suggests that a useful way is to calculate relative change or percent change, rather than absolute values. This approach was adopted in this study. Each model was solved to determine the initial values of the endogenous variables; then each model was rerun by increasing by 1% a given exogenous variable or parameter. Elasticities were then calculated using the following formula:

$$\varepsilon = \frac{\dfrac{Y_1 - Y_o}{Y_o}}{0.01}$$

Y_o is the initial value of an endogenous variable, and Y_1 is the value after the change. Thus, elasticities measure sensitivity of model output to a parameter change. If the elasticity is high, then the model is very sensitive to values of that parameter.

Detailed results for three key endogenous variables (royalty, harvest volume, and government revenue) are presented in Tables E1 through E5 in Appendix E. These variables, and three parameters (γ, α, and β) were chosen to explain the results because of their importance as decision variables for the government and concessionaires. As seen in Tables E1 through E5, it is surprising that government revenue and royalty are sensitive to parameters in the timber value distribution. As expected, the labor share (in a model in which labor is the only private choice variable) has a great impact on harvest volume. Further results indicate that royalties were elastic with respect to labor share (γ) in four of the models. Government revenues were elastic with respect to maximum log price (α) in all models. Royalty was sensitive to the slope of timber value distribution (β) in the dynamic models. The results also showed that harvest volumes were elastic with respect to labor share (γ) in static models, and to maximum log price (α) in Model III only.

The results of sensitivity analysis therefore indicate that simulation output is very sensitive to these three parameters. Nevertheless the simulation results might be acceptable with respect to α and β. Since data on log prices were obtained from an official publication, it is less likely that these data were unreliable. This was also true with α and β. In the regression analysis done in the study, the estimated coefficients of determination in estimating α and β were high. However, the parameter γ was based on much less reliable data. If more data are collected, labor share parameter should be given due consideration.

5.3 Simulation Results

The magnitudes of the optimal levels of royalties, premiums, harvest volumes, and government revenues from the base-case analysis for all models are presented in Tables 18, 20, and 21. Major findings of the analyses are presented in the following sections.

5.3.1 Static and Dynamic Uniform Royalty Systems

As seen in Table 18, the optimal levels of royalty rates differed substantially in the two models. Within a given model, the rates also differed among sites. Depending on a particular site, Model II royalty rates were 23% to 108% less, compared to those in Model I. The royalty rates obtained in Model II conformed to theoretical expectations: that is, the royalty rates in Model II were less than those in Model I when the volume of the prescribed harvest level (V^{SY}) was greater than the simulated static harvest level (V). Model I harvests were below the prescribed harvest level. Hence, Model II, in which the government values this deviation,

Table 18. Simulation Results for the Uniform Royalty System

Site	Commercial Timber Volume[1] (≥ 30 cm) (m^3/ha)	Prescribed Harvest Volume[1] (Above the Cutting Limits) (V^{SY}) (m^3/ha)	Model I				Model II			
			Optimal Royalty (RM/m^3)	Premium (RM/ha)	Harvest Volume (m^3/ha	Government Revenue (RM/ha)	Optimal Royalty (RM/m^3)	Premium (RM/ha)	Harvest Volume (m^3/ha)	Government Revenue (RM/ha)
P1a	95.13	76.65	189.52	1,877	41.69	9,424	95.38	6,656	62.86	12,286
P1b	122.88	109.96	235.36	4,468	53.79	16,400	105.49	13,018	84.07	21,236
P2a	99.58	55.68	162.18	1,421	32.50	6,310	77.80	4,709	49.89	8,230
P2b	105.09	62.16	117.44	1,713	43.97	5,573	76.42	2,773	59.86	7,014
T1a	113.40	74.15	166.51	2,171	50.48	9,973	118.75	4,786	65.31	11,929
T1b	108.83	66.58	148.78	1,696	52.28	9,188	119.83	3,284	62.41	10,499

[1]These are actual data, not the simulation results.

predicts that royalty should be decreased to induce the concessionaire to harvest more. The royalty rates in Model I ranged from RM117.44 to RM235.36 per m^3; they ranged from RM76.42 to RM119.83 per m^3 in Model II. The differences reflect the variation in maximum log price and the slope of timber value distribution. In comparison to the figures shown in Table 14, the results indicate that higher royalties can be imposed on more productive sites (i.e., sites with large values of α and β).

In Model II, the cost of deviation, μ, imposed on unharvested timber above the cutting limit or timber harvested below the cutting limit, discourages the concessionaire from deviating too far from V^{SY}. Because the concessionaire's objective function is the same in both the dynamic and static models, the government reduces the royalty to induce larger harvests. The lower royalty provides concessionaires an incentive to hire additional labor.

The results also show that the ranking of royalties can differ in Model II as compared to Model I. For example, the two highest royalty rates in Model I are for sites P1a and P1b, but the rates are moderate in Model II. On the contrary, moderate royalty rates are found in sites T1a and T1b in Model I, but these sites show the highest royalty rates in Model II. However, the lowest royalty rates in sites P2a and P2b are also the lowest in Model II. These variations result from differences in the cost of deviation, μ. Sites P2a and P2b have the highest values of μ. All else being equal, the royalty rate in Model II is low when the cost of deviation is high. The results indicate that the government is more willing to lower the royalty rate when it highly values compliance with V^{SY}.

The royalty rates in both models are higher than the actual royalty rates (compare to Table 19). This suggests that the present royalty rates are well below the optimal level, from either a static or a dynamic perspective. For instance, the lowest optimal static and dynamic rates which are for site P2b, are each at least four times larger than the actual royalty rates in Pahang (Table 19). They are also higher than those in Sarawak, but they are mixed when compared to the rates in Sabah for export logs. The optimal royalty rates found in this study also tend to be larger than the actual rates reported for other tropical countries (Gillis, 1980; Gillis & Repetto, 1988; Gray, 1983; Page et al., 1976; Ruzicka, 1979).

The premium indicates the maximum lump-sum amount that the government could charge the concessionaire in addition to royalty. In Table 18, the premium rates are much higher than the present rates: 3 to 8 times higher in Model I, and 10 to 25 times higher in Model II. Model II premiums are higher than those premiums in Model I by a factor of two in four of the six sites. Thus, the decrease in the royalty in Model II is offset by a corresponding increase in the premium. In general, the lower the royalty, the higher the premium.

Premiums vary among sites because of variations in timber value distribution parameters. These variations affect the concessionaire's total revenue. The reason the premium is so high in site P1b is obvious from the maximum log price. Site P1b has the highest value of α compared to the values of α in the other sites. If the government collects revenue solely through a uniform royalty, then the premiums indicated in Table 18 represent the magnitude of windfall profits to the concessionaire.

Table 19. Comparison of Optimal Uniform Royalty Rates With the Present Royalty Rates in Pahang, Sabah, and Sarawak (Selected Species, RM/m^3)

Species	Pahang	Sabah[1]		Sarawak		Model I		Model II	
		Export	Local	Export	Local[2]	Low	High	Low	High
Merbau	19	498	30	18	3.60	117	235	76	126
Mengilan	-	374	30	-	-	117	235	76	126
Keruing	13	235	30	35	7	117	235	76	126
Jelutong	14	133	30	20	4	117	235	76	126
Sepetir	6	117	30	20	4	117	235	76	126
Bintangor	6	99	30	15	3	117	235	76	126
Simpoh	6	82	30	15	3	117	235	76	126
Ranggu	-	69	30	35	7	117	235	76	126
Other	6	50	30	15	3	117	235	76	126

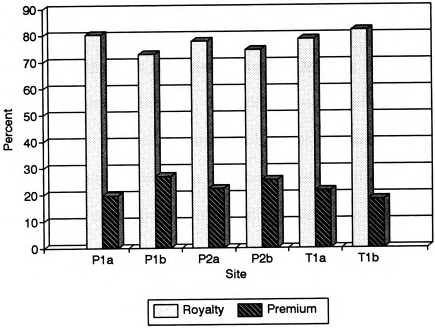
[1]Effective March 1 through December 31, 1993.

[2]Royalty is calculated based on 80% rebate on logs for export.

It is important to consider the results of harvest volume when evaluating concessionaires' harvest behavior under different government objectives. This is because the simulated harvest volume will determine the degree to which concessionaires deviate from the prescribed harvest level. In Table 18, Model I harvests are smaller than Model II harvests. In absolute terms, the deviations range from 14.30 m^3 per ha to 53.17 m^3 per ha in Model I, and from 21.48 m^3 per ha to 49.71 m^3 per ha in Model II. The results indicate that the uniform royalty system induces concessionaires not to harvest all timber above the cutting limits. This is expected because higher royalty will reduce labor input, which causes concessionaires to reduce harvests. This finding is consistent with the conclusions from Gillis (1980, 1988a).

Government revenues in both models are substantial. Surprisingly, Model II revenues are greater than those of Model I. One would expect that the higher royalty in Model I should provide higher government revenue. However, further examination reveals that the significant share of premium plays a role in relation to government revenue (Figure 7). Thus, premium payment becomes more significant than royalty payment in the dynamic model. The reasons for this were explained earlier. The average shares of premium are 22% and 46% for Models I and II, respectively. The significance of premium share to government revenue in Model II suggests that the government could lower the royalty rate and obtain a higher premium to induce a larger harvest, in order to achieve the dynamic forest management objective. A government that chooses to use only the royalty to

(a) Model I



(b) Model II

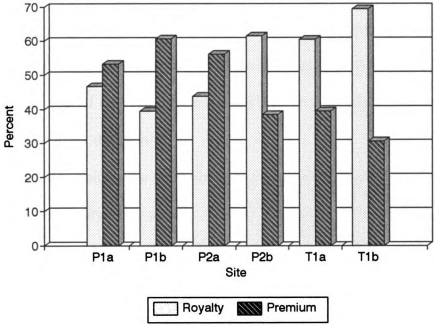


Figure 7. Royalty and Premium Shares of Government Revenue (Uniform Royalty).

maximize revenue, and determines the premium residually, will actually raise less revenue than one whose objective is not simply to raise revenue.

5.3.2 Static and Dynamic *Ad Valorem* Royalty Systems

As can be seen in Table 20, the optimal levels of *ad valorem* royalty rates vary with respect to different government objectives and among sites. The estimated royalty rates in Model IV are lower than those in Model III. The lower royalty rate estimates obtained in the dynamic model are parallel to the results obtained in the case of uniform royalty. The rates obtained in this study are higher than the stipulated 10% of the log price. The rates in Model IV range from 11% to 16%; they range from 26% to 33% in Model III. The variations in the two models with respect to different sites are not very large. The largest variations are 12% and 5% in Models III and IV, respectively. Variations among sites in *ad valorem* royalties are not very large because of the structure of the optimal royalty formula: it is the ratio between the two values. Even though there are differences in timber value distribution, cost of collecting revenue, and harvest level, these parameters do not significantly affect the ratio.

As for premium, the rates obtained in the static model are lower than the rates found in the dynamic model, and they also vary by site. As can be seen in Table 20, the premium rates in Model III range from about RM2,400 to RM13,000; they range from RM6,000 to RM22,500 in Model IV. Thus, the premiums in the dynamic model are about double those in the static model. The higher premiums in Model IV are associated with lower optimal royalty.

Table 20. Simulation Results for an *Ad Valorem* Royalty System

Site	Commercial Timber Volume[1] (≥ 30 cm) (m³/ha)	Prescribed Harvest Volume[1] (Above the Cutting Limits) (V^{SY}) (m³/ha)	Model III				Model IV			
			Optimal Royalty (% of log price)	Premium (RM/ha)	Harvest Volume (m³/ha)	Government Revenue (RM/ha)	Optimal Royalty (% of log price)	Premium (RM/ha)	Harvest Volume (m³/ha)	Government Revenue (RM/ha)
P1a	95.13	76.65	0.26	6,658	52.35	10,280	0.15	11,040	74.52	13,482
P1b	122.88	109.96	0.29	12,947	65.66	19,416	0.14	22,518	103.72	26,417
P2a	99.58	55.68	0.33	4,086	38.14	7,111	0.16	8,186	56.60	10,010
P2b	105.09	62.16	0.35	2,443	50.72	5,633	0.14	6,027	64.09	7,424
T1a	113.40	74.15	0.33	6,331	59.31	11,167	0.12	12,802	81.17	14,834
T1b	108.83	66.58	0.32	5,420	61.76	9,897	0.11	10,236	73.65	11,839

[1]These are actual data, not the simulation results.

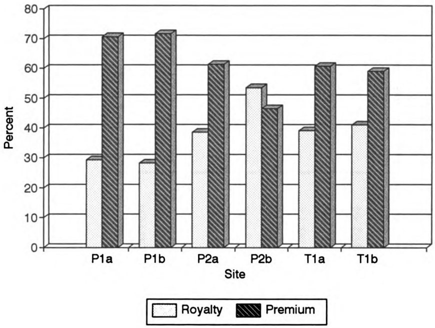
Model III harvests are below the prescribed harvest level in all sites. In contrast, Model IV harvests are above the prescribed harvest level in four of the sites. The results indicate that the static *ad valorem* royalty encourages leaving timber above the cutting limits, but the dynamic royalty could either result in leaving timber above the cutting limits or harvesting timber below the cutting limits. In reality, these effects cannot be observed because the royalty system in Peninsular Malaysia is only loosely an *ad valorem* system (refer to section 2.5).

The results also show that government revenues are substantial. Model IV revenues are greater than those in Model III. A substantial share of government revenue comes from royalties, about 62% and 82% in Models III and IV, respectively (Figure 8). Thus, a lower royalty as found in Model IV is offset by higher premiums, which contributes greatly to higher government revenue. This suggests that a government that chooses to use only the royalty to maximize revenue, and determines the premium residually, will actually raise less revenue than one whose objective is not simply to raise revenue.

5.3.3 Static Premium

Premium, harvest volume, and government revenue from the simulation analysis of Model V are presented in Table 21. The premiums indicate the *maximum* amount that could be charged per ha when a concession is to be harvested (without levying a volume-based royalty). The premium rates differ substantially among sites, and they vary by a factor of more than two. In four of the sites, the premium is more than RM10,000 per ha. The highest premium rate is in Site P1b,

(a) Model III



(b) Model IV

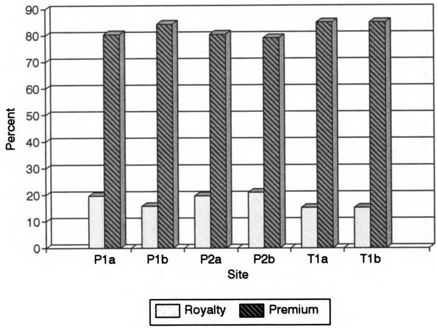


Figure 8. Royalty and Premium Shares of Government Revenue (*Ad Valorem* Royalty).

Table 21. Simulation Results for the Static Premium

Site	Commercial Timber Volume[1] (≥ 30 cm) (m^3/ha)	Prescribed Harvest Volume[1] (Above the Cutting Limits) (V^{SY}) (m^3/ha)	Premium (RM/ha)	Harvest Volume (m^3/ha)	Government Revenue (RM/ha)
P1a	95.13	76.65	13,481	84.46	13,219
P1b	122.88	109.96	22,742	108.89	22,409
P2a	99.58	55.68	8,978	66.11	8,778
P2b	105.09	62.16	8,307	89.90	8,028
T1a	113.40	74.15	14,211	102.64	13,910
T1b	108.83	66.58	13,293	106.40	12,966

[1]These are actual data, not the simulation results.

whereas the lowest is in Site P2b. It is not surprising that the static premium induces a harvest below the cutting limits, which approaches the commercial timber volume. The harvest volume is greater than the prescribed harvest level in five of the sites, a range from 8 m^3 per ha (10%) to 40 m^3 per ha (60%). The harvest volume for site P1b is very close to the prescribed harvest level (harvest deviation is very small, 1.8%). Government revenue ranges from RM8,000 per ha to about RM22,400 per ha, indicating 4 to 14 times more actual government revenue.

CHAPTER SIX

DISCUSSION AND CONCLUSIONS

6.1 Discussion

The economic and empirical models developed in this study differ in view of the government's forest management objectives: maximizing revenue (static models--Models I, III, and V) and maximizing revenue and future benefits (dynamic models--Models II and IV). Comparing the simulation results to draw lessons for policy requires comparing the results for models having the same objective.

When the forest management objective is only maximizing revenue, the preferred revenue system is one based on the premium (Model V). This suggests that the government could collect almost 100% of the stumpage value by auctioning without distorting logging decisions. The results for the premium could be used as reservation price in auctioning.

Model V predicts that concessionaires are likely to harvest almost all timber, in some cases close to commercial-sized timber volumes (compare Tables 18 and 21). Overharvesting occurs because concessionaires have no incentive to recognize V^{SY} without sufficient enforcement of logging regulations. On the other hand, if the government relies on uniform or *ad valorem* systems, much mature timber goes unharvested (Figure 9). Hence, Models I and III show royalty-induced selective

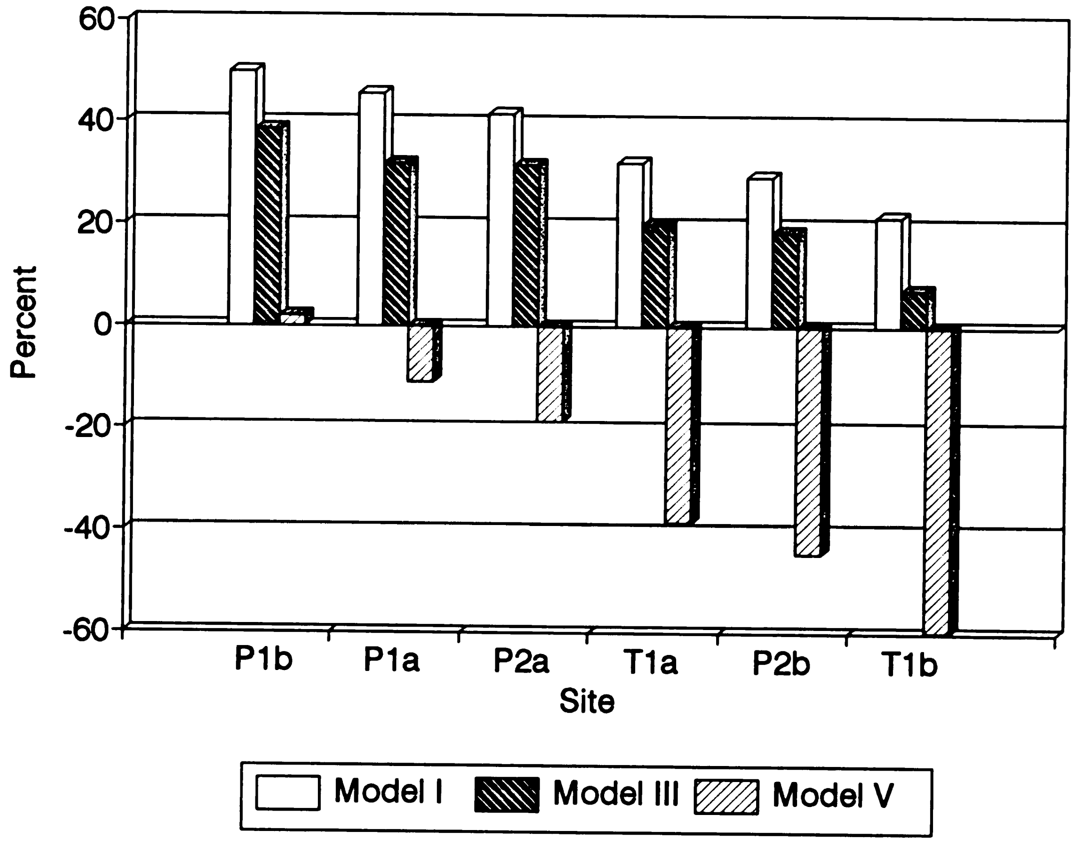


Figure 9. Prescribed Harvest Volume Minus Actual Volume (V^{SY}-V), Static Models.

logging. The results indicate that the deviations are greater under uniform royalty than they are under *ad valorem* royalty. It appears that the results obtained in this study are consistent with Gillis's (1980, 1988a) and Hyde and Sedjo's (1992) findings that uniform and *ad valorem* royalties result in incomplete harvests above the cutting limits. The larger timber harvest below the cutting limits obtained in Model V is expected because the concessionaires' harvest decision is not affected by premiums. With the tendering system, the first-order condition for the choice of labor input (L) is not affected by the premium (m). Thus, the profit-maximizing behavior of concessionaires is not distorted; they would otherwise be tempted to harvest more timber that provides positive stumpage value. Under the royalty systems, the optimal labor input will be determined once the optimal royalty has been decided by the government. Because the royalty rate is fixed by the government, the concessionaires will reduce their optimal labor input, causing them to deviate from V^{SY}.

Without considering future benefits and at prevailing public and private sector discount rates in Malaysia, there is indeed an economic loss when mature timber goes unharvested, as shown in Models I and III. Given that royalties are chosen to maximize short-run revenue and ignore future benefits, the losses may be very large. The government suffers a loss in revenue, which reduces the funds that potentially could be used for forest management, among other uses. The loss, on average, is estimated at 28% and 21% from Models I and III, respectively, relative to the amount of revenue that would have been estimated under the tendering system.

In the dynamic objective, the government seeks to maximize not only current revenue but also future forest benefits. The preferred revenue system can be determined by comparing the values of the objective functions for Models II and IV. The values of the objective function were computed by subtracting the opportunity cost of over- or under-harvesting from total government revenue. The cost of deviation indicates the reduction in the discounted value of future harvests, due to either overmature timber left in the forest or immature timber harvested in the current cutting cycle. The results are presented in Table 22. The results shown in the table indicate that the values of the objective function in Model IV are much higher than those in Model II. This suggests that *ad valorem* royalty is superior to the uniform royalty under the dynamic forest management objective. This finding seems to support Gillis (1980), Gillis & Repetto (1988), and Vincent (1990), who called for replacing the uniform fixed royalty, which is the most common type of royalty levied by tropical countries, with alternative fees.

Table 22. Values of the Government Objective Function (RM/ha)

Site	Model II	Model IV
P1a	11,038	13,452
P1b	18,432	26,361
P2a	7,777	9,999
P2b	6,924	7,361
T1a	11,537	14,586
T1b	10,386	11,504

The *ad valorem* royalty induces small violations of the cutting limits, ranging from 1% to 10% of the prescribed harvest volume in four of the sites (Figure 10). Limiting harvests to the prescribed volumes would require sufficient enforcement of cutting-limit regulations, which involves substantial cost. On the other hand, the uniform royalty system may result in leaving timber volume above the cutting limits. The results show that unharvested mature timber ranges from 4% to 21% of the prescribed harvest volume, which is within the allowable timber volume that concessionaires can leave in the forest. Thus, the uniform royalty may not entail greater long-term costs than the Forestry Department is willing to tolerate. Both mature timber going unharvested and immature timber being harvested cause dynamic losses (that is, the fourth term on the right-hand side of Equation 17) . The dynamic losses are higher under a uniform royalty system, ranging from 1% to 10% of the government revenue, compared to 0.2% to 3% percent under an *ad valorem* royalty system.

It should be pointed out that the management of forests for static and dynamic objectives does not depend solely on the forest revenue system. As seen above, different levels and structures of forest revenue systems affect socially optimal behavior and government revenue. Other public options also play an important role in achieving forest management objectives. These include the structure of the concession contract, provision for financial incentives, and privatization of forest management activities. These options can be achieved through legislation and other related forest policies and laws.

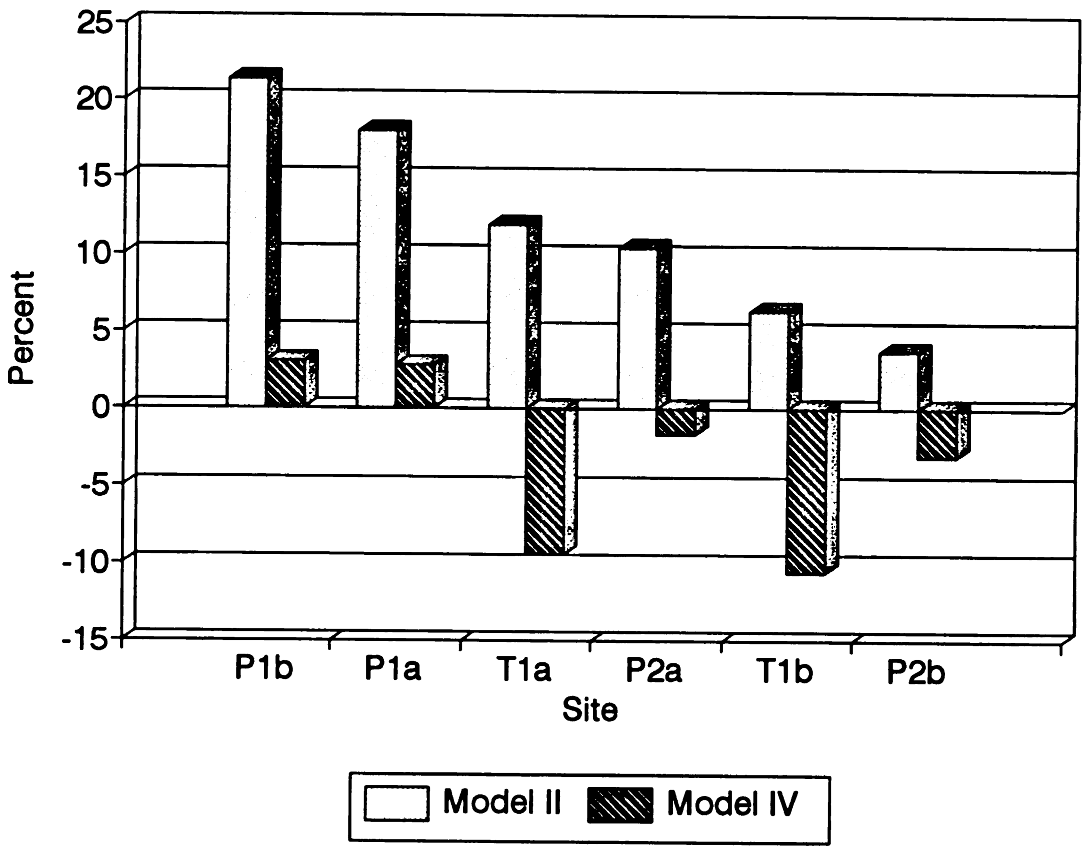


Figure 10. Prescribed Harvest Volume Minus Actual Volume (V^{SY}-V), Dynamic Models.

6.2 Policy Implications

The government is now concerned about forest revenue system because of its impact not only on revenue but also on concessionaires' harvest behavior. One important assumption in making policy prescriptions is that the government will continue to maintain forest ownership. Hence, the amount of stumpage value captured by the government must be sufficient for financing forest management. There are two options available for increasing revenue--raising the present royalty rate or changing the forest revenue system. The results of this study provide some insights into these options.

If the capture of stumpage value from current harvest is obviously low, then the main policy suggestion is to raise the present royalty rates consistent with the government's real forest management objective. The government's real forest management objective is to maximize long-term socio-economic benefits of forest resources (section 2.6). Therefore, the estimated dynamic uniform royalty rates could be used as a basis for setting the optimal rates.

The present royalty rates have remained virtually constant over a long period of time. Only recently have some of the states increased their timber fees. The results from this study suggest that royalty and premium rates are in fact far below their optimal levels. These rates could be increased without eliminating normal profit margins for concessionaires. The new rates should take into account many factors, such as timber harvesting costs, log prices, profit margins, transaction costs, and risks and uncertainty. Higher timber fees not only provide more funds for respective state governments, but they also provide more financial allocations for forest management activities. Thus, increasing timber fees can be fully justified for long-term sustainable harvest level. The optimal rates can be analyzed if further additional information (such as logging cost, normal profit margins, cost of deviation) is available. The availability of computer hardware and software for economic modeling now makes such efforts possible.

The second policy option--changing the forest revenue system--will also depend on the government objective. If the government objective is purely maximizing revenue, the preferred forest revenue system is tendering. A tendering system is already being used in State Land Forests, where logging is carried out by clear felling (that is, without a minimum-diameter cutting limit). Tendering also shifts the risks from the government to the concessionaire. This is because the government can formulate a reservation price based on information from the pre-F inventory. The tender price can be estimated in advance based on stumpage value for a given compartment. The types of tendering, however, can be decided on depending upon the type of concessionaire (*bumiputera*, or concessionaires who have wood-based plants) or the scale of operation (small, medium, or large). Tendering would require a certain degree of competition. Given that a competitive market is apparently functioning well in the logging industry, the tendering system is likely to be preferred over uniform or *ad valorem* royalties.

If the government objective is maximizing both revenue and future benefits, the government could probably replace the uniform royalty with the *ad valorem* royalty. This would mean setting the royalty rate based on the percentage of log price for extracted logs. The premium can be determined by tendering, which can be estimated in advance as a residual using zero-profit condition of the concessionaire. The minimum reservation premium rate can be decided if the government is responsible for forest management. On the other hand, the government can provide sufficient financial incentive to the concessionaire if the concessionaire is allowed to be involved in and responsible for forest management. Giving a financial incentive to the concessionaire would make the benefit of the *ad valorem* royalty more apparent.

This royalty system can best be applied to forests in the Permanent Forest Estates (PFE), which restrict logging to trees whose dbh is above a specified minimum-diameter cutting limit according to the SMS. This is because the government is concerned with small harvest deviations (V^{SY}-V), which is necessary for second-growth and protecting nontimber benefits. The model predicts that the deviation is small, and this requirement can be fully justified. In addition, strict enforcement of logging regulations might not be needed. New guidelines for timber harvesting (incorporating the volume-area approach in timber harvesting) and well defined legislation would make *ad valorem* royalty more favorable than uniform royalty. However, information on log prices needs to be maintained and updated regularly.

6.3 Conclusion and Recommendations for Further Studies

In conclusion, the empirical analyses revealed that the present royalty and premium rates are far below the optimal level, regardless of whether the government's objective is short-run or long-run. Optimality in this sense refers to the optimal level of royalty that is associated with the highest revenue or revenue and future benefits to the government without affecting the normal profit margin for the concessionaire. Tendering is the preferred system when the only objective for forest management is to maximize revenue. Tendering captures the full stumpage value, even though harvesting below the cutting limits is greater. The static uniform and *ad valorem* royalties induced leaving timber above the cutting limits, which implies an economic loss. The driving mechanism is the royalty rates, which signal concessionaires to reduce their harvest levels below the prescribed level. However, when the objective of forest management is to maximize revenue and future benefits, the preferred forest revenue system would rely upon *ad valorem* royalty. This is because the highest value of the dynamic objective function (which is accounted for by the reduction in the discounted value of overharvesting timber below the cutting limits) could be obtained, compared to those provided by a uniform royalty. Because overharvesting is too small under an *ad valorem* royalty, the appropriate royalty rate could be determined to provide a greater incentive to concessionaires to abide by the cutting-limit regulations.

Although the static objective is expected to generate higher revenue than the dynamic objective for uniform and *ad valorem* royalties, this was not the case when the premium was included and determined residually. The government revenue for uniform and *ad valorem* royalties is always higher in the dynamic models than in the static model when revenue from the residually determined premium is included as well. The lower royalty rates obtained in the dynamic model induce larger harvests, which significantly affect the magnitude of government revenue in the dynamic model. Choosing the optimal royalty to maximize revenue and future benefits, and determining premiums residually, will actually raise more revenue than choosing the optimal royalty only to maximize revenue. The values of both static and dynamic optimal royalties and premiums were found to be much higher than actual rates. Government efforts aimed at revising and increasing the present royalty and premium rates will increase government revenue and enhance future forestry benefits.

The results of this study demonstrate the importance of revising the forest revenue system in Peninsular Malaysia and suggest the magnitude of optimal royalties. However, there are some caveats which affect the reliability of the results and to what degree they can be used in making generalization. The assumptions used and data available for this study were subject to some constraints. These include simplifying assumptions about the role of natural systems, optimal cutting cycle and diameter cutting limits, and the use of uniform data such as log price, logging cost, damage rate, and labor share. The interrelationship between the human system and the natural system is complex. Excluding the natural system from the modeling framework makes it impossible to study other types of environmental impacts of decisions made by the government and concessionaires. The length of cutting cycle and cutting limits were taken as given and were assumed optimal. This restricted the analysis to calculate optimal royalties. Ideally, the choice of optimal cutting cycle, cutting limits, and forest revenue system should be considered simultaneously to study combined effects on harvest behavior. Some errors related to volume estimation might have occurred due to sampling procedures and formulas used. Some of the data used in the study were based on average condition or uniform values--uniform price for all species within each of the three miscellaneous categories (i.e, OLHW, OMHW, and OHHW), uniform logging cost for all timber within a given compartment, uniform damage rate for all timber, and uniform labor share for all sites. Values might not be uniform in reality. The use of uniform values could result in upward or downward biases in the solutions. Due to these limitations, efforts to improve the models through future studies should be pursued.

Several additional studies are outlined below. Firstly, the fact that the high cost of deviation affects concessionaires' harvest decision suggests that logging fines should be reviewed. Logging fines need to be determined for timber above and below the cutting limits. A study should also be done to analyze the effects of financial incentives on concessionaires' harvest behavior.

Secondly, a study is needed to analyze the effects of proposed forest concession policies in relation to transaction costs (cost of contracting, information, and policing). This relationship has been given little attention in the past. Even though it was included in this study, the analysis is not comprehensive enough to take into account all associated costs involved in the contractual arrangements. This is important if the government's policy is to restructure the concession contracts. The evaluation of risks and uncertainty in concession contracts should also be included in such a study, as should concessionaires' willingness to pay for the off-site environmental costs of logging.

Thirdly, an extensive empirical analysis is needed to study the effects of timber fees on harvest volume and government revenue in other states of Malaysia.

This is because optimal timber fees may be highly sensitive to log prices and logging costs with respect to locations. In particular, results from sensitivity analyses have shown that data on log prices, forest characteristics, and labor share should be collected intensively. Emphasis also should be given to analyzing the trend of log prices. Thus, an adjustment can be made to the level of royalty rates with respect to changes in log prices. In addition, such a study should focus on the structure and distribution of forest growth under varying forest revenue systems.

Fourthly, a study of harvesting costs under different spatial locations of forest concessions and harvesting methods is necessary. Such a study would be timely because no intensive research has been carried out to investigate the economics of timber harvesting. Information on logging costs, normal profit margins, and elasticity of substitution is limited or not readily available. Because any optimal forest revenue system will depend heavily on the economics of timber harvesting, such information is critical.

Fifthly, a study of cutting cycle and diameter cutting limit in relation to production functions and how they are affected by changes in timber fees, log price, management costs, and interest rate is required. Efforts might be directed at developing a comprehensive microeconomic model of concessionaires' and government behaviors, which incorporates all these variables. Detailed empirical analysis can be performed to estimate parameter values using an econometric model. Since databases are still lacking for testing models specification and functional forms, data collection on variables identified above should also be given high priority.

All of the proposed studies could be done at the local, regional, and national levels. An integrated approach is useful in gaining a better understanding of the optimal forest revenue system and its effect on concessionaires' harvest behavior and government revenue.

APPENDIX A

Derivation of *Ad Valorem* Royalty: Static and Dynamic Models

1. Static Model

The concessionaire's production function is taken as CES

$$V = A[\gamma L^{-\rho} - (1-\gamma)K^{-\rho}]^{-\frac{1}{\rho}} \tag{A1}$$

The objective function of the concessionaire is written as

$$\underset{L}{Max}\ \pi = (1-\sigma)(1-t)\int_0^{V^*} P(V)dv - wL(1+\delta) - rK(1+\delta) - m \tag{A2}$$

The timber value distribution P(V) is linear, i.e.,

$$P(V) = \alpha - \beta V$$

Integrating this function yields

$$\int_0^{V^*} P(V)dv = (\alpha V - \frac{\beta}{2}V^2) \tag{A3}$$

The first-order condition for a maximum profit is

$$(1-\sigma)(1-t)(\alpha-\beta V)V_L = w(1+\delta) \tag{A4}$$

Note that the net marginal value product of labor will shift downward at every level of labor input. Royalty payment is thus equal to percentage of log price for each cubic meter of logs extracted. From the first-order condition, the marginal product of labor is given by

$$V_L = \frac{w(1+\delta)}{(1-\sigma)(1-t)(\alpha-\beta V)} \tag{A5}$$

The optimal level of labor input, L^* is obtained by equating Equation A5 and the partial derivative of Equation A1 with respect to L,

$$L^* = V^* A^{-\rho\theta}[k(1-t)(\alpha-\beta V^*)]^{\theta} \tag{A6}$$

where

$$k = \frac{\gamma(1-\sigma)}{w(1+\delta)}, \quad \mathit{and} \quad \theta = \frac{1}{1+\rho}.$$

The objective function of the government is written as

$$\underset{t}{Max}\ R = (1-\sigma)t\int_0^{V^*} P(V)dv + m - c(1-\sigma)V^* \tag{A7}$$

The first-order condition of government maximization yields

$$(\alpha V^* - \frac{\beta}{2}V^{*2}) = -[t(\alpha-\beta V^*)-c]V_L\frac{\partial L^*}{\partial t} \tag{A8}$$

where $\partial L^*/\partial t$ is obtained by differentiating Equation A6 with respect to t,

$$\frac{\partial L^*}{\partial t} = \frac{-V^*A^{-\rho\theta}\theta k(\alpha-\beta V^*)}{g^{1-\theta}-A^{-\rho\theta}[\gamma-k\theta(1-t)\beta V^*V_L]} \tag{A9}$$

and g is given by $k(1\text{-}t)(\alpha\text{-}\beta V)$. Substitute $\partial L^*/\partial t$ in Equation A9, and obtain the general expression for **t**

$$(\alpha V^* - \frac{\beta}{2}V^{*2})[1^{1-\theta}-A^{-\rho\theta}\{\gamma-k\theta(1-t)\beta V^*V_L\}]$$

$$= [t(\alpha-\beta V^*)-c]A^{-\rho\theta}V_L[V^*\theta k(\alpha-\beta V^*)] \tag{A10}$$

To solve Equation A10 for optimal royalty, t^*, substitute the values of θ corresponding to the Cobb-Douglas and Leontief production functions, and after doing much calculus, the following results were obtained:

Cobb-Douglas (θ = 1):

$$t^*_{S,CD} = \frac{(\alpha V^* - \frac{\beta}{2}V^{*2})[1-\gamma+\frac{\gamma\beta V^*}{(\alpha-\beta V^*)}]+\gamma c V^*}{(\alpha V^* - \frac{\beta}{2}V^{*2})[1-\gamma+\frac{\gamma\beta V^*}{(\alpha-\beta V^*)}]+\gamma(\alpha-\beta V^*)} \quad \textbf{(A11)}$$

Leontief (θ = 0):

$$t^*_{S,LF} = 1-\frac{\gamma}{k}[\frac{1}{(\alpha-\beta V^*)}] \quad \textbf{(A12)}$$

2. Dynamic Model

The objective function of the concessionaire and results obtained in the static model still hold and are used in the dynamic model. The objective function of the government is written as

$$\underset{t}{Max}\ R = (1-\sigma)t\int_0^{V^*}P(V)dv+m-c(1-\sigma)V^*-\mu(V^{SY}-V^*)^2 \quad \textbf{(A13)}$$

The first-order condition of government maximization yields

$$(\alpha V^* - \frac{\beta}{2}V^{*2}) = -[t(\alpha-\beta V^*)-c+2\mu(V^{SY}-V^*)]V_L\frac{\partial L^*}{\partial t} \quad \textbf{(A14)}$$

where $\partial L^*/\partial t$, as shown by Equation A9. After substituting $\partial L^*/\partial t$ into Equation A14, the general expression for t can be written as

$$(\alpha V^* - \frac{\beta}{2}V^{*2})[1^{-\rho\theta} - A^{-\rho\theta}\{\gamma - k\theta(1-t)\beta V^* V_L)\}]$$

$$= [t(\alpha - \beta V^*) - c + \frac{2\mu}{(1-\sigma)}(V^{SY} - V^*)]V_L[V^*\theta k(\alpha - \beta V^*)] \tag{A15}$$

Using the same procedure as in the static model, the optimal level of royalty is obtained as follows:

Cobb-Douglas ($\theta = 1$):

$$t^*_{D,CD} = \frac{(\alpha V^* - \frac{\beta}{2}V^{*2})[1 - \gamma + \frac{\gamma\beta V^*}{(\alpha - \beta V^*)}] + [c - \frac{2\mu}{(1-\sigma)}(V^{SY} - V^*)]\gamma V^*]}{(\alpha V^* - \frac{\beta}{2}V^{*2})[1 - \gamma + \frac{\gamma\beta V^*}{(\alpha - \beta V^*)}] + \gamma V^*(\alpha - \beta V^*)} \tag{A16}$$

Leontief ($\theta = 0$):

$$t^*_{D,LF} = 1 - \frac{\gamma}{k}[\frac{1}{(\alpha - \beta V^*)}] \tag{A17}$$

which is the same as Equation A12 derived in the static model.

APPENDIX B

Comparative Static: Uniform Royalty System

The purpose of comparative static analysis is to study the effect of changes in certain parameters on the equilibrium (optimal) level of decision variables when certain assumptions change, holding other variables or parameters constant (Hadar, 1971; Silberberg, 1978). The analysis considers the effects of the *direction* of the changes in the equilibrium value rather than the magnitude of the changes.

In this study, comparative static analysis examines how the optimal level of royalty changes in response to changes in two parameters, one representing technology change (measured by labor share, γ), and the other representing forest characteristics (measured by the slope of timber value distribution, β). Perhaps uncertainty about these parameters is of utmost importance from the forest revenue systems point of view. Changing the values of γ and β shifts the shape of the production function and the slope of timber value distribution. This will affect the optimal level of royalty. Only the results of uniform royalty are presented. Comparative static analysis for *ad valorem* royalty requires extensive work; thus, it is not presented here.

Model I (Static Uniform Royalty)

1. A shift in the Production Technology Parameter (γ)

1.1 Cobb-Douglas

Totally differentiating Equation 14 (in the text) with respect to γ yields:

$$\frac{dt^*}{d\gamma} = -(\alpha - c) + (2\gamma - 1)\beta V_L \frac{\partial L^*}{\partial \gamma} + 2\beta V^* \tag{B1}$$

To determine the sign of the above total differentiation, it is necessary, among other things, to know the sign of $\partial L^*/\partial\gamma$. It also depends on the value of γ. By differentiating Equation 7 (in the text) with respect to γ, one obtains the general expression for $\partial L^*/\partial\gamma$,

$$\frac{\partial L^*}{\partial \gamma} = \frac{\frac{1}{\gamma}\theta g^{\theta} V^*}{1 - g^{\theta} V_L + \theta k g^{\theta - 1} \beta V^* V_L} \tag{B2}$$

where

$$V_L = \frac{w(1+\delta)}{(1-\sigma)(\alpha - \beta V - t)} > 0,$$

$$g = k(\alpha - \beta V - t),$$

$$k = \frac{\gamma(1-\sigma)}{w(1+\delta)},$$

$$\theta = \frac{1}{1+\rho}.$$

In the case of the Cobb-Douglas technology, substituting for $\theta = 1$ in Equation B2, $\partial L^*/\partial\gamma$ becomes

$$\frac{\partial L^*}{\partial \gamma} = \frac{\frac{1}{\gamma} g V^*}{1 - gV_L - k\beta V^* V_L} > 0, \qquad \textbf{(B3)}$$

because the denominator is always > 0. To show that the denominator is > 0, the denominator in Equation B3 can be written as

$$1 - k(\alpha - \beta V - t)V_L + k\beta V V_L,$$

$$1 - kV_L(\alpha - \beta V - t - \beta V),$$

$$1 - kV_L(\alpha - 2\beta V - t).$$

If it is found that α-2βV-t < 0, the above expression is clearly > 0. If α-2βV-t > 0, the above expression is found to be

$$1 - \frac{\gamma(\alpha - 2\beta V - t)}{(\alpha - \beta V - t)} > 0$$

because γ cannot be > 1 or < 0, and α-2βV-t < α-βV-t. Because the optimal royalty is related to the specific value of γ, **dt/dγ** can be evaluated for two extreme cases: γ = 0 and γ = 1.

Case 1. $\gamma = 0$

Substituting γ = 0 in Equation B1,

$$\frac{dt^*}{d\gamma} = -(\alpha - c) - \beta V_L \frac{\partial L^*}{\partial \gamma} + 2\beta V^* <, > 0 \tag{B4}$$

Clearly, the definite sign of $dt^*/d\gamma$ cannot be determined because one cannot be sure of the combined effects of all the terms on the RHS.

Case 2. $\gamma = 1$

Substituting γ = 1 in Equation B1,

$$\frac{dt^*}{d\gamma} = -(\alpha - c) + \beta V_L \frac{\partial L^*}{\partial \gamma} + 2\beta V^* <, > 0 \tag{B5}$$

Similarly, the definite sign of $dt^*/d\gamma$ cannot be determined because one cannot be sure of the combined effects of all the terms on the RHS.

1.2 Leontief

Totally differentiating Equation 15 (in the text) with respect to γ, one obtains

$$\frac{dt^*}{d\gamma} = -\beta V_L \frac{\partial L^*}{\partial \gamma} = 0, \tag{B6}$$

because the sign of $\partial L^{*}/\partial\gamma = 0$. In the case of the Leontief technology, substituting for $\theta = 0$ in Equation (B2), it is found that $\partial L^{*}/\partial\gamma = 0$.

1.3 Linear

Because the optimal level of royalty is equivalent to the revenue collection costs (assumed fixed for each cubic meter of logs extracted), the effect of γ on **t** is zero.

2. A Shift in the Steepness of the Timber Value Distribution (β)

2.1 Cobb-Douglas

Following the same steps as described in section 1, one can obtain the total derivative of **t** with respect to β of Equation 14 (in the text):

$$\frac{dt^{*}}{d\beta} = (2\gamma-1)V^{*}+\beta V_{L}\frac{\partial L^{*}}{\partial\beta} \tag{B7}$$

Similarly, to determine the sign of $dt^{*}/d\beta$, we need to know the sign of $\partial L^{*}/\partial\beta$. Differentiating Equation 7 (in the text) with respect to β, the general expression for $\partial L^{*}/\partial\beta$ can be written as:

$$\frac{\partial L^{*}}{\partial\beta} = \frac{-\theta g^{\theta-1}kV^{*2}}{1-g^{\theta}V_{L}+\theta kg^{\theta-1}\beta V^{*}V_{L}} \tag{B8}$$

Substituting the above equation for $\theta = 1$, one has

$$\frac{\partial L^*}{\partial \beta} = \frac{-kV^{*2}}{1-gV_L+k\beta V^* V_L} < 0, \tag{B9}$$

because the denominator is always > 0 (from section 1.1). Following the same procedure for evaluating $dt^*/\partial\gamma$, the sign of the $dt^*/d\beta$ can be determined for two extreme values of γ.

<u>Case 1. $\gamma = 0$</u>

Substituting $\gamma = 0$ in Equation B7, one has

$$\frac{dt^*}{d\beta} = -V^* - \beta V_L \frac{\partial L^*}{\partial \beta} <, > 0, \tag{B10}$$

because one cannot be sure whether $V > \beta V_L * \partial L^*/\partial\beta$ or $V < \beta V_L * \partial L^*/\partial\beta$, even though the sign of $\partial L^*/\partial\beta < 0$.

<u>Case 2. $\gamma = 1$</u>

Substituting $\gamma = 1$ in Equation B7, one has

$$\frac{dt^*}{d\beta} = V^* + \beta V_L \frac{\partial L^*}{\partial \beta} <, > 0, \tag{B11}$$

This is for the same reason as explained in the first case.

2.2 Leontief

Totally differentiating Equation 15 (in the text) with respect to β

$$\frac{dt}{d\beta} = -V - \beta V_L \frac{\partial L}{\partial \beta} < 0, \tag{B12}$$

because the sign of $\partial L^*/\partial\beta = 0$. From the general expression in Equation B8 it is clear that, when $\theta = 0$, $\partial L^*/\partial\beta = 0$.

2.3 Linear

Because the optimal level of royalty is equivalent to the revenue collection costs (assumed fixed for each cubic meter of logs extracted), the effect of β on **t** is zero.

Model II (Dynamic Uniform Royalty)

3. A shift in the Production Technology Parameter (γ)

3.1 Cobb-Douglas

Totally differentiating Equation 21 with respect to γ yields:

$$\frac{dt^*}{d\gamma} = -[\alpha - c + \frac{2\mu V^{SY}}{(1-\sigma)}] + [(2\gamma-1)\beta - \frac{2\gamma\mu}{(1-\sigma)}]V_L\frac{\partial L^*}{\partial\gamma}$$

$$+[2\beta - \frac{2\mu}{(1-\sigma)}]V^* \tag{B13}$$

The sign of the $\partial L^{*}/\partial\gamma$ is the same as the one found in the static model (Equation B3). Therefore, one can evaluate the sign of $dt^{*}/d\gamma$ for two extreme cases: $\gamma = 0$ and $\gamma = 1$.

Case 1. $\gamma = 0$

Substituting $\gamma = 0$ in Equation B13, one obtains:

$$\frac{dt^{*}}{d\gamma} = -[\alpha - c + \frac{2\mu V^{SY}}{(1-\sigma)}] - \beta V_L \frac{\partial L^{*}}{\partial\gamma}$$

$$+[2\beta - \frac{2\mu}{(1-\sigma)}]V^{*} <, > 0 \qquad \textbf{(B14)}$$

Case 2. $\gamma = 1$

Substituting $\gamma = 1$ in Equation B13, one has:

$$\frac{dt^{*}}{d\gamma} = -[\alpha - c + \frac{2\mu V^{SY}}{(1-\sigma)}] + [(\beta - \frac{2\mu}{(1-\sigma)}]V_L \frac{\partial L^{*}}{\partial\gamma}$$

$$+[2\beta - \frac{2\mu}{(1-\sigma)}]V^{*} <, > 0 \qquad \textbf{(B15)}$$

3.2 Leontief

The results of the comparative static were found to be same as the ones derived in the static model because the optimal royalty in the dynamic model is the same as it is in the static case.

3.3 Linear

Totally differentiating of Equation 23 (in the text) with respect to γ yields:

$$\frac{dt^*}{d\gamma} = \frac{2\mu}{(1-\sigma)} V_L \frac{\partial L^*}{\partial \gamma} > 0 \tag{B16}$$

This is because $\partial L^*/\partial\gamma > 0$, which was obtained from Equation B2. Substituting $\theta = \infty$ in Equation B2 yields

$$\frac{\partial L^*}{\partial \gamma} = \frac{\frac{1}{\gamma} V^*}{k\beta V^* V_L} > 0 \tag{B17}$$

4. A Shift in the Steepness of the Timber Value Distribution (β)

4.1 Cobb-Douglas

Following the same steps as described above, one obtains the total derivative of **t** with respect to β in Equation 21 (in the text) :

$$\frac{dt^*}{d\beta} = (2\gamma-1)V^* + [\beta + \frac{2\mu}{(1-\sigma)}] V_L \frac{\partial L^*}{\partial \gamma} \tag{B18}$$

Similarly, to determine the sign of $dt^*/d\beta$, one needs to know the sign of $\partial L^*/\partial\beta$. From (B9), $\partial L^*/\partial\beta < 0$, and evaluating $dt^*/d\beta$ for two extreme values of γ:

<u>Case 1. $\gamma = 0$</u>

Substituting $\gamma = 0$ in Equation B18, one has

$$\frac{dt^*}{d\beta} = -V^* - \beta V_L \frac{\partial L^*}{\partial \beta} <, > 0 \tag{B19}$$

<u>Case 2. $\gamma = 1$</u>

Substituting $\gamma = 1$ in Equation B18, one has

$$\frac{dt^*}{d\beta} = V^* + [\beta - \frac{2\mu}{(1-\sigma)}] V_L \frac{\partial L^*}{\partial \beta} <, > 0 \tag{B20}$$

4.2 <u>Leontief</u>

The results of the comparative static were found to be same as the ones derived in the static model because the optimal royalty in the dynamic model is the same as it is in the static model.

4.3 Linear

Totally differentiate Equation 23 (in the text) with respect to β yields:

$$\frac{dt^*}{d\beta} = \frac{2\mu}{(1-\sigma)} V_L \frac{\partial L^*}{\partial \beta} < 0 \tag{B21}$$

This is because $\partial L^*/\partial \beta < 0$, which was obtained from Equation B2. Substituting $\theta = \infty$ in Equation B2 yields

$$\frac{\partial L^*}{\partial \gamma} = -\frac{V^*}{\beta V_L} < 0$$

APPENDIX C

Data Used in the Empirical Analysis

Site	Variable						
	V	π	R	t	m	L	K
P1a	67.89	19,599	1,887	11	500	64	14,289
P1b	55.39	20,441	1,738	13	500	53	11,658
P2a	37.41	8,388	3,749	10	2,526	36	7,874
P2b	61.91	9,258	2,747	10	930	59	13,030
T1a	60.12	14,089	1,677	14	300	60	13,277
T1b	70.57	15,042	1,791	13	300	70	15,585
	Variable and Parameter						
Site	α	β	σ	c	A	μ	V^{SY}
P1a	380.45	3.6048	.028	3.20	.0832	6.56	76.65
P1b	474.54	3.2935	.044	3.20	.0832	5.35	106.96
P2a	327.59	3.3437	.054	3.20	.0832	13.54	55.68
P2b	236.95	1.6621	.032	3.20	.0832	16.94	62.16
T1a	336.46	2.2214	.054	3.10	.0793	5.02	74.15
T1b	298.05	1.9295	.010	3.10	.0793	6.53	66.58

APPENDIX D

Simulation of Empirical Models in TSP Using SIML Command

```
? FREQ NONE
?? READ IN DATA FOR THE SIMULATION ANALYSIS FROM THE TSP DATA BANK FILE
AWANG.TLB
? IN AWANG
? OUT AWANG
? SMPL 1 6
?? PRINT DATA BANK FOR THE RUN
? DBPRINT AWANG
```

Values for all series in Databank AWANG.TLB

	V	L	T	P	M
1	67.89000	64.4513	11.00000	19598.99023	500.00000
2	55.39000	52.58445	13.00000	20440.58398	500.00000
3	37.41000	35.51516	10.00000	8387.68164	2526.00000
4	61.91000	58.77421	10.00000	9258.20020	930.00000
5	60.12000	59.88968	14.00000	14088.70801	300.00000
6	70.57000	70.29964	13.00000	15041.60449	300.00000

	GR	K	ALPHA	B	S
1	1887.00000	14288.73633	380.44901	3.60480	0.028428
2	1738.00000	11657.87402	474.53601	3.29350	0.044412
3	3749.00000	7873.64307	327.58801	3.34370	0.053729
4	2747.00000	13030.13184	236.94600	1.66210	0.032466
5	1677.00000	13277.42969	336.45801	2.22140	0.054225
6	1791.00000	15585.29883	298.05301	1.92950	0.0096358

	A	COST	U
1	0.083189	3.20000	6.56000
2	0.083189	3.20000	5.35000
3	0.083189	3.20000	13.54000
4	0.083189	3.20000	16.94000
5	0.079279	3.10000	5.02000
6	0.079279	3.10000	6.53000

	VSY	DT	DGR	ST
1	76.65000	11.00000	1887.00000	0.50000
2	106.96000	13.00000	1738.00000	0.50000
3	55.68000	10.00000	3749.00000	0.50000
4	62.16000	10.00000	2747.00000	0.50000
5	74.15000	14.00000	1677.00000	0.50000
6	66.58000	13.00000	1791.00000	0.50000

	SL	SP	SGR	SM	DM
1	64.45132	19598.99023	1887.00000	500.00000	500.00000
2	52.58445	20440.58398	1738.00000	500.00000	500.00000
3	35.51516	8387.68164	3749.00000	500.00000	2526.00000
4	58.77421	9258.20020	2747.00000	500.00000	930.00000
5	59.88968	14088.70801	1677.00000	300.00000	300.00000
6	70.29964	15041.60449	1791.00000	300.00000	300.00000

	DV	DL	DP	SVA	SLA
1	67.89000	64.45132	19598.99023	67.89000	64.45132
2	55.39000	52.58445	20440.58398	55.39000	52.58445
3	37.41000	35.51516	8387.68164	37.41000	35.51516
4	61.91000	58.77421	9258.20020	61.91000	58.77421
5	60.12000	59.88968	14088.70801	60.12000	59.88968
6	70.57000	70.29964	15041.60449	70.57000	70.29964

	SPA	SGRA	STA	SMA	DVA
1	19598.99023	1887.00000	0.50000	500.00000	67.89000
2	20440.58398	1738.00000	0.50000	500.00000	55.39000
3	8387.68164	3749.00000	0.50000	2526.00000	37.41000
4	9258.20020	2747.00000	0.50000	930.00000	61.91000
5	14088.70801	1677.00000	0.50000	300.00000	60.12000
6	15041.60449	1791.00000	0.50000	300.00000	70.57000

	DLA	DPA	DGRA	DTA	DMA
1	64.45132	19598.99023	1887.00000	0.50000	500.00000
2	52.58445	20440.58398	1738.00000	0.50000	500.00000
3	35.51516	8387.68164	3749.00000	0.50000	2526.00000
4	58.77421	9258.20020	2747.00000	0.50000	930.00000
5	59.88968	14088.70801	1677.00000	0.50000	300.00000
6	70.29964	15041.60449	1791.00000	0.50000	300.00000

?? DISPLAY THE CONTENTS OF DATA BANK
? DBLIST AWANG
Contents of Databank AWANG.TLB

Class	Name	Description
-----	----	-----------
SERIES	V	6 obs. from 1-6, no frequency
	L	6 obs. from 1-6, no frequency
	T	6 obs. from 1-6, no frequency
	P	6 obs. from 1-6, no frequency
	M	6 obs. from 1-6, no frequency
	COST	6 obs. from 1-6, no frequency

	GR	6 obs. from 1-6, no frequency
	K	6 obs. from 1-6, no frequency
	ALPHA	6 obs. from 1-6, no frequency
	B	6 obs. from 1-6, no frequency
	S	6 obs. from 1-6, no frequency
	A	6 obs. from 1-6, no frequency
	U	6 obs. from 1-6, no frequency
	VSY	6 obs. from 1-6, no frequency
	DT	6 obs. from 1-6, no frequency
	DGR	6 obs. from 1-6, no frequency
	ST	6 obs. from 1-6, no frequency
	SL	6 obs. from 1-6, no frequency
	SP	6 obs. from 1-6, no frequency
	SGR	6 obs. from 1-6, no frequency
	SM	6 obs. from 1-6, no frequency
	DM	6 obs. from 1-6, no frequency
	DV	6 obs. from 1-6, no frequency
	SGRA	6 obs. from 1-6, no frequency
	STA	6 obs. from 1-6, no frequency
	SMA	6 obs. from 1-6, no frequency
	DL	6 obs. from 1-6, no frequency
	DP	6 obs. from 1-6, no frequency
	SPA	6 obs. from 1-6, no frequency
	DVA	6 obs. from 1-6, no frequency
	DLA	6 obs. from 1-6, no frequency
	DPA	6 obs. from 1-6, no frequency
	DGRA	6 obs. from 1-6, no frequency
	DTA	6 obs. from 1-6, no frequency
	DMA	6 obs. from 1-6, no frequency
	SVA	6 obs. from 1-6, no frequency
	SLA	6 obs. from 1-6, no frequency
EQUATION	PROFIT	formula
	PREMIUM	formula
	VOLUME	formula
	REVENUE	formula
	ROYALTY	formula
	LABOR	formula
	DVOLUME	formula
	DLABOR	formula
	DPROFIT	formula
	DREVENUE	formula
	DROYALTY	formula
	DPREMIUM	formula
	AVOLUME	formula
	APROFIT	formula
	AREVENUE	formula
	AROYALTY	formula
	ALABOR	formula
	APREMIUM	formula
	VOLUMEA	formula
	LABORA	formula
	PROFITA	formula

```
                  REVENUEA    formula
                  PREMIUMA    formula
                  ROYALTYA    formula

SCALAR            GAMMA       parameter 0.53000
                  W           parameter 30.00000
                  DELTA       parameter 0.13200
                  R           parameter 0.12000
```

```
?? PRINT ALL EQUATIONS
? PRINT VOLUME LABOR PROFIT REVENUE ROYALTY PREMIUM DVOLUME DLABOR
DPROFIT DREVENUE DROYALTY DPREMIUM AVOLUME ALABOR APROFIT AREVENUE
AROYALTY APREMIUM VOLUMEA LABORA PROFITA REVENUEA ROYALTYA
PREMIUMA

 EQUATION: VOLUME
    FRML VOLUME V = (A* L** GAMMA)* K** (1- GAMMA)

 EQUATION: LABOR
    FRML LABOR L = V* (((GAMMA* (1- S))/ (W* (1+ DELTA)))* ((ALPHA- B* V)-
T))
 EQUATION: PROFIT

    FRML PROFIT P = ((((1- S)* (ALPHA* V- (B/ 2)* V** 2)- (W* L)* (1+
 DELTA))- (R* K)* (1+ DELTA))- (T* V)* (1- S))- M

 EQUATION: REVENUE
    FRML REVENUE GR = (((1- S)* V)* T+ M)- ((1- S)* V)* COST

 EQUATION: ROYALTY
    FRML ROYALTY T = (ALPHA- GAMMA* (ALPHA- COST))+ ((2* GAMMA- 1)* B)* V

 EQUATION: PREMIUM
    FRML PREMIUM M = (((1- S)* (ALPHA* V- (B/ 2)* V** 2)- (W* L)* (1+
 DELTA))- (R* K)* (1+ DELTA))- (T* V)* (1- S)

 EQUATION: DVOLUME
    FRML DVOLUME DV = (A* DL** GAMMA)* K** (1- GAMMA)

 EQUATION: DLABOR
    FRML DLABOR DL = DV* (((GAMMA* (1- S))/ (W* (1+ DELTA)))* ((ALPHA- B*
 DV)- DT))

 EQUATION: DPROFIT
    FRML DPROFIT DP = ((((1- S)* (ALPHA* DV- (B/ 2)* DV** 2)- (W* DL)* (1+
 DELTA))- (R* K)* (1+ DELTA))- ((1- S)* DT)* DV)- DM

 EQUATION: DREVENUE
    FRML DREVENUE DGR = (((1- S)* DV)* DT+ DM)- ((1- S)* DV)* COST
```

EQUATION: DROYALTY
FRML DROYALTY DT = (ALPHA- GAMMA* ((ALPHA- COST)+ ((2* U)* VSY)/ (1- S)))+ ((2* GAMMA- 1)* B+ ((2* GAMMA)* U)/ (1- S))* DV

EQUATION: DPREMIUM
FRML DPREMIUM DM = (((1- S)* (ALPHA* DV- (B/ 2)* DV** 2)- (W* DL)* (1+ DELTA))- (R* K)* (1+ DELTA))- ((1- S)* DT)* DV

EQUATION: AVOLUME
FRML AVOLUME SVA = (A* SLA** GAMMA)* K** (1- GAMMA)

EQUATION: ALABOR
FRML ALABOR SLA = SVA* ((((GAMMA* (1- S))/ (W* (1+ DELTA)))* (ALPHA- B* SVA))* (1- STA))

EQUATION: APROFIT
FRML APROFIT SPA = ((((1- S)* (1- STA))* (ALPHA* SVA- (B/ 2)* SVA** 2)- (W* SLA)* (1+ DELTA))- (R* K)* (1+ DELTA))- SMA

EQUATION: AREVENUE
FRML AREVENUE SGRA = (((1- S)* STA)* (ALPHA* SVA- (B/ 2)* SVA** 2)+ SMA)- ((1- S)* SVA)* COST

EQUATION: AROYALTY
FRML AROYALTY STA = ((ALPHA* SVA- (B/ 2)* SVA** 2)* ((1- GAMMA)+ ((GAMMA* B)* SVA)/ (ALPHA- B* SVA))+ (GAMMA* COST)* SVA)/ ((ALPHA* SVA- (B/ 2)* SVA** 2)* ((1- GAMMA)+ ((GAMMA* B)* SVA)/ (ALPHA- B* SVA))+ (GAMMA* SVA)* (ALPHA- B* SVA))

EQUATION: APREMIUM
FRML APREMIUM SMA = (((1- S)* (1- STA))* (ALPHA* SVA- (B/ 2)* SVA** 2)- (W* SLA)* (1+ DELTA))- (R* K)* (1+ DELTA)

EQUATION: VOLUMEA
FRML VOLUMEA DVA = (A* (DLA* GAMMA))* K** (1- GAMMA)

EQUATION: LABORA
FRML LABORA DLA = ((DVA* ((GAMMA* (1- S))/ (W* (1+ DELTA))))* (ALPHA- B* DVA))* (1- DTA)

EQUATION: PROFITA
FRML PROFITA DPA = ((((1- S)* (1- DTA))* (ALPHA* DVA- (B/ 2)* DVA** 2)- (W* DLA)* (1+ DELTA))- (R* K)* (1+ DELTA))- DMA

EQUATION: REVENUEA
FRML REVENUEA DGRA = (((1- S)* DTA)* (ALPHA* DVA- (B/ 2)* DVA** 2)+ DMA)- ((1- S)* COST)* DVA

EQUATION: ROYALTYA

FRML ROYALTYA DTA = ((ALPHA* DVA- (B/ 2)* DVA** 2)* ((1- GAMMA)+ ((GAMMA* B)* DVA)/ (ALPHA- B* DVA))+ ((COST- ((2* U)/ (1- S))* (VSY- DVA))* GAMMA)* DVA)/ ((ALPHA* DVA- (B/ 2)* DVA** 2)* ((1- GAMMA)+ ((GAMMA* B)* DVA)/

```
(ALPHA- B* DVA))+ (GAMMA* DVA)* (ALPHA- B* DVA))

EQUATION: PREMIUMA
   FRML PREMIUMA DMA = (((1- S)* (1- DTA))* (ALPHA* DVA- (B/ 2)* DVA** 2)-
(W* DLA)* (1+ DELTA))- (R* K)* (1+ DELTA)


?? SET PARAMETERS FOR THE BASE RUN
? PARAM  W 30, GAMMA 0.53, R 0.12, DELTA 0.132


?? SIMULATION OF MODEL I
? SIML (ENDO=(V,L,P,GR,T,M)) VOLUME LABOR PROFIT REVENUE ROYALTY PREMIUM

                    MODEL SIMULATION
                    ****************
NUMBER OF EQUATIONS:   6
METHOD:  NEWTON     STEPSIZE METHOD:  BARD
PRINT OPTIONS:  PRINT = F  PRNRES = F  PRNDAT = F  PRNSIM = T
SILENT = F  DEBUG = F
STATIC SIMULATION

Working space used by SIML =     1182
F= 0.99921E+08  FNEW=  0.30037E+08 ISQZ=  0 STEP=  1.0000     CRIT= 0.99921E+08
F= 0.30037E+08 FNEW=   90903.     ISQZ=  0 STEP=  1.0000     CRIT= 0.30037E+08
F= 90903.       FNEW=   2858.8     ISQZ=  0 STEP=  1.0000     CRIT=  90903.
F= 2858.8       FNEW=  0.41877     ISQZ=  0 STEP=  1.0000     CRIT=  2858.8
F= 0.41877      FNEW=  0.10410E-07 ISQZ=  0 STEP=  1.0000     CRIT= 0.41877

 CONVERGENCE  ACHIEVED  AFTER   5 ITERATIONS.
 F=  0.13513E+09 FNEW=  0.80106E+07 ISQZ=  0 STEP=  1.0000     CRIT= 0.13513E+09
 F=  0.80106E+07 FNEW=    95588.    ISQZ=  0 STEP=  1.0000     CRIT= 0.80106E+07
 F=   95588.     FNEW=   269.36     ISQZ=  0 STEP=  1.0000     CRIT=  95588.
 F=   269.36     FNEW=  0.11942E-02 ISQZ=  0 STEP=  1.0000     CRIT=  269.36
 F=  0.11942E-02 FNEW=  0.43471E-13 ISQZ=  0 STEP=  1.0000     CRIT= 0.11942E-02

 CONVERGENCE  ACHIEVED  AFTER   5 ITERATIONS.
 F=  0.18086E+08 FNEW=  0.55528E+07 ISQZ=  0 STEP=  1.0000     CRIT= 0.18086E+08
 F=  0.55528E+07 FNEW=  0.14264E+07 ISQZ=  0 STEP=  1.0000     CRIT= 0.55528E+07
 F=  0.14264E+07 FNEW=    77642.    ISQZ=  0 STEP=  1.0000     CRIT= 0.14264E+07
 F=   77642.     FNEW=   212.35     ISQZ=  0 STEP=  1.0000     CRIT=  77642.
 F=   212.35     FNEW=  0.10725E-01 ISQZ=  0 STEP=  1.0000     CRIT=  212.35
 F=  0.10725E-01 FNEW=  0.12458E-10 ISQZ=  0 STEP=  1.0000     CRIT= 0.10725E-01

 CONVERGENCE  ACHIEVED  AFTER   6 ITERATIONS.
 F=  0.23839E+08 FNEW=  0.96165E+07 ISQZ=  0 STEP=  1.0000     CRIT= 0.23839E+08
 F=  0.96165E+07 FNEW=  0.62992E+06 ISQZ=  0 STEP=  1.0000     CRIT= 0.96165E+07
 F=  0.62992E+06 FNEW=    47546.    ISQZ=  0 STEP=  1.0000     CRIT= 0.62992E+06
 F=   47546.     FNEW=   77.508     ISQZ=  0 STEP=  1.0000     CRIT=  47546.
 F=   77.508     FNEW=  0.17434E-02 ISQZ=  0 STEP=  1.0000     CRIT=  77.508
 F=  0.17434E-02 FNEW=  0.31706E-12 ISQZ=  0 STEP=  1.0000     CRIT= 0.17434E-02

 CONVERGENCE  ACHIEVED  AFTER   6 ITERATIONS.
```

```
F= 0.61192E+08 FNEW= 0.14080E+08 ISQZ= 0 STEP= 1.0000 CRIT= 0.61192E+08
F= 0.14080E+08 FNEW= 0.15776E+07 ISQZ= 0 STEP= 1.0000 CRIT= 0.14080E+08
F= 0.15776E+07 FNEW= 69763. ISQZ= 0 STEP= 1.0000 CRIT= 0.15776E+07
F= 69763. FNEW= 87.611 ISQZ= 0 STEP= 1.0000 CRIT= 69763.
F= 87.611 FNEW= 0.73322E-03 ISQZ= 0 STEP= 1.0000 CRIT= 87.611
F= 0.73322E-03 FNEW= 0.23006E-13 ISQZ= 0 STEP= 1.0000 CRIT= 0.73322E-03

CONVERGENCE ACHIEVED AFTER 6 ITERATIONS.
F= 0.64954E+08 FNEW= 0.19063E+08 ISQZ= 0 STEP= 1.0000 CRIT= 0.64954E+08
F= 0.19063E+08 FNEW= 0.10192E+07 ISQZ= 0 STEP= 1.0000 CRIT= 0.19063E+08
F= 0.10192E+07 FNEW= 52111. ISQZ= 0 STEP= 1.0000 CRIT= 0.10192E+07
F= 52111. FNEW= 54.045 ISQZ= 0 STEP= 1.0000 CRIT= 52111.
F= 54.045 FNEW= 0.31010E-03 ISQZ= 0 STEP= 1.0000 CRIT= 54.045
F= 0.31010E-03 FNEW= 0.44014E-14 ISQZ= 0 STEP= 1.0000 CRIT= 0.31010E-03


CONVERGENCE ACHIEVED AFTER 6 ITERATIONS.
```

SIMULATION RESULTS

	V	L	P	GR	T
1	41.69238	25.68651	-7.16116D-17	9424.01654	189.52459
2	53.78943	49.75426	0.00000	16400.71316	235.35726
3	32.49839	27.23214	0.00000	6310.46623	162.18226
4	43.97059	30.81855	0.00000	5573.05224	117.44563
5	50.48446	43.07424	0.00000	9973.10187	166.50704
6	52.28072	39.91577	0.00000	9187.60391	147.78045

	M
1	1876.54188
2	4467.70969
3	1421.39913
4	712.69856
5	2170.91424
6	1696.49156

?? **SIMULATION OF MODEL II**
? SIML (ENDO=(DV,DL,DP,DGR,DT,DM)) DVOLUME DLABOR DPROFIT DREVENUE DROYALTY PREMIUM

```
                MODEL SIMULATION
                ****************
        NUMBER OF EQUATIONS:  6
        METHOD:  NEWTON      STEPSIZE METHOD:  BARD
        PRINT OPTIONS:  PRINT = F  PRNRES = F  PRNDAT = F  PRNSIM = T
                 SILENT = F  DEBUG = F
        STATIC SIMULATION

Working space used by SIML =    1268
F= 0.99911E+08 FNEW= 0.23623E+06 ISQZ= 0 STEP= 1.0000 CRIT= 0.99911E+08
F= 0.23623E+06 FNEW= 3.5258 ISQZ= 0 STEP= 1.0000 CRIT= 0.23623E+06
F= 3.5258 FNEW= 0.10185E-07 ISQZ= 0 STEP= 1.0000 CRIT= 3.5258
```

```
CONVERGENCE ACHIEVED AFTER   3 ITERATIONS.
F= 0.13511E+09 FNEW= 0.37762E+08 ISQZ= 1 STEP= 0.71818    CRIT= 0.13511E+09
F= 0.37762E+08 FNEW=  51527.    ISQZ= 0 STEP= 1.0000    CRIT= 0.37762E+08
F=  51527.    FNEW= 0.33160    ISQZ= 0 STEP= 1.0000    CRIT= 51527.
F= 0.33160     FNEW= 0.28229E-10 ISQZ= 0 STEP= 1.0000    CRIT= 0.33160

CONVERGENCE ACHIEVED AFTER   4 ITERATIONS.
F= 0.18082E+08 FNEW= 0.46408E+07 ISQZ= 0 STEP= 1.0000    CRIT= 0.18082E+08
F= 0.46408E+07 FNEW=  12473.    ISQZ= 0 STEP= 1.0000    CRIT= 0.46408E+07
F=  12473.    FNEW= 0.50305E-01 ISQZ= 0 STEP= 1.0000    CRIT= 12473.
F= 0.50305E-01 FNEW= 0.10894E-11 ISQZ= 0 STEP= 1.0000    CRIT= 0.50305E-01

CONVERGENCE ACHIEVED AFTER   4 ITERATIONS.
F= 0.23838E+08 FNEW=  25971.    ISQZ= 0 STEP= 1.0000    CRIT= 0.23838E+08
F=  25971.    FNEW= 0.52401E-01 ISQZ= 0 STEP= 1.0000    CRIT= 25971.
F= 0.52401E-01 FNEW= 0.46324E-12 ISQZ= 0 STEP= 1.0000    CRIT= 0.52401E-01

CONVERGENCE ACHIEVED AFTER   3 ITERATIONS.
F= 0.61183E+08 FNEW= 0.84287E+06 ISQZ= 0 STEP= 1.0000    CRIT= 0.61183E+08
F= 0.84287E+06 FNEW=  267.53    ISQZ= 0 STEP= 1.0000    CRIT= 0.84287E+06
F=  267.53    FNEW= 0.57287E-04 ISQZ= 0 STEP= 1.0000    CRIT= 267.53
F= 0.57287E-04 FNEW= 0.24760E-17 ISQZ= 0 STEP= 1.0000    CRIT= 0.57287E-04

CONVERGENCE ACHIEVED AFTER   4 ITERATIONS.
F= 0.64958E+08 FNEW= 0.10960E+07 ISQZ= 0 STEP= 1.0000    CRIT= 0.64958E+08
F= 0.10960E+07 FNEW=  159.11    ISQZ= 0 STEP= 1.0000    CRIT= 0.10960E+07
F=  159.11    FNEW= 0.27740E-04 ISQZ= 0 STEP= 1.0000    CRIT= 159.11
F= 0.27740E-04 FNEW= 0.40313E-18 ISQZ= 0 STEP= 1.0000    CRIT= 0.27740E-04

CONVERGENCE ACHIEVED AFTER   4 ITERATIONS.
```

SIMULATION RESULTS

	DV	DL	DP	DGR	DT
1	62.85710	55.73344	2.22045D-16	12286.11169	95.38561
2	84.06930	115.54618	0.00000	21235.75124	105.49442
3	49.88693	61.13094	0.00000	8230.48911	77.80545
4	59.86407	55.16327	0.00000	7013.78018	76.42068
5	65.30999	70.01680	8.67362D-19	11928.98938	118.74663
6	62.41279	55.75700	0.00000	10499.00884	119.82822

	DM
1	6656.31986
2	13017.86927
3	4708.62229
4	2772.80176
5	4785.66286
6	3283.87487

```
?? SIMULATION OF MODEL III
? SIML (ENDO=(SVA,SLA,SPA,SGRA,STA,SMA)) AVOLUME ALABOR APROFIT
AREVENUE AROYALTY APREMIUM

                    MODEL SIMULATION
                    ****************
          NUMBER OF EQUATIONS:   6
          METHOD:  NEWTON      STEPSIZE METHOD:  BARD
          PRINT OPTIONS:  PRINT = F  PRNRES = F  PRNDAT = F  PRNSIM = T
                SILENT = F  DEBUG = F
          STATIC SIMULATION

Working space used by SIML =    1746
F= 0.15495E+09 FNEW= 0.31284E+06 ISQZ= 0 STEP= 1.0000    CRIT= 0.15495E+09
F= 0.31284E+06 FNEW=  353.46     ISQZ= 0 STEP= 1.0000    CRIT= 0.31284E+06
F=  353.46     FNEW= 0.16303E-03 ISQZ= 0 STEP= 1.0000    CRIT=  353.46
F= 0.16303E-03 FNEW= 0.72070E-16 ISQZ= 0 STEP= 1.0000    CRIT= 0.16303E-03

CONVERGENCE ACHIEVED AFTER  4 ITERATIONS.
F= 0.15819E+09 FNEW= 0.11136E+07 ISQZ= 0 STEP= 1.0000    CRIT= 0.15819E+09
F= 0.11136E+07 FNEW=  240.83     ISQZ= 0 STEP= 1.0000    CRIT= 0.11136E+07
F=  240.83     FNEW= 0.87608E-04 ISQZ= 0 STEP= 1.0000    CRIT=  240.83
F= 0.87608E-04 FNEW= 0.20586E-16 ISQZ= 0 STEP= 1.0000    CRIT= 0.87608E-04

CONVERGENCE ACHIEVED AFTER  4 ITERATIONS.
F= 0.41743E+08 FNEW=  1111.2     ISQZ= 0 STEP= 1.0000    CRIT= 0.41743E+08
F=  1111.2     FNEW= 0.15614E-03 ISQZ= 0 STEP= 1.0000    CRIT=  1111.2
F= 0.15614E-03 FNEW= 0.10274E-14 ISQZ= 0 STEP= 1.0000    CRIT= 0.15614E-03

CONVERGENCE ACHIEVED AFTER  3 ITERATIONS.
F= 0.41928E+08 FNEW=  67253.     ISQZ= 0 STEP= 1.0000    CRIT= 0.41928E+08
F=  67253.     FNEW= 0.45187     ISQZ= 0 STEP= 1.0000    CRIT=  67253.
F= 0.45187     FNEW= 0.15036E-08 ISQZ= 0 STEP= 1.0000    CRIT= 0.45187
F= 0.15036E-08 FNEW= 0.17062E-23 ISQZ= 0 STEP= 1.0000    CRIT= 0.15036E-08

CONVERGENCE ACHIEVED AFTER  4 ITERATIONS.
F= 0.80666E+08 FNEW=  1254.4     ISQZ= 0 STEP= 1.0000    CRIT= 0.80666E+08
F=  1254.4     FNEW= 0.17635E-04 ISQZ= 0 STEP= 1.0000    CRIT=  1254.4
F= 0.17635E-04 FNEW= 0.88010E-17 ISQZ= 0 STEP= 1.0000    CRIT= 0.17635E-04

CONVERGENCE ACHIEVED AFTER  3 ITERATIONS.
F= 0.94984E+08 FNEW=  90052.     ISQZ= 0 STEP= 1.0000    CRIT= 0.94984E+08
F=  90052.     FNEW= 0.32351E-01 ISQZ= 0 STEP= 1.0000    CRIT=  90052.
F= 0.32351E-01 FNEW= 0.31081E-11 ISQZ= 0 STEP= 1.0000    CRIT= 0.32351E-01

CONVERGENCE ACHIEVED AFTER  3 ITERATIONS.
                    SIMULATION RESULTS
```

	SVA	SLA	SPA	SGRA	STA
1	52.35097	39.46832	0.00000	11107.31064	0.74068
2	65.66228	72.48737	0.00000	18744.51206	0.71340
3	38.14135	36.83652	0.00000	7085.83864	0.67310
4	50.72184	40.35108	0.00000	6262.13651	0.65485

5	59.31419	58.38410	0.00000	11218.60441	0.67422
6	61.75683	54.65648	-1.96918D-17	10422.59146	0.67992

	SMA
1	492.18783
2	2543.90207
3	792.13492
4	159.17711
5	1158.66655
6	695.27685

```
?? SIMULATION OF MODEL IV
? SIML (ENDO=(DVA,DLA,DPA,DGRA,DTA,DMA)) VOLUMEA LABORA PROFITA
REVENUEA ROYALTYA PREMIUMA


                MODEL SIMULATION
                ****************
        NUMBER OF EQUATIONS:  6
        METHOD: NEWTON     STEPSIZE METHOD: BARD
        PRINT OPTIONS: PRINT = F PRNRES = F PRNDAT = F PRNSIM = T
                 SILENT = F DEBUG = F
        STATIC SIMULATION

Working space used by SIML =    1850
F= 0.15496E+09 FNEW=  84479.    ISQZ= 0 STEP= 1.0000   CRIT= 0.15496E+09
F=  84479.    FNEW=  5.0629    ISQZ= 0 STEP= 1.0000   CRIT= 84479.
F=  5.0629    FNEW= 0.24470E-06 ISQZ= 0 STEP= 1.0000   CRIT= 5.0629
F= 0.24470E-06 FNEW= 0.90883E-21 ISQZ= 0 STEP= 1.0000   CRIT= 0.24470E-06

CONVERGENCE ACHIEVED AFTER  4 ITERATIONS.
F= 0.15820E+09 FNEW= 0.86418E+08 ISQZ= 0 STEP= 1.0000   CRIT= 0.15820E+09
F= 0.86418E+08 FNEW= 0.27311E+06 ISQZ= 0 STEP= 1.0000   CRIT= 0.86418E+08
F= 0.27311E+06 FNEW=  3590.2    ISQZ= 0 STEP= 1.0000   CRIT= 0.27311E+06
F=  3590.2    FNEW= 0.30059E-01 ISQZ= 0 STEP= 1.0000   CRIT= 3590.2
F= 0.30059E-01 FNEW= 0.11472E-10 ISQZ= 0 STEP= 1.0000   CRIT= 0.30059E-01


CONVERGENCE ACHIEVED AFTER  5 ITERATIONS.
F= 0.41745E+08 FNEW= 0.35619E+07 ISQZ= 0 STEP= 1.0000   CRIT= 0.41745E+08
F= 0.35619E+07 FNEW=  305.01    ISQZ= 0 STEP= 1.0000   CRIT= 0.35619E+07
F=  305.01    FNEW= 0.67117E-05 ISQZ= 0 STEP= 1.0000   CRIT= 305.01
F= 0.67117E-05 FNEW= 0.19315E-20 ISQZ= 0 STEP= 1.0000   CRIT= 0.67117E-05

CONVERGENCE ACHIEVED AFTER  4 ITERATIONS.
F= 0.41941E+08 FNEW=  16569.    ISQZ= 0 STEP= 1.0000   CRIT= 0.41941E+08
F=  16569.    FNEW= 0.16247E-03 ISQZ= 0 STEP= 1.0000   CRIT= 16569.
F= 0.16247E-03 FNEW= 0.24572E-20 ISQZ= 0 STEP= 1.0000   CRIT= 0.16247E-03

CONVERGENCE ACHIEVED AFTER  3 ITERATIONS.
F= 0.80679E+08 FNEW= 0.49857E+07 ISQZ= 0 STEP= 1.0000   CRIT= 0.80679E+08
```

```
F= 0.49857E+07 FNEW=   464.68    ISQZ=  0 STEP=  1.0000    CRIT= 0.49857E+07
F=   464.68    FNEW= 0.99084E-06 ISQZ=  0 STEP=  1.0000    CRIT=  464.68
F= 0.99084E-06 FNEW= 0.34652E-21 ISQZ=  0 STEP=  1.0000    CRIT= 0.99084E-06

CONVERGENCE ACHIEVED AFTER  4 ITERATIONS.
F= 0.95005E+08 FNEW=   59584.    ISQZ=  0 STEP=  1.0000    CRIT= 0.95005E+08
F=   59584.    FNEW= 0.18804E-02 ISQZ=  0 STEP=  1.0000    CRIT=  59584.
F= 0.18804E-02 FNEW= 0.85225E-19 ISQZ=  0 STEP=  1.0000    CRIT= 0.18804E-02

CONVERGENCE ACHIEVED AFTER  3 ITERATIONS.

                    SIMULATION RESULTS

          DVA          DLA          DPA           DGRA          DTA
1      74.51969     18.84006  -4.79368D-20   15007.97952     0.85089
2     103.72185     28.85476      0.00000    27223.81776     0.85967
3      56.60369     18.93653      0.00000    10593.60397     0.83623
4      64.09544     16.92230      0.00000     8847.64784     0.86593
5      81.17078     22.28956      0.00000    16109.86040     0.88085
6      73.65058     18.75708      0.00000    13577.26721     0.89434

          DMA
1      76.41926
2    1661.06256
3     330.84958
4    -817.51132
5    -307.71187
6   -1004.60925


?? SIMULATION OF MODEL V
?? SET ROYALTY EQUALS ZERO
? GENR T=T*0
?? EXCLUDES ROYALTY EQUATION
? SIML (ENDO=(V,L,P,GR,M)) VOLUME LABOR PROFIT REVENUE PREMIUM


                    MODEL SIMULATION
                    ****************
          NUMBER OF EQUATIONS:   5
          METHOD:  NEWTON      STEPSIZE METHOD:  BARD
          PRINT OPTIONS:  PRINT = F  PRNRES = F  PRNDAT = F  PRNSIM = T
                    SILENT = F  DEBUG = F
          STATIC SIMULATION
Working space used by SIML =    980
F= 0.10404E+09 FNEW= 0.69949E+06 ISQZ=  0 STEP=  1.0000    CRIT= 0.10404E+09
F= 0.69949E+06 FNEW=   1955.1    ISQZ=  0 STEP=  1.0000    CRIT= 0.69949E+06
F=   1955.1    FNEW= 0.13326E-01 ISQZ=  0 STEP=  1.0000    CRIT=  1955.1
F= 0.13326E-01 FNEW= 0.91211E-12 ISQZ=  0 STEP=  1.0000    CRIT= 0.13326E-01

CONVERGENCE ACHIEVED AFTER  4 ITERATIONS.
F= 0.14390E+09 FNEW= 0.10320E+09 ISQZ=  2 STEP= 0.62500E-01 CRIT= 0.14390E+09
F= 0.10320E+09 FNEW= 0.36985E+06 ISQZ=  0 STEP=  1.0000    CRIT= 0.10320E+09
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```
F= 0.36985E+06 FNEW=  120.71    ISQZ=  0 STEP=  1.0000   CRIT= 0.36985E+06
F=  120.71     FNEW= 0.38840E-04 ISQZ=  0 STEP=  1.0000   CRIT=  120.71

CONVERGENCE  ACHIEVED  AFTER   4 ITERATIONS.
F= 0.18634E+08 FNEW= 0.11568E+08 ISQZ=  1 STEP= 0.25000   CRIT= 0.18634E+08
F= 0.11568E+08 FNEW= 0.38000     ISQZ=  0 STEP=  1.0000   CRIT= 0.11568E+08
F= 0.38000     FNEW= 0.96775E-03 ISQZ=  0 STEP=  1.0000   CRIT= 0.38000
F= 0.96775E-03 FNEW= 0.72495E-14 ISQZ=  0 STEP=  1.0000   CRIT= 0.96775E-03

CONVERGENCE  ACHIEVED  AFTER   4 ITERATIONS.
F= 0.26638E+08 FNEW= 0.41639E+07 ISQZ=  0 STEP=  1.0000   CRIT= 0.26638E+08
F= 0.41639E+07 FNEW=  92502.     ISQZ=  0 STEP=  1.0000   CRIT= 0.41639E+07
F=  92502.     FNEW=  42.736     ISQZ=  0 STEP=  1.0000   CRIT=  92502.
F=  42.736     FNEW= 0.29019E-04 ISQZ=  0 STEP=  1.0000   CRIT=  42.736
F= 0.29019E-04 FNEW= 0.74781E-17 ISQZ=  0 STEP=  1.0000   CRIT= 0.29019E-04

CONVERGENCE  ACHIEVED  AFTER   5 ITERATIONS.
F= 0.68078E+08 FNEW= 0.31905E+08 ISQZ=  1 STEP= 0.25000   CRIT= 0.68078E+08
F= 0.31905E+08 FNEW=  5727.2     ISQZ=  0 STEP=  1.0000   CRIT= 0.31905E+08
F=  5727.2     FNEW=  1.3993     ISQZ=  0 STEP=  1.0000   CRIT=  5727.2
F=  1.3993     FNEW= 0.40130E-08 ISQZ=  0 STEP=  1.0000   CRIT=  1.3993

CONVERGENCE  ACHIEVED  AFTER   4 ITERATIONS.
F= 0.72069E+08 FNEW= 0.24158E+08 ISQZ=  0 STEP=  1.0000   CRIT= 0.72069E+08
F= 0.24158E+08 FNEW= 0.72712E+06 ISQZ=  0 STEP=  1.0000   CRIT= 0.24158E+08
F= 0.72712E+06 FNEW=  984.19     ISQZ=  0 STEP=  1.0000   CRIT= 0.72712E+06
F=  984.19     FNEW= 0.61220E-02 ISQZ=  0 STEP=  1.0000   CRIT=  984.19
F= 0.61220E-02 FNEW= 0.14186E-12 ISQZ=  0 STEP=  1.0000   CRIT= 0.61220E-02

CONVERGENCE  ACHIEVED  AFTER   5 ITERATIONS.
```

SIMULATION RESULTS

	V	L	P	GR	M
1	84.45967	97.31548	0.00000	13218.92461	13481.51219
2	108.88611	188.23854	0.00000	22409.37871	22742.33943
3	66.11558	104.00349	0.00000	8777.80685	8978.00929
4	89.90096	118.81024	0.00000	8028.30050	8306.64353
5	102.64054	164.30614	-1.31297D-16	13910.43112	14211.36322
6	106.39759	152.54230	0.00000	12966.28753	13292.94186

APPENDIX E

Table E1. Royalty, Harvest Volume, and Government Revenue Elasticities of Model I

Site	Elasticity with respect to								
	γ	r	w	δ	β	α	c	K	σ
					Royalty				
P1a	-0.26	0.00	-0.01	0.00	0.01	0.99	0.01	0.01	0.00
P1b	-0.31	0.00	-0.01	0.00	0.01	0.99	0.00	0.01	0.00
P2a	-0.41	0.00	-0.01	0.00	0.01	0.99	0.01	0.01	0.00
P2b	-0.46	0.00	-0.01	0.00	0.02	0.99	0.02	0.02	0.00
T1a	-0.41	0.00	-0.02	-0.01	0.01	0.99	0.01	0.01	-0.01
T1b	-0.40	0.00	-0.01	0.00	0.01	0.99	0.01	0.01	0.00
					Harvest Volume				
P1a	-0.89	0.00	-0.22	-0.02	-0.82	0.00	0.00	0.19	0.00
P1b	-0.89	0.00	-0.26	-0.02	-0.78	0.00	-0.02	0.22	-0.02
P2a	-1.23	0.00	-0.34	-0.03	-0.71	0.01	-0.03	0.31	-0.03
P2b	-1.59	0.00	-0.39	-0.05	-0.66	0.01	-0.02	0.34	-0.02
T1a	-1.27	0.00	-0.34	-0.02	-0.69	0.01	0.00	0.30	-0.02
T1b	-1.30	0.00	-0.33	-0.04	-0.71	0.01	-0.02	0.29	0.00
					Government Revenue				
P1a	-0.26	0.00	-0.01	0.00	0.01	0.99	0.01	0.01	-0.04
P1b	-0.31	0.00	-0.01	0.00	0.01	0.99	0.00	0.01	-0.06
P2a	-0.41	0.00	-0.01	0.00	0.01	0.99	0.01	0.01	-0.09
P2b	-0.46	0.00	-0.01	0.00	0.02	0.99	0.02	0.02	-0.06
T1a	-0.41	0.00	-0.02	-0.01	0.01	0.99	0.01	0.01	-0.09
T1b	-0.40	0.00	-0.01	0.00	0.01	0.99	0.01	0.01	-0.02

Table E2. Royalty, Harvest Volume, and Government Revenue Elasticities of Model II

Site	Elasticity with respect to									
	γ	r	w	δ	β	α	c	K	σ	μ
					Royalty					
P1a	-2.03	0.00	-0.38	-0.03	-1.43	3.20	0.01	0.35	-0.02	-0.38
P1b	-2.29	0.00	-0.51	-0.05	-1.48	3.53	0.01	0.46	-0.05	-0.52
P2a	-3.53	0.00	-0.81	-0.06	-1.59	3.69	0.01	0.72	-0.05	-0.26
P2b	-3.38	0.00	-0.71	-0.07	-1.14	2.90	0.00	0.62	-0.03	-0.03
T1a	-1.95	0.00	-0.40	-0.04	-0.76	2.29	0.00	0.34	-0.03	-0.15
T1b	-1.80	0.00	-0.35	-0.03	-0.71	2.12	0.00	0.30	-0.01	-0.07
					Harvest Volume					
P1a	-0.29	0.00	-0.08	-0.02	-0.33	0.27	-0.02	0.06	0.00	0.13
P1b	-0.27	0.00	-0.11	-0.01	-0.33	0.29	0.00	0.10	0.00	0.15
P2a	-0.24	0.00	-0.10	-0.02	-0.18	0.16	0.00	0.06	0.00	0.08
P2b	-0.17	0.00	-0.05	0.00	-0.08	0.10	0.00	0.05	0.00	0.03
T1a	-0.40	0.00	-0.12	-0.02	-0.26	0.31	0.00	0.11	0.00	0.08
T1b	-0.34	0.00	-0.10	0.00	-0.21	0.26	0.00	0.08	0.00	0.05
					Government Revenue					
P1a	-1.00	-0.16	-0.19	-0.03	-0.71	2.02	-0.02	0.01	-0.04	-0.38
P1b	-0.97	-0.07	-0.23	-0.03	-0.65	1.91	-0.01	0.12	-0.06	-0.52
P2a	-1.34	-0.13	-0.29	-0.04	-0.55	1.96	-0.02	0.12	-0.08	-0.26
P2b	-1.58	-0.25	-0.30	-0.05	-0.46	2.02	-0.03	0.01	-0.05	-0.03
T1a	-1.31	-0.15	-0.27	-0.04	-0.53	1.93	-0.02	0.09	-0.08	-0.15
T1b	-1.27	-0.20	-0.24	-0.04	-0.50	1.94	-0.02	0.01	-0.01	-0.07

Table E3. Royalty, Harvest Volume, and Government Revenue Elasticities of Model III

Site	Elasticity with respect to								
	γ	r	w	δ	β	α	c	K	σ
					Royalty				
P1a	2.43	0.00	0.40	0.04	-0.35	-0.03	-0.01	-0.35	0.01
P1b	2.02	0.00	0.37	0.03	-0.33	-0.03	-0.01	-0.33	0.02
P2a	1.98	0.00	0.32	0.03	-0.29	-0.03	-0.01	-0.29	0.02
P2b	2.03	0.00	0.30	0.03	-0.26	-0.02	-0.01	-0.26	0.01
T1a	2.00	0.00	0.33	0.03	-0.29	-0.02	-0.01	-0.29	0.02
T1b	2.10	0.00	0.33	0.03	-0.29	-0.02	-0.01	-0.29	0.00
					Harvest Volume				
P1a	-1.32	0.00	-0.32	-0.02	-0.71	0.00	0.00	0.29	0.00
P1b	-1.19	0.00	-0.37	-0.03	-0.67	0.00	0.00	0.32	-0.02
P2a	-1.57	0.00	-0.45	-0.03	-0.60	0.01	0.00	0.39	-0.03
P2b	-1.91	0.00	-0.47	-0.04	-0.57	0.01	0.00	0.43	-0.02
T1a	-1.57	0.00	-0.44	-0.03	-0.61	0.01	0.00	0.39	-0.02
T1b	-1.65	0.00	-0.44	-0.05	-0.62	0.01	-0.02	0.37	-0.02
					Government Revenue				
P1a	-1.56	-0.17	-0.32	-0.04	-0.88	2.42	-0.02	0.11	-0.04
P1b	-1.40	-0.08	-0.35	-0.04	-0.77	2.23	-0.01	0.23	-0.07
P2a	-2.00	-0.15	-0.47	-0.06	-0.73	2.39	-0.02	0.27	-0.09
P2b	-2.71	-0.28	-0.59	-0.08	-0.76	2.68	-0.03	0.24	-0.06
T1a	-2.03	-0.16	-0.47	-0.06	-0.74	2.41	-0.02	0.26	-0.09
T1b	-2.15	-0.20	-0.48	-0.06	-0.77	2.50	-0.02	0.22	-0.02

Table E4. Royalty, Harvest Volume, and Government Revenue Elasticities of Model IV

Site	Elasticity with respect to									
	γ	r	w	δ	β	α	c	K	σ	μ
					Royalty					
P1a	2.64	0.00	0.82	0.07	1.35	-2.16	-0.01	-0.38	0.03	0.04
P1b	2.52	0.00	0.81	0.07	1.37	-2.17	1.92	-0.38	0.04	0.04
P2a	2.64	0.00	0.93	0.09	1.11	-1.97	0.00	-0.43	0.05	-0.02
P2b	3.04	0.00	0.98	0.09	0.77	-1.69	0.00	-0.45	0.03	-0.02
T1a	2.90	0.00	0.91	0.08	0.86	-1.68	-0.01	-0.44	0.04	-0.08
T1b	3.07	0.00	0.96	0.09	0.76	-1.60	0.00	-0.44	0.01	-0.07
					Harvest Volume					
P1a	-0.20	0.00	-0.08	-0.01	-0.44	0.50	0.00	0.04	0.00	0.01
P1b	-0.19	0.00	-0.08	-0.01	-0.47	0.53	0.00	0.04	0.00	0.02
P2a	-0.11	0.00	-0.05	0.00	-0.19	0.27	0.00	0.04	0.00	0.00
P2b	-0.05	0.00	-0.02	0.00	-0.06	0.12	0.00	0.02	0.00	-0.02
T1a	-0.16	0.00	-0.06	-0.01	-0.26	0.39	0.00	0.02	-0.01	-0.06
T1b	-0.12	0.00	-0.05	0.00	-0.18	0.30	0.00	0.02	0.00	-0.08
					Government Revenue					
P1a	-0.27	-0.13	-0.08	-0.02	-0.86	2.08	-0.02	-0.09	-0.04	0.01
P1b	-0.23	-0.06	-0.07	-0.01	-0.82	1.96	-0.01	-0.03	-0.05	0.01
P2a	-0.30	-0.10	-0.09	-0.02	-0.60	1.82	-0.02	-0.06	-0.07	-0.01
P2b	-0.31	-0.20	-0.09	-0.03	-0.43	1.76	-0.02	-0.16	-0.04	-0.02
T1a	-0.30	-0.11	-0.09	-0.02	-0.60	1.88	-0.02	-0.07	-0.07	-0.04
T1b	-0.29	-0.16	-0.09	-0.02	-0.52	1.84	-0.02	-0.12	-0.01	-0.06

Table E5. Premium, Harvest Volume, and Government Revenue Elasticities of Model V

Site	Elasticity with respect to								
	γ	r	w	δ	β	α	c	K	σ
					Premium				
P1a	-1.23	-0.14	-0.24	-0.03	-0.92	2.33	0.00	0.07	-0.04
P1b	-1.12	-0.07	-0.28	-0.03	-0.81	2.18	0.00	0.18	-0.06
P2a	-1.71	-0.11	-0.39	-0.04	-0.76	2.29	0.00	0.23	-0.08
P2b	-2.29	-0.21	-0.48	-0.06	-0.78	2.49	0.00	0.21	-0.05
T1a	-1.73	-0.13	-0.39	-0.04	-0.77	2.31	0.00	0.22	-0.09
T1b	-1.81	-0.16	-0.39	-0.05	-0.81	2.37	0.00	0.18	-0.01
					Harvest Volume				
P1a	-0.08	0.00	-0.26	0.00	-0.80	1.85	0.00	0.17	-0.01
P1b	-0.70	0.00	-0.30	0.00	-0.07	1.82	0.00	0.22	-0.02
P2a	-1.10	0.00	-0.30	0.00	-0.60	2.19	0.00	0.30	-0.02
P2b	-1.40	0.00	-0.30	0.00	-0.60	2.52	0.00	0.34	-0.01
T1a	-1.10	0.00	-0.30	0.00	-0.70	2.21	0.00	0.29	-0.02
T1b	-1.10	0.00	-0.30	0.00	-0.70	2.23	0.00	0.28	-0.01
					Government Revenue				
P1a	-1.26	-0.05	-0.24	-0.03	-0.92	2.35	-0.02	0.01	-0.04
P1b	-1.18	-0.07	-0.28	-0.03	-0.81	2.20	-0.01	0.18	-0.06
P2a	-1.75	-0.12	-0.39	-0.04	-0.77	2.32	-0.02	0.22	-0.09
P2b	-2.37	-0.22	-0.49	-0.06	-0.78	2.54	-0.03	0.21	-0.06
T1a	-1.77	-0.13	-0.39	-0.05	-0.77	2.34	-0.02	0.22	-0.09
T1b	-1.86	-0.16	-0.39	-0.05	-0.81	2.41	-0.02	0.18	-0.02

LIST OF REFERENCES

Abd. Latif Nordin, and Nik Mohd. Shah Nik Mustafa. 1984. *Implikasi ekonomi perlaksanaan sistem tebangan memilih (Selective Management System) di kompleks perkayuan Negeri Pahang*. Paper Presented at the Persidangan Perhutanan Keempat Wilayah Pantai Timur. Kota Bharu, Kelantan.

Ahmad Zabidi. 1990. Personal communication.

Ahmad Zainal Mat Isa. 1984. *Forest management and development strategies for timber complexes in Terengganu.* Paper Presented at the Persidangan Perhutanan Keempat Wilayah Pantai Timur. Kota Bharu, Kelantan.

Alias Mohd. Sood. 1993. *Percubaan perlaksanaan pengurusan pembalakan melalui kawalan isipadu di Negeri Pahang Darul Makmur.* State Forestry Department, Pahang Darul Makmur. (Unpublished).

Apong, S. 1989. *Data on logging costs at Mentiga Timber complex (Pahang, Peninsular Malaysia)*, from unpublished undergraduate thesis. Fakulti Perhutanan, Universiti Pertanian Malaysia, Serdang, Selangor, Malaysia.

Arrow, K.J., H.B. Chenery, B.S. Minhas, and R.M. Solow. 1961. "Capital-labor substitution and economic efficiency." *Review of Economics and Statistics* 43(3):225-250.

Awang Noor Abd. Ghani, J.R. Vincent, and Yusuf Hadi. 1992. "Comparative economic analysis of forest revenue systems in Peninsular Malaysia." *Final report submitted to Osborn Center Forestry Policy Grants Program.*

Awang Noor Abd. Ghani, and J.R. Vincent. 1993. "Comparative economic analysis of forest revenue systems in Peninsular Malaysia." *Report for Osborn Program Workshop.* Chiang Mai, Thailand.

Binkley, C. 1987. "Economic models of timber supply." Pp. 109-136 in K. Markku, D. Dykstra, and C. Binkley, eds., *The global forest sector: An analytical perspective.* John Wiley and Sons, Chichester, U.K.

Boado, E.L. 1988. "Incentive policies and forest use in the Philippines." Pp. 165-204 in R. Repetto and M. Gillis, eds., *Public policies and the misuse of forest resources*. Cambridge University Press, Cambridge, U.K.

Cardellichio, P.A., and M. Kirjasniemi. 1987. Pp. 139-168 in K. Markku, D. Dykstra, and C. Binkley, eds., *The global forest sector: An analytical perspective*. John Wiley and Sons, Chichester, U.K.

Chang, S.J. 1982. "An economic analysis of forest taxation's impact on optimal rotation age." *Land Economics* 58(3):310-323.

Chiang, A.C. 1992. *Elements of dynamic optimization*. McGraw-Hill, New York.

Chung, K.S. 1984. "Costs of logging in hill and swamp forests of Sarawak: 1979, 1980, and 1981." Sarawak Forest Department. Kuching, Sarawak, Malaysia. (Unpublished).

Clutter, J.L., J.C. Fortson, L.V. Pienaar, G.H. Brister, and R.L. Bailey. 1983. *Timber management: A quantitative approach*. John Wiley and Sons, New York.

Dan, Y.M. 1993. Personal communication.

Dorfman, R. 1969. "An economic interpretation of optimal control theory." *The American Economic Review* 59:817-831.

Forestry Department, Peninsular Malaysia. 1978. *National forest policy*. Forestry Department, Peninsular Malaysia. Kuala Lumpur, Malaysia.

______. 1979. *Forest statistics: Peninsular Malaysia (1971-78)*. Forestry Department, Peninsular Malaysia. Kuala Lumpur, Malaysia.

______. 1986. *Forest statistics: Peninsular Malaysia (1979-85)*. Forestry Department, Peninsular Malaysia. Kuala Lumpur, Malaysia.

______. 1991a. *Forest statistics: Peninsular Malaysia (1986-90)*. Forestry Department, Peninsular Malaysia. Kuala Lumpur, Malaysia.

______. 1991b. *Annual Report*. Forestry Department Peninsular Malaysia. Kuala Lumpur, Malaysia.

Forest resource, base, policy and legislation of Peninsular Malaysia. 1979. *The Malaysian Forester* 42(4):328-389.

Gillis, M. 1980. "Fiscal and financial issues in tropical hardwood concessions." *Development Discussion Paper No. 110*. Harvard Institute for International Development. Cambridge, Mass.

_____. 1988a. "Indonesia: Public policies, resource management, and the tropical forest." Pp. 43-113 in R. Repetto and M. Gillis, eds., *Public policies and the misuse of forest resources*. Cambridge University Press, Cambridge, U.K.

_____. 1988b. "West Africa: Resource management policies and the tropical forest." Pp. 299-351 in R. Repetto and M. Gillis, eds., *Public policies and the misuse of forest resources*. Cambridge University Press, Cambridge, U.K.

_____. 1988c. "Malaysia: Public policies and the tropical forest." Pp. 115-164 in R. Repetto and M. Gillis, eds., *Public policies and the misuse of forest resources*. Cambridge University Press, Cambridge, U.K.

_____. 1992. "Forest concession management and revenue policies." Pp. 139-175 in N. Sharma, ed., *Managing the world's forests*. Kendall/Hunt Publishing Company, Dubuque.

Gillis, M., and R. Repetto. 1988. "Conclusion: Findings and policy implications." Pp. 385-410 in R. Repetto and M. Gillis, eds., *Public policies and the misuse of forest resources*. Cambridge University Press, Cambridge, U.K.

Gray, J.W. 1983. "Forest revenue systems in developing countries." *FAO Forestry Paper No. 43*. FAO, Rome.

Greene, W.H. 1990. *Econometric analysis*. Mcmillan, New York.

Hall, B.H. 1991. *TSP user's guide*. TSP International, Palo Alto, California.

Heaps, T., and J.F. Helliwell. 1985. "The taxation of natural resources." Pp. 421-472 in A. J. Anerbach and M. Feldstein, eds., *Handbook of Public Economics*. Elsevier Science Publishers B. V., North Holland.

Hiller, F.S., and G.J. Lieberman. 1980. *Introduction to operations reserach*. 3rd. ed. Helden-Day, San Francisco.

Hufscmidt, M.M., D.E. James, A.D. Meister, B.T. Tower, and J.A. Dixon. 1983. *Environmental natural systems, and development: An economic guide*. The Johns Hopkins University Press, Baltimore.

Hyde, W.F. 1980. *Timber supply, land allocation, and economic efficiency*. The Johns Hopkins University Press, Baltimore.

Hyde, W.F., and R.A. Sedjo. 1992. "Managing tropical forests: Reflections on the rent distribution discussion." *Land Economics* 68(3):343-350.

Isaac, S., and W.B. Michael. 1982. *Handbook in research and evaluation*. 2nd. ed. Edits, San Diego.

Johansson, P.O., and K.G. Lofgren. 1985. *The economics of forestry and natural resources*. Basil Blackwell, New York.

Jalaluddin Abdul Moin. 1989. *Location and concentration of wood-based industries in Peninsular Malaysia*. B.Sc. Thesis. Fakulti Perhutanan, Universiti Pertanian Malaysia, Serdang, Selangor, Malaysia.

Klemperer, W.D. 1976a. "Impacts of tax alternatives on forest values and investment." *Land Economics* 52(2):132-157.

______.1976b. "Taxation of forest products and forest resources". Pp. 276-287 in P. V. Ellefson, ed., *Forest resource economics and policy research*. Westview Press, Boulder.

Kmenta, J. 1986. *Elements of econometrics*. 2nd. ed. Macmillan, New York.

Ku Azmi Ku Aman. 1993. Personal communication.

Kumar, R. 1986. *The forest resources of Malaysia: Their economics and development*. Oxford University Press, Oxford.

Lanly, J.P. 1982. "Tropical forest resources." *FAO Forestry Paper No. 30*. FAO, Rome.

McFadden, D. 1963. "Constant elasticity of substitution production functions." *Review of Economic Studies* 30:73-83.

Mead, W.J. 1967. "Natural resource disposal policy-oral auction versus sealed bid." *Natural Resources Journal* 7(2):194-224.

Meerschaert, M.M. 1993. *Mathematical modeling*. Academic Press, Boston.

Ministry of Finance, Malaysia. 1992. Economic Report 1992/93. Ministry of Finance, Malaysia. Kuala Lumpur, Malaysia.

Mohd. Shahwahid Othman. 1985. "Determining an economic cutting regime for the tropical rainforest." *The Malaysian Forester* 48(1):57-74.

_____. 1986. "Sources of growth for the timber-based manufacturing industries of Peninsular Malaysia during the period 1968-1981. *The Malaysian Forester* 49(3):208-222.

Muraoka, D.D., and R.W. Watson. 1983. "Improving the efficiency of federal timber sales procedures." *Natural Resources Journal* 23:815-825.

Neher, P.A. 1990. *Natural resource economics.* Cambridge University Press, Cambridge.

Newman, D.H., C.B. Gilbert, and W.F. Hyde. 1985. "The optimal forest rotation with evolving prices." *Land Economics* 61(4)347-353.

Ollikainen, M. 1990. "Forest taxation and the timing of private nonindustrial forest harvests under interest rate uncertainty." *Canadian Journal of Forestry Research* 20:1823-1829.

Page, J.M., S.R. Pearson, and H.E. Leland. 1976. "Capturing economic rents from Ghanaian timber." *Food Research Institute Studies* 15(1):27-51.

Paris, R., and I. Ruzicka. 1991. "Barking up the wrong tree: The role of rent appropriation in sustainable tropical forest management." *ADB Environment Office Occasional Paper No. 1.* Asian Development Bank, Manila.

_____. 1993. "The case against environmental taxes for sustainable forestry." *Journal of Forestry 91(4):22-26.*

Perlaksanaan pengusahasilan hutan melalui kawalan isipadu di Negeri Johor Darul Ta'zim. (1993). (Unpublished).

Repetto, R. 1988a. *The forest for trees? Government policies and the misuses of forest resources.* World Resource Institute, Washignton, D.C.

_____. 1988b. "Overview." Pp. 1-41 in R. Repetto and M. Gillis, eds., *Public policies and the misuse of forest resources.* Cambridge University Press, Cambridge, U.K.

Repetto, R., and M. Gillis. (Eds). 1988. *Public policies and the misuse of forest resources.* Cambridge University Press, Cambridge, U.K.

Robinson, V.L., and W.R. Frey. 1983. "Use of system dynamic approaches to regional forest sector models." Pp. 93-103 in R. Seppala, C. Row, and A. Morgan, eds., *Forest sector models.* A B Academic Publishers, Berkhanstedt.

Ruzicka, I. 1979. "Rent appropriation in Indonesian logging: East Kalimantan, 1972-73 to 1976-1977." *Bulletin of Indonesian Economic Studies* 15(2):49-56.

Salleh Mohd. Nor. 1983. "Forestry in Malaysia." *Journal of Forestry* 81(3):164-166.

Shaharuddin Mohd. Ismail. 1993. Personal communication.

Sato, R. 1975a. "Homothetic and non-homothetic CES production functions." *American Economic Review* 67(4):559-569.

______. 1975b. "The most general class of CES functions." *Econometrica* 43(5-6):999-1003.

Sedjo, R.A., and K.S. Lyon. 1990. "*The long-term adequacy of world-timber supply.*" Resources for the Future, Washington D.C.

Sheikh Ibrahim Sheikh Ali, and Shaharuddin Mohd. Ismail. 1984. *Keupayaan kawasan sumber menampung perusahaan kompleks perkayuan.* Paper presented at the Persidangan Perhutanan Keempat Wilayah Pantai Timur. May 7-9, 1984, Kota Bharu, Kelantan.

Silberberg, E. 1978. *The structure of economics.* McGraw-Hill, New York.

Sulaiman Nordin. 1977. "A method of forest revenue assessment based on inventory data." *Malaysian Forester* 40(3):144-159.

Synder, D., and R.N. Bhattacharyya. 1990. "A more general dynamic economics model of the optimal rotation of multiple-use forests." *Journal of Environment Economics and Management* 18:168-175.

Tang, H.T. 1987. "Problems and strategies for regenerating dipterocarp forests in Malaysia." Pp. 23-45 in F. Mergen and J. R. Vincent, eds., *Natural management of tropical moist forests.* Yale University, School of Forestry and Environmental Studies, New Haven, Conn.

Teo, P.C. 1966. "Revision of royalty rates." *Malayan Forester* 29(4):254-258.

Thang, H.C. 1985. "Timber supply and domestic demand in Peninsular Malaysia." *The Malaysian Forester* 48(2):87-97.

______. 1986. "Concept and practice of selective management system in Peninsular Malaysia." *The Malaysian Forester* 49(3):249-260.

Thompson, T. 1984. *Malaysia forest revenues.* Consultant report to the Forestry Department, Peninsular Malaysia. Wellington, New Zealand.

Varian, H.R. 1984. *Microeconomic analysis.* 2nd. ed. W. W. Norton, New York.

Vincent, J.R. 1986. "Growth of the forest products industry in Malaysia: 1961-1985. *The Malaysian Forester* 49(3):223-240.

______. 1990. "Rent capture and the feasibility of tropical forest management." *Land Economics* 66(2):212-223.

______. 1992. "The tropical timber trade and sustainable development." *Science 256(5064):1651-1655.*

______. 1993a. Managing tropical forests: Comment. *Land Economics.* 69(3):313-318.

______. 1993b. Response: depletion and degradation are not the same. *J Forestry 91(4):24-25.*

Vincent, J.R., and C.S. Binkley. 1991. Forest-based industrialization: A dynamic perspective." *Development Discussion Paper No. 389.* Harvard Institute for International Development, Cambridge, Mass.

Vincent, J.R., and Yusuf Hadi. 1991. Deforestation and agricultural expansion in Peninsular Malaysia. *Development Discussion Paper No. 396.* Harvard Institute for International Development, Cambridge, Mass.

Vincent, J.R., Awang Noor Abd. Ghani, and Yusuf Hadi. 1993. Economics of tropical timber fees and logging in tropical forest concessions. Unpublished ms.

Yacui, T. 1965. The CES production function: A note. *Econometrica* 33(8):646-647.