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Option valuation of Philippine forest plantation leases

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ABSTRACT. The Philippine forest plantation lease is modelled as an option whose value arises from market uncertainty and the irreversibility inherent in sunk costs required to establish plantations. The value of this option could be a significant factor in the planting decisions of leaseholders. Real options theory could help explain why in spite of the prospects of adequate financial returns, Filipino leaseholders are slow to establish plantations. The opportunity cost of investing is demonstrated to be highly sensitive to uncertainty of the future value of the plantation. Real options analysis is also utilized to evaluate policies intended by the Philippine government to promote plantation development.

1. Introduction

Plantation forests are playing an increasingly important role in meeting the world's growing requirements for wood and nonwood forest products. They represent less than 3 per cent of world forest, yet are estimated to supply a third of industrial roundwood and 10 per cent of fuelwood (see ABARE, 1999; Sedjo and Botkin, 1997). Plantations also supply a large range of nonwood products and services – including animal fodder, cork, nuts and fruits, latex, and oils – and are used for recreation and environmental protection, such as soil and water protection. Forest plantations can also serve as carbon sinks.

According to the *Forest Resources Assessment 2000 (FRA 2000)* produced by the Food and Agricultural Organization (FAO, 2001a), new forest plantation areas were reported as being established globally at the rate of 3 million hectares per year during the 1990s. *FRA 2000* identified the ten countries with the largest reported plantation development programmes (by area); China with 24 per cent of the global area, India with 18 per cent, the Russian Federation and the US each with 9 per cent, Japan with 6 per cent, Indonesia with 5 per cent, Brazil and Thailand each with 3 per cent, the Ukraine with

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2 per cent, and Iran with 1 per cent. Together these countries account for 80 per cent of the global forest plantation area.

However, over 60 per cent of the plantations in Asia and Africa have been assessed as being unsuccessful for wood production for a number of reasons, including ineffective planning and management, marketing factors, fire, and disease (ABARE, 1999). This paper shows that the Philippines is one of those countries which has not been too successful in establishing forest plantations and investigates how timber price uncertainty could be one possible explanation for its poor performance.

Since 1977, the Philippine government has had a programme for large-scale industrial forest plantation development by the private sector to supply raw material requirements for wood industries. Areas considered suitable for forest plantations such as open and denuded brushlands and inadequately stocked forest lands have been leased by the government to private developers for a period of 25 years, renewable for another 25.[1] As of June 1999, 295 leases had been awarded covering a total of 662,656 hectares. However, the performance of the Philippine forest plantation programme has been dismal (see FMB, 1999b). Of the 295 leases awarded, only 113 (38 per cent) have been planted and most of these consist of only a portion of their awarded areas. Only 120,394 ha (18 per cent) have been planted out of the total 662,656 ha awarded.

Lack of suitable financing has been considered the main reason for the slow development of forest plantations (see Sedjo, 1992). Hence in 1991, the Asian Development Bank provided a $25 million loan for a project to establish industrial forest plantations in the Philippines. However the project was terminated in January 1999 with unsatisfactory results.[2] The project had planted a total of 5,997 ha, only about 24 per cent of the project target of 25,000 ha. Of the $25 million allocated for the project, only $9.1 million was disbursed. Of the five targeted investors, one was not even able to draw the funds committed to it by the Bank; another only partly utilized the funds it received. While suitable financing is considered necessary for the development of forest plantations, the experience of the Asian Development Bank project is anecdotal evidence that the provision of financing is not sufficient.

Standard benefit–cost analysis shows that financial returns to plantation forestry are favourable and are enhanced by suitable financing.[3] Thus, the dismal development of forest plantations in the Philippines remains a puzzle. This paper argues that one possible reason is that investment rules derived from standard calculations of NPV are misleading because these conventional calculations pay too little attention to risk and uncertainty of market conditions. We show that uncertainty about timber prices could be a plausible reason for the lack of investment in forest plantations. If the rules for investing take into account timber price uncertainty, then the lack

[1] In the Philippines, all 'forest land' is owned by the state.

[2] Forestry Specialist, Asian Development Bank, Manila, personal communication, 1999.

[3] See the feasibility studies of ADB (1991), BOI (1990), DENR (1990), and Niskanen and Sasstamoinen (1996).

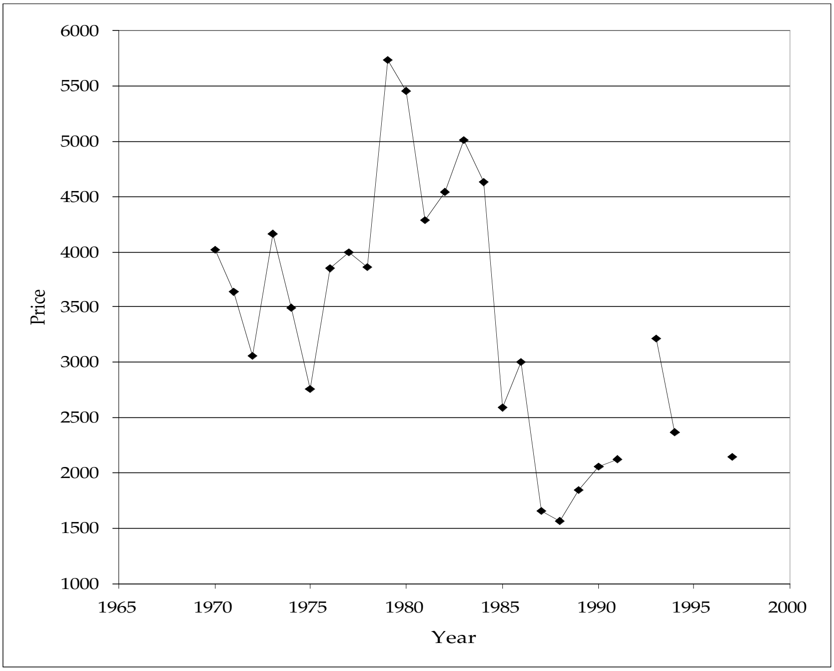

Figure 1. *Average Philippine Log Export Price per m*^{3}*, 1970–1997 (1995 Philippine Pesos ₽)*
Source: FMB (1999a, Table 4.23).

of forest plantation investments in the Philippines will become less of a puzzle.

Timber price uncertainty is a factor which cannot be ignored by Philippine forest plantation leaseholders. Figure 1 presents the average export prices of Philippine logs. This price series has a mean of ₽3,403 per m^3 and a standard deviation of ₽1,189 (₽ denotes Philippine pesos).[4] Inter-annual price changes of 50 per cent are not uncommon (as in 1978 to 1979 or 1986 to 1987).[5] Such fluctuations make the returns to investments in forest plantations quite risky and uncertain. This uncertainty matters because plantation investment is irreversible, that is, the high establishment costs

[4] It is sensible to present log export prices not in US dollars but in Philippine pesos because during most of the period of this price series, the Philippine government imposed foreign exchange controls. There have been volatile exchange rate fluctuations during the time period of this price series.

[5] I am grateful for the observation of an anonymous reviewer that since the average price is a composite of all kinds of logs exported in a given year, it is possible that the fluctuations observed are being driven by changes in the composition of species exported. Unfortunately, there are no time series data for single species and it cannot be verified whether the price series is contaminated by variations in composition.

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cannot be recovered should market conditions turn out to be worse than anticipated. In other words, uncertainty looms large when *sunk costs* cannot be recouped.

To take into explicit account price uncertainty and irreversibility, this paper uses the real options approach to analyse Philippine forest plantation leases. In developing a model of the option to plant industrial forests we incorporate an exogenously specified harvest rule. A dynamic programming solution is followed. The solution shows how an exogenous harvest rule affects the optimal decision to plant or exercise the option provided by the plantation lease. We then implement the model empirically using parameters relevant to the Philippine forest plantation programme. We also study policies used by the Philippine government to hasten planting by leaseholders. A binomial simulation is used to approximate finite leases and the threat of lease cancellation is examined as a Poisson process.

Previous papers have applied different models of the real options approach to forestry operations. Most of these papers apply options theory to the *tree-cutting* problem or optimal *harvesting* under uncertainty. Shaffer (1984) uses the Black-Scholes option pricing formula to value long-term timber cutting contracts. Morck, Schwartz, and Strangeland (1989) analyse the *tree-pruning* problem in the case of stochastic timber prices and stochastic timber inventories. Clarke and Reed (1989) study the harvesting problem when the tree is subject to stochastic age-dependent growth and price uncertainty. Reed and Clarke (1990) develop optimal harvest rules when the tree is subject to stochastic size-dependent growth in a stochastic price environment. Thomson (1992) uses the binomial option pricing model to analyse optimal forest rotation. Yin and Newman (1995) extend the Clarke and Reed (1989) paper by incorporating rental and management costs if a harvest is postponed. Plantinga (1998) compares the harvesting decision when the price process is a random walk and when it is autoregressive. This paper differs by applying real options theory to the *tree-planting* problem under timber price uncertainty. Two papers by Yin and Newman (1996, 1999) examine investment decisions covering all the production activities of harvesting, planting, and management of timber producers who manage a plantation forest on a sustained-yield basis. Hughes (2000) uses option pricing methodology to value the forest assets of a forestry corporation. This paper is specifically concerned with the optimal planting decision of holders of plantation forest leases corresponding to a single timber rotation.

2. A model of the option to plant industrial forests

Consider a holder of a forest plantation lease who has the *option* to plant now or later. This option is of course constrained by the time limitation of the lease. For analytical purposes, it is assumed that the lease has an infinite time horizon, unless otherwise stated. The main implication of an infinite time horizon is that the leaseholder can decide to exercise the option at any time in the future. We later relax this assumption and consider a finite lease using a binomial simulation.

We assume an *exogenous harvest rule*, that is, a forest planted at time t is harvested τ-years later.[6] We likewise assume that τ is not sensitive to price changes. We also assume that at time $t + \tau$ the plantation produces a unit output of timber. We further assume that the leaseholder will only do a single rotation (with a τ-year length) of planting and harvesting. We model the plantation project as involving a single investment decision in a single discrete project producing a unit output whose sale yields a single payoff for the leaseholder.

We assume that the fluctuations in the value of the plantation are due to the uncertainty of the timber price. Therefore, we allow the timber price P to be exogenous and determine the value V of the plantation, and the value F of the lease (that is, the option to plant) in terms of the stipulated stochastic process for P. We assume that the timber price is an exogenous stochastic variable which follows a geometric Brownian motion

$$dP = \alpha P\,dt + \sigma P\,dz \tag{1}$$

where α and σ are constants equal to the drift and standard deviation of prices, and dz is the increment of a standard Wiener process with $E(dz) = 0$ and $E(dz^2) = dt$. It is useful to note that if current price is P_0, the expected value is given by

$$E[P(t)] = P_0 e^{\alpha t} \tag{2}$$

Equation (1) is of course a simplified view of the evolution of returns to plantation forestry. Later in the paper we examine a variation in which the value is subject to policy-induced discrete jumps.

Given that P evolves stochastically, the problem of the leaseholder is to determine at what point is it optimal to pay a sunk cost K for a forest plantation whose value is $V(P)$. This planting decision can be specified as an optimal stopping problem solved using the technique of dynamic programming (see Dixit and Pindyck, 1994). We take the value of the lease (the option to plant), $F(P)$ as the objective function to be maximized. With an exogenous harvest rule and the assumption that the leaseholder will only do a single rotation of τ-year length, the *single* payoff from planting at time t is

$$V[P(t+\tau)] - K$$

We want to maximize the expected present value of this *single* payoff

$$F(P) = \max\left[E(V[P(X+\tau)])\,e^{-\rho(X+\tau)} - Ke^{-\rho X}\right] \tag{3}$$

where E denotes expectation, X is the (unknown) future time that the leaseholder plants, ρ is an exogenously specified discount rate, and the maximization is subject to equation (1). For this problem to make sense, we assume that $\rho > \alpha$, otherwise it will be best never to plant the industrial

[6] An exogenous harvest rule is commonly assumed in feasibility studies of forest plantations (see ADB, 1991 and BOI, 1990). The common use of this assumption by Philippine plantation leaseholders was also confirmed by the Project Director, Plantation Forestry, C. Alcantara and Sons, Inc., Davao, Philippines, personal communication, 1999.

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forest. If $\rho < \alpha$, timber prices are growing faster in expectation than the discount rate, and so at all times it will pay to postpone planting forever.

It is helpful to note that if the timber price P follows the Hotelling rule for renewable resources, then the growth rate (α) of the timber price *plus* the natural growth rate of the timber stock must *equal* the rate of return (ρ) obtained by investing in assets elsewhere in the economy. Put differently, if the timber price follows the Hotelling rule of efficient renewable resource use, then $\rho > \alpha$.[7]

Note that the aim in (3) is to maximize the expected (in the statistical sense of mean or probability-weighted average) present value of the project. Our implicit assumptions are that the leaseholder is *risk-neutral* and the exogenously specified discount rate ρ is equal to the *risk-free rate*.[8]

To solve the maximization problem (3), we need to derive the expected present value of the plantation when the forest is planted at time t and harvested τ years later

$$V[P(t)] = E(V[P(t+\tau)])\,e^{-\rho(t+\tau)}$$

Since the single-rotation plantation produces a unit output, we can use equation (2) to determine the expected present value of the plantation. If the plantation is established when timber price is P, the value of the plantation is

$$V(P) = Pe^{-(\rho-\alpha)\tau} \tag{4}$$

Part of the sunk cost in our model K_H, the cost of harvesting is paid at the end of the project. This is equivalent to assuming that part of the sunk cost equal to $K_H e^{-\rho\tau}$ is paid at the start of the project. Hence, the sunk cost in our model is composed of

$$K = K_G + K_H e^{-\rho\tau} \tag{5}$$

where K_G is the cost of planting incurred immediately at time t when the decision to plant is made and K_H is the cost of harvesting paid $t+\tau$ years later.[9]

The solution to $F(P)$, the current value of the lease (the option to plant) is a stochastic differential equation, whose solution also yields an optimal planting rule. Since P evolves stochastically, the planting rule takes the form of a '*trigger*' price P^* such that it is optimal to plant once $P \geq P^*$ and to wait otherwise, keeping alive the option to plant.

Real options theory has a standard procedure to derive the stochastic differential equation for determining the value of the option *F(P)* using Ito's

[7] I thank Charles Perrings for suggesting the use of the Hotelling rule in interpreting this condition.

[8] A better treatment of the discount rate would have been to use a theory such as the Capital Asset Pricing Model (CAPM) which informs the choice of the discount rate (see Luenberger, 1998). The CAPM relates the discount rate to the riskless rate and the market price of risk. However, the CAPM requires a complete set of markets in risky assets, a condition which is unlikely to hold in a developing country like the Philippines.

[9] Subscript $_G$ denotes growing trees or planting and subscript $_H$ denotes harvesting.

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Lemma and to solve the 'value-matching' and 'smooth-pasting' conditions for the trigger price P^* (see Dixit and Pindyck, 1994). Following this procedure, we obtain

$$P^* = \frac{\beta}{\beta - 1} \frac{K_G + K_H e^{-\rho\tau}}{e^{-(\rho-\alpha)\tau}} \tag{6}$$

where

$$\beta = \frac{1}{2} - \frac{\alpha}{\sigma^2} + \sqrt{\left(\frac{\alpha}{\sigma^2} - \frac{1}{2}\right)^2 + \frac{2\rho}{\sigma^2}} > 1 \tag{7}$$

In order for the lease to have a finite value, we assumed $\rho > \alpha$, in which case $\beta > 1$.

We can compare the planting rule prescribed by the real options approach with the planting rule from conventional benefit–cost analysis. The conventional rule is derived by setting the value of the plantation, equation (4), to the sunk cost, equation (5), and solving for what we will call the '*breakeven*' price, denoted P^B

$$P^B = \frac{K_G + K_H e^{-\rho\tau}}{e^{-(\rho-\alpha)\tau}} \tag{8}$$

Once $P \geq P^B$, conventional benefit–cost analysis prescribes planting; otherwise the lease should be abandoned, since investment is considered conventionally as a now-or-never proposition.

Comparing equations (6) and (8), we can easily see that $P^* > P^B$ because $\beta > 1$. The trigger price of real options theory modifies the breakeven price of conventional benefit–cost analysis by incorporating a correction for the value of waiting. With this correction P^* exceeds P^B by a multiple which we denote as q

$$q = \frac{\beta}{\beta - 1} \tag{9}$$

where $q > 1$ because $\beta > 1$. We refer to q as the '*waiting premium*'.

If the waiting premium is large enough, then it is rational for the leaseholder to delay planting even when the expected present value of revenue is in excess of the sunk cost, that is, conventional NPV is positive or $P > P^B$. If $P^* > P > P^B$, it is sensible for the leaseholder to delay planting as there is value in waiting to ensure that the current state of affairs is not fleeting. Moreover, even if $P < P^B$ the leaseholder should not necessarily abandon the forest plantation lease. Rather, it may be better for the leaseholder to wait and keep alive the option on the chance that the future may be brighter. Waiting enables the leaseholder to avoid the downside risk, while realizing the upside potential. Option value can significantly affect the decision to invest.

3. Option value of the Philippine forest plantation lease

Numerical calculations of option value require empirical estimation of the exogenous parameters ρ, α, and σ. Following the Asian Development Bank (ADB, 1991) in its benefit–cost appraisal of industrial forest plantations in the Philippines, we set the discount rate, $\rho = 0.12$.[10] The drift and variance parameters are estimated from a series of annual average Philippine log export prices from 1970–1997 (FMB, 1999a, table 4.23). We use the Wholesale Price Index as our deflator and make our estimates in terms of 1995 prices. Applying the Dickey–Fuller test for unit-root on this admittedly short time series for the price of Philippine timber, we fail to reject the hypothesis of a geometric random walk; giving some support to our presumption that the price of timber might be characterized by geometric Brownian motion.

We follow the method developed by Campbell, Lo, and MacKinlay (1997) to estimate the drift and variance parameters of a price process stochastically evolving as a geometric Brownian motion. Applying their method to the 1970–1997 series of Philippine log export prices, we estimate the annual drift as 0.0045 with a variance of 0.0554. The average timber price is ₱3,403 per m^3, with an annual drift rate $\alpha = 0.004$ and a standard deviation of $\sigma = 0.2354$. In other words, the average price grows at 0.4 per cent annually[11] with a volatility (standard deviation) of approximately 23 per cent.

The calculation of the trigger price P^* (equation (6)) requires estimates of the exogenous harvest rule and of the sunk costs. The parameters used in the calculation of the trigger price are based on information provided by a company operating forest plantation leases in Southern Philippines.[12] This company plants fast-growing species and uses an exogenous harvest rule of $\tau = 12$ years in its feasibility studies. In terms of 1995 Philippine prices, plantation establishment cost is estimated to be ₱294 per m^3 and the harvesting cost at ₱816 per m^3.[13] Table 1 summarizes the parameter values used in the numerical calculations.

Using the specified parameters in table 1, we calculate the price that will trigger planting as $P^* =$ ₱3,212. We can compare this trigger price with the breakeven price of conventional benefit–cost analysis, $P^B =$ ₱1,948. With a waiting premium, $q = 1.65$, leaseholders following the real options rule will

[10] In its project appraisal, the ADB considers 12 per cent as the risk-free rate of return in the Philippine economy (ADB, 1991, pp. 86–87).

[11] Assuming a risk-free rate of return of 12 per cent and assuming that the timber price follows the Hotelling rule of efficient renewable resource use, the natural growth rate of the tree must be 11.6 per cent to make up for the growth rate of the price ($\alpha = 0.4$ per cent). The required tree growth rate would be too high for most common species. However, we use $\rho = 12$ per cent so we can compare our assessment with that of the ADB project appraisal. It should be noted that the ADB appraisal assumed a constant and certain timber price.

[12] Project Director, Plantation Forestry, C. Alcantara and Sons, Inc., Davao, Philippines, personal communication, 1999. C. Alcantara and Sons, Inc. has a track record of planting over 2,000 hectares of industrial forests consisting mostly of bagras and falcata species.

[13] There are also other cost estimates used by the Asian Development Bank in its technical feasibility study of the Philippine industrial forest plantations project (ADB, 1991). The cost estimates reported by C. Alcantara and Sons, Inc. are approximately the same as the estimates used by the Bank in its feasibility study. It should be noted that C. Alcantara and Sons, Inc. was one of the five leaseholders who participated in the Bank's project and one of the four who were able to draw from the ADB loan.

Table 1. *Summary of exogenously specified parameters*

Parameter definition	*Notation & value*
Price drift rate	$\alpha = 0.004509$
Price volatility	$\sigma = 0.235392$
Discount rate	$\rho = 0.12$
Rotation	$\tau = 12$ years
Planting cost *per* m^3, *1995* ₱	$K_G =$ ₱294
Harvest cost *per* m^3, *1995* ₱	$K_H =$ ₱816
Total sunk cost, $K = K_G + K_H e^{-\rho\tau}$	$K =$ ₱487

require a higher price than the conventional breakeven price before they decide to plant.

Table 2 compares the decisions based on these different planting rules provided by conventional benefit–cost analysis (3rd column) and the real options approach (4th column), given the average log export price of a particular year. Given the timber price in each year, the conventional benefit–cost rule would prescribe planting immediately in 15 of the 18 years (for which there are available prices) of the Philippine forest plantation programme from 1977 to 1997; and abandoning the lease for the other three years. However, the real options rule would prescribe planting immediately for only nine of the 18 years (for one year, 1993, the decision is marginally in favour of planting); and advise waiting and keeping alive the option to plant for the remaining nine years.

Feasibility studies using the conventional benefit–cost rule would mistakenly expect planting to occur during years when it was optimal to wait and erroneously advise abandoning the lease when it would have been better to wait on the chance that the future may turn out better. The prescription of the real options rule for leaseholders to wait during nine of 18 years could perhaps provide a possible explanation for the low planting rate (that is, only 18 per cent of total area awarded has been planted) of the Philippine industrial forest plantation programme.

It would have been more informative to compare how much was actually planted by Philippine forest plantation leaseholders in each particular year. Unfortunately no central statistics on planted areas by species and year and on price trends by species are available. These necessary data would have had to be gathered from each leaseholder, a task which we have been unable to do.

Numerical results for different parameter values are reported in table 3. Consider Case I of changing σ. When $\sigma -> 0$, the conventional benefit–cost decision rule is exactly the same as the real options rule (that is, $P^B = P^*$, $q = 1$). The estimates of σ in the 95 per cent confidence interval are used to calculate critical values. Using the higher (lower) confidence limit results in higher (lower) critical values, P^* and q. With greater price uncertainty, the option value increases, making it more attractive for the leaseholder to wait. This is a standard result in real options pricing theory.

Consider Case II of changes in the drift rate. The estimates of α in the 95 per cent confidence interval are used to calculate critical values. The

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Table 2. *Comparing decisions prescribed by different decision rules*

			Real options approach trigger price		
Year t	*Price* $P(t)$	*Conventional breakeven price* $P^B = 1{,}948$	*Infinite lease* $T = \infty$ $\lambda = 0$ $P^* = 3{,}212$	*One year gestation* $T = 1$ $P^* = 2{,}732$	*Cancellation threat* $\lambda = 0.5$ $P^{**} = 2{,}416$
1977	3,992	Plant Now	Plant Now	Plant Now	Plant Now
1978	3,863	Plant Now	Plant Now	Plant Now	Plant Now
1979	5,734	Plant Now	Plant Now	Plant Now	Plant Now
1980	5,453	Plant Now	Plant Now	Plant Now	Plant Now
1981	4,282	Plant Now	Plant Now	Plant Now	Plant Now
1982	4,545	Plant Now	Plant Now	Plant Now	Plant Now
1983	5,008	Plant Now	Plant Now	Plant Now	Plant Now
1984	4,633	Plant Now	Plant Now	Plant Now	Plant Now
1985	2,592	Plant Now	Wait	Wait	Plant Now
1986	3,002	Plant Now	Wait	Plant Now	Plant Now
1987	1,658	Abandon Lease	Wait	Wait	Wait
1988	1,568	Abandon Lease	Wait	Wait	Wait
1989	1,846	Abandon Lease	Wait	Wait	Wait
1990	2,055	Plant Now	Wait	Wait	Wait
1991	2,132	Plant Now	Wait	Wait	Wait
1992	NA	–	–	–	–
1993	3,219	Plant Now	Plant Now	Plant Now	Plant Now
1994	2,371	Plant Now	Wait	Wait	Wait
1995	NA	–	–	–	–
1996	NA	–	–	–	–
1997	2,150	Plant Now	Wait	Wait	Wait

Notes:
Unit of prices – 1995 ₱ per m^3.
NA – Price Not Available.
Comparing the actual price at each year, $P(t)$ with P^B: if $P(t) \geq P^B$, then 'Plant Now,' otherwise 'Abandon Lease'.
Comparing the actual price at each year, $P(t)$ with P^*: if $P(t) \geq P^*$, then 'Plant Now,' otherwise 'Wait'.

breakeven price decreases as α increases because a higher drift rate lowers the future value of the sunk costs. The waiting premium q increases as the drift rate increases because a higher drift rate raises the value of waiting. The numerical calculations show that changes in the drift rate have ambiguous effects on the trigger price.

For the effects of changes in the discount rate (Case III), we consider rates 50 per cent lower and 150 per cent higher than the assumed rate in the base case. Within this range, as ρ increases, the waiting premium q decreases. While the breakeven price is increasing in the discount rate because a higher discount rate increases the future value of planting costs. The numerical values of P^* increase as ρ increases. This is also because of an increase in the future value of planting costs brought about by a higher ρ.

Table 3. *Critical values for Philippine forest plantation lease*

Case	σ	α	ρ	τ	P^B	P^*	q^*
Base case	0.235	0.004	0.12	12	1,948	3,212	1.65
I. Changes in σ	$- > 0$	0.004	0.12	12	1,948	1,948	1
		0.185				2,905	1.49
		0.235				3,212	1.65
		0.322				3,817	1.96
II. Changes in α	0.235	−0.089	0.12	12	5,956	7,425	1.25
		0.004			1,948	3,212	1.65
		0.098			637	4,343	6.81
III. Changes in ρ	0.235	0.004	0.06	12	1,345	2,763	2.05
			0.12		1,948	3,212	1.65
			0.18		3,187	4,780	1.5
IV. Changes in τ	0.235	0.004	0.12	6	1,382	2,279	1.65
				12	1,948	3,212	
				18	3,102	5,115	

Notes: The unit of rotation parameter τ is years. The unit of the variables, P^B, P^* is 1995 ₱ per m^3.

Changes in the exogenous harvest rule are considered in Case IV. Critical values are calculated for lengths 50 per cent shorter and 150 per cent longer than the assumed rotation in the base case. The values of both P^B and P^* increase as τ increases. The reason is that a longer rotation increases the future value of planting costs.

4. Evaluation of policies to promote establishment of plantations

The Philippine Department of Environment and Natural Resources, the government agency responsible for the forest plantation programme has implemented several policies to try to encourage leaseholders to establish as many hectares of plantation forest as possible in the quickest possible time. One of these policies is the specification of a maximum number of years in which non-planting by the leaseholder is tolerated or a maximum gestation period. Another is the threat of cancellation of leases which have not been planted. We now model these policies and analyse their effects on the optimal planting decision.

4.1. Shorter gestation period

A policy set by the Philippine government to promote planting is the prescription that the lease should be planted within a specified number of years. According to the rules, a lease which has not been planted within the specified period of time will be terminated. In effect, a leaseholder who has not planted within the specified number of years will have the lease ended prematurely. This policy of required planting within a specified time period can be construed as the prescription of a maximum period for project development. This specification of a maximum number of years when non-planting is tolerated sets a limit to the gestation period of the project. In this section, we evaluate the effect of shortening the period of project gestation on the planting decision.

Table 4. *Critical values for different time lengths of development (1995 ₱ per m³)*

T [years]	P^B [₱]	P^*[₱]	*q*
1	1,948	2,732	1.40
3	1,948	2,974	1.53
5	1,948	3,064	1.57
10	1,948	3,142	1.61
25	1,948	3,173	1.63
∞	1,948	3,212	1.65

The analysis thus far assumes an infinitely lived option to plant. We now consider lease expiration at a known date in the future. With a specified gestation period, the lease could be terminated at a known expiration date. Hence, the option to plant becomes a lease with a finite life.

It is not typically possible to solve analytically for the option value in the case of a finitely lived lease; however numerical solutions may be obtained (McDonald and Siegel, 1986). The general solution procedure in the case of a finite lease involves using a discrete approximation to the continuous-time problem and numerically solving the dynamic programming problem to obtain approximations to the solution (see Hull, 2000). Here, we solve for the option value of the finite lease by applying the binomial numerical procedure for solving an optimal stopping problem. This method uses the binomial model as a discrete approximation to the continuous stochastic price process (Cox, Ross, and Rubinstein, 1979).

Using this binomial numerical procedure, we solve the optimal stopping problem assuming different lengths of the gestation period. We calculate the value of the option to plant assuming different maximum time lengths for project development, that is, T =1, 3, 5, 10, 25 years. The critical values calculated for these different time lengths are presented in table 4.

First, we note in table 4 that the trigger price for a development period of 25 years ($P^* =$ ₱3,173) when rounded off to the hundredths' place is quite close to the trigger price when the lease has an infinite time horizon ($P^* =$ ₱3,212). Thus a 25-year time horizon is already quite close to infinity as far as the effect of the future on the decision whether to plant or to wait. This result is important to note because the Philippine forest plantation lease is awarded for 25 years and renewable for another 25. Our numerical analysis suggests that the Philippine lease can be analysed as if it had an infinite time horizon, the approach followed in the previous section.

Second, table 4 indicates that the specification of a gestation period could promote faster planting by leaseholders. When a leaseholder is required to plant within a specific time period after the award of the lease ($T \neq \infty$), the trigger price is lower compared to the case when there is no such requirement ($T = \infty$). A lease with an infinite time horizon implies that the leaseholder can plant at any time in the future. Option value is highest in this case. The prescription of a gestation period makes finite the time horizon of the lease and the waiting premium of a finitely lived lease is lower than that of a lease with no time limitation. Thus, a gestation period policy could lead leaseholders to plant sooner rather than later.

Third, we observe that the price threshold P^* and the waiting premium q both decrease as the time length of the gestation period T gets shorter. Option value is lower when the gestation period is shorter. Leaseholders facing briefer gestation periods would plant sooner rather than later. This result suggests that a policy of shorter periods for plantation development could be effective to promote planting.

Fourth, we note however, in table 4 that even when the gestation period is relatively brief, there is still a waiting premium, that is, $q = P^*/P^B$, is greater than one. Even when the lease lives only for one year ($T = 1$), waiting is still valuable (q =1.4).[14] When the lease has a life of three years or more, the trigger price is over 50 per cent greater than the breakeven price, that is, $q \geq 1.5$. Considering that an infinite lease has a waiting premium of $q = 1.65$, this numerical analysis shows that leases with shorter periods of project development still have significant option values. Even if the leaseholder only has one year or three years to exercise his option to plant, waiting is still valuable. Waiting has value even for leases with short lives.

As an illustration that a gestation period policy may not be effective, table 2 compares decisions based on different planting rules provided by the real options approach when the lease has an infinite time horizon, $T = \infty$ (see 4th column) and when it has a gestation period of one year, $T = 1$ (see 5th column). Given the timber price in each year, the real options approach would prescribe that the holder of a lease with an infinite time horizon plant immediately for nine of the 18 years and wait for the remaining nine years. While the holder of the lease which faces termination if the lease is unplanted after one year would be advised to plant immediately for ten of the 18 years and wait for the remaining eight years. The prescription changes very slightly (only for the year 1986) when a policy of a one year gestation period is imposed. This comparison suggests that a gestation period policy may not substantially change the planting behaviour of Philippine leaseholders.

4.2. Threat of lease cancellation

As of June 1999, 103 out of 295 forest plantation leases (35 per cent) awarded from 1977 to 1999 have been cancelled by the Philippine government (FMB, 1999b). However, the processes of evaluating the performance of the leaseholders and cancelling the leases of non-performers have not been conducted on a regular and systematic manner. There have been elements of randomness and of being *ad hoc* in the way the government has cancelled these leases. For example, although the plantation programme began in 1977, 60 of the 103 cancelled leases were terminated only during the years 1996–1999; 31 leases were cancelled during the period 1989–1991 (FMB, 1999b). Furthermore, 79 of 182 unplanted leases have not been cancelled. Hence, we can consider the cancellation of a lease as an event that is *likely* to happen with some probability and construe government policy as a *threat* to cancel leases and that government uses this threat to encourage plantation

[14] When there is a one year gestation period $T = 1$, a decision to '*Wait*' leaves open the option to plant on or before the 365th day when an unplanted lease would otherwise be terminated.

development. We analyse the implications of this policy by modelling the risk of lease cancellation on planting decisions.

We introduce the risk of cancellation into our model by assuming that lease cancellation occurs randomly and follows a Poisson process. A Poisson process is a process subject to jumps of fixed or random size, for which the arrival times of the jumps follow a Poisson distribution. These jumps are called 'events'. Letting λ denote the *mean arrival rate* of an event, during a time interval of infinitesimal length dt, the probability that an event will occur is given by $\lambda\, dt$, and the probability that an event will not occur is given by $1 - \lambda\, dt$. The event is a jump of size u, which can itself be a random variable.

We assume there is a positive probability, λ, that the timber price can take a discrete jump to zero. Thus the stochastic process for P is a mixed geometric Brownian motion–Poisson process of the form

$$dP = \alpha P dt + \sigma P\, dz + P ds \tag{10}$$

where

$$ds = \begin{cases} -1 \textit{ with probability } \lambda\, dt \\ \;\;0 \textit{ with probability } 1 - \lambda\, dt \end{cases}$$

Equation (10) assumes that if a Poisson event occurs, P falls by 100 per cent with probability 1. The occurrence of the Poisson event induces the stochastic price process to stop, since zero is a natural absorbing barrier for a geometric Brownian motion process. We assume that there is no correlation between the Brownian motion and the Poisson process (so that $E(dz\, ds) = 0$).

Notice that, when the Poisson event occurs, it is as if the forest plantation lease expires, since its value becomes zero, that is, $F(P) = F(0) = 0$. Thus, calculating the value of the option to plant when P can jump to zero is like calculating the value of the lease with an uncertain expiration date. In contrast to a policy of a gestation period under which the lease could be terminated at a known and specified date in the future, under a policy of a cancellation threat, there is a risk that the lease could be ended at any time.

In order to gauge the effects of changing λ, it is useful to know the expected value of T, the amount of time that P fluctuates continuously as a Brownian motion before dropping to zero. We can determine $E(T)$, by using the fact that the probability that no event occurs in the interval $(0, T)$ is $e^{-\lambda T}$. Therefore the probability that the first event occurs in the short interval $(T, T + dT)$ is $e^{-\lambda T} \lambda\, dT$. Therefore the expected time until P takes a Poisson jump is

$$E(T) = \int_0^\infty \lambda T e^{-\lambda T} dT = \frac{1}{\lambda} \tag{11}$$

Only leases which have not been planted face the threat of cancellation. Leaseholders who have planted do not face this threat and so will expect to harvest and collect the harvest revenue. Hence, the value of the plantation, $V(P)$, is not affected by the risk of cancellation. Even under a policy of a threat to cancel unplanted leases, the expected present value of the

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single-rotation plantation which is planted at time t and harvested τ years later is the same as equation (4).

Following the standard procedure of real option theory in solving for the investment threshold (see Dixit and Pindyck, 1994), we obtain the trigger price

$$P^{**} = \frac{\beta'}{\beta' - 1} \frac{K_G + K_H e^{-\rho\tau}}{e^{-(\rho-\alpha)\tau}} \tag{12}$$

where

$$\beta' = \frac{1}{2} - \frac{\alpha}{\sigma^2} + \sqrt{\left(\frac{\alpha}{\sigma^2} - \frac{1}{2}\right)^2 + \frac{2(\rho+\lambda)}{\sigma^2}} > 1 \tag{13}$$

For the lease to have a finite value, we assume $\rho > (\alpha - \lambda)$, thus $\beta' > 1$.

We can compare this trigger price with the breakeven price. Note that even under the threat of cancellation, the breakeven price is the same as equation (8). Comparing equations (8) and (12), we can easily observe that there is again a waiting premium

$$q' = \frac{\beta'}{\beta' - 1} \tag{14}$$

By comparing equations (7) and (13), we can verify that $\beta' > \beta$, thus

$$\frac{\beta'}{\beta' - 1} < \frac{\beta}{\beta - 1} \tag{15}$$

Or $q' < q$, that is, the waiting premium is lower when there is a risk of lease cancellation (equation (14)) than where there is no such threat (equation (9)). The value of waiting is lower when there is a risk of lease cancellation. With a lower waiting premium, the trigger price when there is a risk of cancellation, P^{**} (equation (12)), is lower than the trigger price when there is no such threat, P^* (equation (6)). Therefore, a policy of cancellation threat would make leaseholders plant sooner rather than later.

The magnitude of the effect of a risk of cancellation on the trigger price, P^{**}, can be calculated using the parameters relevant to the Philippine forest plantation programme specified in table 1. The results of the calculations are presented in table 5.

First, we observe the second column of table 5 which gives the expected time, $E(T)$, that timber price fluctuates continuously before dropping to zero. This expected time is computed using equation (11), $E(T) = 1/\lambda$. We can interpret $E(T)$ as the expected time until an unplanted lease is cancelled. These calculations of the expected time allow us to choose values of λ which are realistic for the Philippine forest plantation programme. The Philippine lease is awarded for 25 years, renewable for another 25. Thus, the lower bound for a realistic value of λ for the Philippine programme would be $\lambda = 0.02$ and $E(T) = 50$.

Second, we note from table 5 that even with a small threat of lease cancellation, for example, $\lambda = 0.02$, the trigger price ($P^{**} = \mathrm{P} = 3{,}091$) is lower than when then there is no risk of lease cancellation ($P^{**} = \mathrm{P} = 3{,}212$ when $\lambda = 0$). Even a small risk of lease cancellation reduces the waiting

Table 5. *Critical values when there is a probability λ of lease cancellation*

λ	$E(T)$	P^B	P^{**}	q^*
0	0	1,948	3,212	1.65
0.02	50	1,948	3,091	1.59
0.04	25	1,948	2,997	1.54
0.05	20	1,948	2,957	1.52
0.066666	15	1,948	2,900	1.49
0.10	10	1,948	2,808	1.44
0.20	5	1,948	2,634	1.35
0.25	4	1,948	2,577	1.32
0.333333	3	1,948	2,507	1.29
0.5	2	1,948	2,416	1.24
1	1	1,948	2,284	1.17

Notes: $E(T)$ is the expected number of years until an unplanted lease is cancelled, calculated using equation (11).
The unit of the variables P^B and P^{**} is 1995 ₱/m^3.

premium and trigger price and thus there is less incentive for leaseholders to wait compared to the case when there is no such threat. A policy of lease cancellation threat reduces the value of waiting and can hasten planting.

Third, we note from table 5 that an increase in λ reduces P^{**} and q'. A higher risk of lease cancellation lowers the trigger price and the waiting premium. Increasing the threat of lease cancellation could bolster planting efforts by leaseholders.

Fourth, table 5 indicates, however, that the threat of lease cancellation does not eliminate completely the waiting premium. We note that, even when $\lambda = 1$, P^{**} is greater than P^B by 17 per cent ($q' = 1.17$). Using equation (11), we know that if $\lambda = 1$, the expected time for an unplanted lease not to be cancelled is one year. Even when the unplanted lease is expected to be cancelled in a year's time, there is still a waiting premium, $q' > 1$. An option to plant which is expected to remain alive even for only one year still has a waiting premium. Hence, it can be argued that a policy of threatening to cancel leases which have not been planted may not be fully effective in encouraging leaseholders to plant sooner.

To illustrate that a lease cancellation threat may not be effective, table 2 compares decisions based on different planting rules provided by the options approach when there is no risk [$\lambda = 0$] that an unplanted lease will be terminated (see 4th column) and when there is a 0.5 probability [$\lambda = 0.5$] that an unplanted lease will be cancelled (see 6th column). Given the average log export price in each year, the real options approach would prescribe that the leaseholder plant immediately for nine of the 18 years and keep the option alive for the remaining nine years when there is no risk that the option will be cancelled. When the leaseholder faces a 0.5 probability that the option will be cancelled, the advice would be to plant immediately for eleven of the 18 years and wait for the remaining seven years. The prescription changes slightly (only for the years 1985 and 1986) when a policy of a lease cancellation threat with $\lambda = 0.5$ is implemented. This comparison

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suggests that a lease cancellation threat may not drastically change the planting behaviour of Philippine leaseholders.

5. Concluding remarks

In this paper, we model the Philippine forest plantation lease as an option to plant. We show that the value of this option can be a significant factor in the planting decisions of leaseholders who follow an exogenously specified harvest rule. We find that with market uncertainty, a trigger price higher than the breakeven price of conventional benefit–cost analysis is required to induce the leaseholder to plant. Furthermore, we find that when the timber price follows a geometric Brownian motion, the greater the price uncertainty, the higher the trigger price.

Our analysis can contribute to our understanding of a non-trivial puzzle in the Philippine forest plantation programme: In spite of the prospects of adequate financial returns (as indicated by positive NPVs) and the provision of suitable financing, why are leaseholders not establishing forest plantations? The uncertainty of timber prices could be one plausible reason why leaseholders are delaying the planting of their leases. In uncertain market circumstances, leaseholders will require that NPVs be more than merely positive. Leaseholders may understand that their options are valuable and that it is often desirable to keep these options open. If the data were available, it would be an important area of future research to test whether or not Philippine plantation leaseholders account for option values when making planting decisions. This empirical test could use the techniques as in Provencher (1995).

As for policy implications, it can be stated that under price uncertainty, investment analysis of forest plantation programmes which do not include option values could be misleading. Put constructively, benefit–cost analysis needs to include option values in its definition of NPV when there is price uncertainty. The NPV rule needs to be redefined by subtracting from the conventional calculation the cost of exercising the option to plant and then saying that the rule ‘plant if NPV is positive’ holds. In this paper, we show how option value can be included in an appropriate modification of benefit–cost analysis.

Real options analysis also allows us to evaluate the effects of certain policies to promote faster establishment of forest plantations. We show that the shortening of the gestation period of the lease and the threat to cancel leases could be effective policies to encourage planting. However, we also show that these policies would reduce but not eliminate option values. Waiting would still be valuable even for leases with short lives. Even with high risks of lease cancellation, there is still a premium in waiting. Hence, we argue that these policies may not be fully effective in speeding up planting.

Our model did not consider forest growth and yield functions. It would be an important area for future research to study how the incorporation of tree growth functions would affect the value of plantation leases. It would also be interesting to analyse how option values change when the leaseholder can abandon the project during the investment lag, that is, at a time after planting but before the end of the rotation (see Bar-Ilan and Savage, 1996).

Another significant area for future research would be to investigate whether market uncertainty is a relevant factor which has hampered forest plantation establishment in other countries. For example, it would be useful to analyse whether price uncertainty affects planting decisions by forest plantation growers in Asian countries (for example, Bangladesh, Malaysia, Myanmar, Pakistan) whose annual planting rates are comparable to the Philippine rate.[15] Such an analysis could apply similar methods used in this paper.

Aside from timber price uncertainty, there are of course other important factors which could explain the dismal performance of the Philippine forest plantation programme. For example, tenuous land rights in the Philippine uplands and the Philippine log export ban could be crucial factors which make leaseholders hesitant to establish plantations. Other relevant factors could include: lack of information on appropriate species, establishment and management techniques; lack of infrastructure to support plantation development; the high risk of marketing products especially small wood from thinnings; and the lack of secondary plantation markets to allow plantation sales before harvesting. It would be crucial for future research to investigate how these types of risks affect the behaviour of Filipino leaseholders.

A more comprehensive analysis covering factors other than timber price uncertainty would be needed to gain a fuller understanding of the Philippine plantation programme. Such an analysis could compare the experience of the Philippines with those of other countries (for example, Brazil, China, India, Indonesia) which have succeeded in plantation forestry.

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