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Economic Management of Eppawela Phosphate Deposit, Sri Lanka: An Empirical Application

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ABSTRACT. *The quantities of non-renewable resources are finite. There use by the present generation reduces the quantity available for the future generations. Hence economic management of non-renewable natural resources is a necessary condition to achieve sustainable development, that best satisfies the present generation whilst leaving development options for future generations to best satisfy itself. Policy making and management of non-renewable resource in Sri Lanka occurs in an analytical vacuum.*

An empirical study was carried out to examine the economically optimum management strategy for the phosphate deposit at Eppawela, Sri Lanka. Optimal management of a non-renewable resource requires information on inter-temporal extraction quantities. A computer programme was developed based on a theoretical model to obtain solutions on inter-temporal extraction quantities of Eppawela Rock Phosphate (ERP). The model was solved for the case of constant extraction cost and for increasing extraction cost cases. Sensitivity analysis was done on the discount rates.

The results reveal that with optimal management strategy (optimum quantity and time of ERP extraction) more than half of the available resource would remain unextracted. Improved technologies with low extraction cost would alter this. The study also demonstrates the application of economic principles to guide optimal management of non-renewable resources.

INTRODUCTION

Phosphate deposits are a non renewable natural resource. Phosphate rock is the raw material for the phosphate fertilizer industry and phosphorus

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based chemicals. More than 90 percent of world phosphate rock is extracted mainly for the manufacture of phosphate fertilizers.

At present Sri Lanka imports a large amount of fertilizer at a cost of nearly US$ 60 million per year (Economic Review, 1988). Between 15-20% of the fertilizers used in the country are phosphates. In 1992 alone soluble phosphate fertilizers such as IRP (Imported Rock Phosphate) and TSP (Triple Super Phosphate) were imported spending foreign exchange which amounted to more than US$ 8 million (National Fertilizer Secretariat, 1990). However, Sri Lanka was able to save some foreign exchange by using Rock Phosphate from extracting phosphate deposits at Eppawela.

The Eppawela rock phosphate deposits were discovered in 1971. There is an estimated reserve of 60 million metric tons. At present, more than 20 years after its discovery, the fertilizer produced by grinding Eppawela rock phosphate to fine particles (-100 mesh size) known as Eppawela Rock Phosphate (ERP) is used mainly for tea, rubber and coconut (Lanka Phosphate Limited, 1990).

In 1987, the tea sector used ERP for 73% of its phosphate requirements, though a 100% application has been recommended, except for nurseries. The rubber sector used 30% of ERP though the recommendation is 50%. Due to the poor solubility of ERP, it is not used or recommended for short term crops such as rice and vegetables.

Although the poor solubility of ERP constraints its use, research suggests that the potential use of ERP is high (Dahanayaka, 1988). Demand for phosphate fertilizer should grow strongly, specially in Asia, over the next decade and this will give an advantage to Sri Lanka in supplying such demand to earn foreign exchange.

Given this potential to use ERP to the economic benefit of Sri Lanka, it is relevant to examine the optimal management strategy to extract ERP. The objective of this study is to examine the optimal management strategy for the extraction of Eppawela phosphate deposit in Sri Lanka to determine the optimum quantity and time of extraction.

METHODS

Description of the study site

Eppawela rock phosphate deposits are located on the Kakirawa - Thalawa road about 175 km from Colombo. These deposits are estimated to contain about 60 million tons (proven and inferred) of phosphate (Lanka Phosphate Limited, 1990). The phosphate is constituted of an average of 37% P_2O_5 and is considered to be one of the richest phosphate deposit in the world. At present open - cast strip mining is adopted for extraction of this deposit.

Method of data collection

Data were collected from secondary sources. Annual Reports of the Fertilizer Secretariat from 1980 - 1995, Annual Reports of Central Bank and Central Bank Staff Studies were used. Direct interviews were also conducted with the relevant officials to get further information.

The types of data collected were: price of the ERP (Rs/ton) for past several years; current extraction rate (Mt/year); price elasticity of fertilizer; economic discount rate; financial discount rate; total availability of the deposit; extraction costs for past years.

Method of analysis

Theoretical basis

The extraction of non-renewable resource over time is a crucial issue in sustainable development. Because there are finite supplies of the resource, extraction of a unit today precludes extraction of that unit in future. Therefore extraction decision must take forgone future net benefits into account. The marginal user cost is the opportunity cost measure that allows this balance to take place.

The optimum management strategy for non-renewable resources can be derived using the dynamic efficiency criterion. The dynamic efficiency criterion assumes that society's objective is to maximise the present value of net benefits from the use of a resource.

According to the Hotelling's theory of natural resource extraction, marginal user cost rises at the rate of interest rate, in an efficient allocation in order to preserve the balance between present versus future extraction. Because of the increasing marginal user cost, total marginal cost (marginal extraction cost + marginal user cost), increases over time. In response to the rising total marginal cost over time, the quantity extracted falls over time, until it finally reaches zero. At this point, where total marginal cost is equal to the highest price that consumers are willing to pay, the quantity demanded is zero (Tietenberg, 1988). Using Hotelling's theory, optimal quantities of extraction over time can be obtained. Two models based on Hotelling's theory were developed to derive dynamically efficient optimal management strategies. These are explained briefly below.

Model I - Constant marginal extraction cost

The following conditions were assumed:

1. Marginal cost of extraction is constant
2. The demand curve is linear and constant over time

Objective Function:

$$Max\ PVNB\ \sum_{t=1}^{n} \frac{(aq_t - \frac{b}{2}q_t^2) - cq_t}{(1+r)^{t-1}} \qquad t = 1 ....n$$

Subject to,

$$Q = \sum_{t=1}^{n} q_t$$

Where;

Max PVNB = Maximise Present Value of Net Benefits from the extraction of ERP.

a = intercept of the demand function for ERP.

q_t = resource extracted in i[th] period (mt)

b = slope of the demand function of ERP

c = marginal extraction cost (Rs.) of ERP.

r = discount rate.

Q = total availability of ERP (mt).

t = time period

The Lagrangian solution to the above maximisation problem which defines dynamically efficient extraction is as follows:

$$\frac{a - bq_t - c}{(1+r)^{t-1}} - \lambda \qquad t = 1.........n$$

$$\sum_{t=1}^{n} q_t - Q = 0$$

In a dynamic efficient allocation, the present value of marginal net benefit (λ) has to be equal in each time period.

Model II - At increasing marginal extraction cost

In this model the cost function for the depletable resource differs from the model - I. The cost function is $TC_t = cq_t + (f/2)(\Sigma q_i)^2$. In this cost function the marginal cost of extraction rises with the cumulative amount extracted (Dasguptha and Heal, 1979). In addition there is no availability constraint: availability in this case is determined by cost, not by a finite limit on the amount available. With this change the objective function is:

Maximize

$$PVNB = \sum_{t=1}^{n} \frac{(a\frac{q_t}{2} - \frac{b}{2} q_t^2 - cq_t)}{(1+r)^{t-1}} - \sum_{t=1}^{n} \frac{fq_t}{(1+r)^{t-1}} < 0 \qquad t = 1...........n$$

Where the symbols are as model I except f = inflation rate of costs. Necessary and sufficient conditions for extraction satisfying this function are:

$$\frac{a - bq_t - c - f(\sum_{t=1}^{t-1} q_t)}{(1+r)^{t-1}} - \sum_{t=1}^{n} \frac{fq_t}{(1+r)^{t-1}} < 0 \quad t = 1.....n$$

Parameters defined were the same as in model - I, except f = 0.1. The solutions for both models were obtained by developing a computer programme using GW-BASIC language.

Model III - Environmental cost model

To include environmental costs the cost parameter value was changed in model II. Environmental cost was added to the marginal extraction cost. Environmental cost was taken as 12% out of unit extraction cost (Lanka Phosphate Limited, 1994).

Sensitivity analysis

Each analysis was done for 3 different discount rates. A lower discount rate (6%) was taken as the economic discount rate. A moderate financial discount rate of 15% was taken by averaging the bank borrowing rate for past years. A high discount rate of 21% was taken from the current loan lending interest rates of commercial banks in Sri Lanka.

RESULTS AND DISCUSSION

Results of model I - At constant marginal extraction cost

If the ERP is to be used to maximise society's welfare, the economic discount rate should be used to derive the optimum management strategy. In this study the economic discount rate was taken as 6%. According to the results obtained, at 6% discount rate 23.19 million Mt phosphate could be extracted for about 124 years (Figure 1a), but there would still be unextracted phosphates (Figure 1b). The quantities extracted over time are given in Figure 1a. The current extraction rate is 30,000 Mt/year (Lanka Phosphate Limited, 1995). Thus the current extraction rate is sub-optimal.

The model was solved using the financial discount rate, taken as 15%. At that discount rate 24.57 million Mt of ERP would be extracted for 68 years (Figure 1a) and the remaining quantity would be 35.43 million Mt (Figure 1b)

The model was tested using a higher discount rate taken as 21%. The results showed 27.00 million Mt of phosphate would be extracted for 56 years

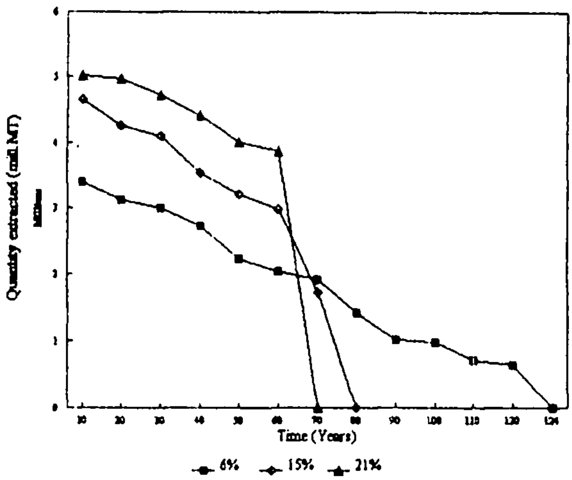

Figure 1a. Quantities of ERP extracted over time, million Mt.

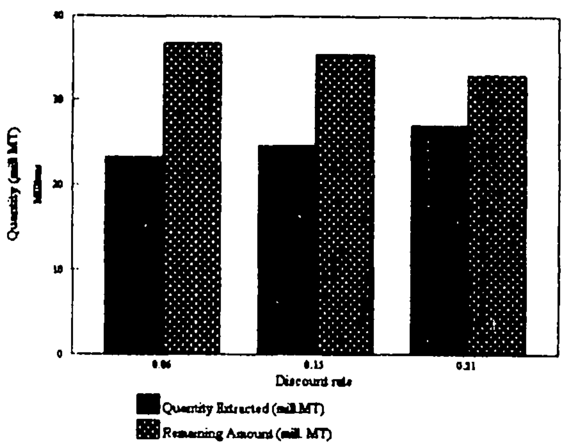

Figure 1b. Quantities of ERP extracted and the remaining amount, million Mt.

Figure 1. Quantities of ERP extracted at constant marginal extraction cost.

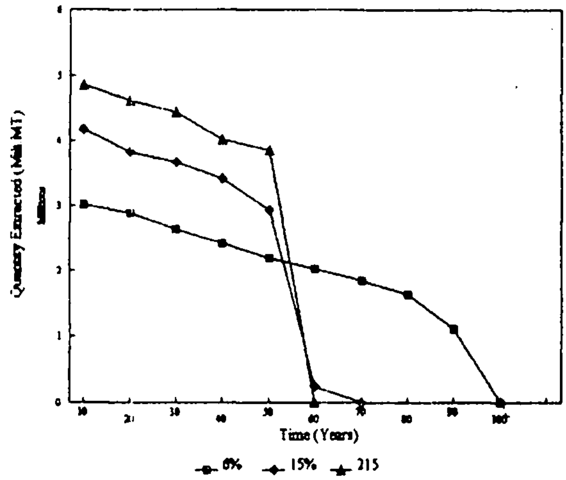

Figure 2a. Quantities of ERP extracted over time, million Mt.

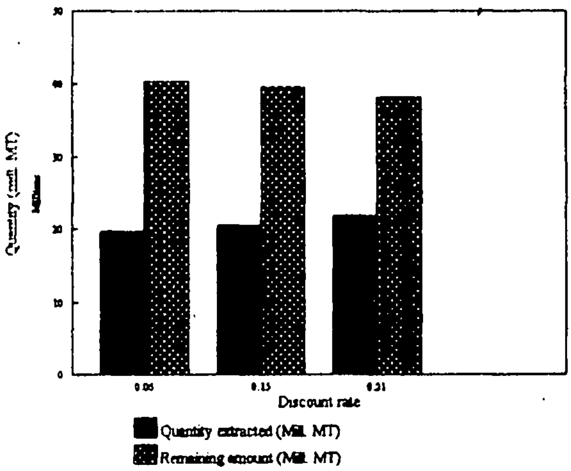

Figure 2b. Quantities of ERP extracted and the balance amount, million Mt.

Figure 2. Quantities of ERP extracted at increasing marginal extraction cost.

and the remaining amount would be 32.96 million Mt. The resource will be extracted sooner compared to the previous case (Figure 1a).

Results of the model II - At increasing marginal extraction cost

The total quantity extracted is less compared to constant cost case for the above mentioned three different discount rates (Figure 2a and Figure 1b). In the increasing cost case a higher quantity of resource would remain unextracted.

Results of including environmental cost

With inclusion of environmental cost, slightly less would be extracted compared to without incorporating of environmental costs.

CONCLUSIONS

The results reveal that with the optimal management strategy (optimal quantity and time of ERP extraction) under present economic variables (extraction cost and discount rates) more than half of the available resource would remain unextracted. This would alter with improved technology to lower extraction costs. The study also demonstrates the application of economic principles to guide optimal management of non -renewable resources.

This analysis should only be considered as a beginning in the use of economic principles for objective policy analysis on the management of non - renewable natural resource in Sri Lanka. The model needs further refinements in prediction of dynamic demand for ERP and technological change in extraction of ERP.

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