MODELS TO MANAGE PRICING IN MINING INDUSTRY

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Abstract: *Given that economic analysis of extractive industry is fundamentally different from the analysis of agriculture, manufacturing and services, this paper deals with finding and applying the political and economic principles of pricing in mining industry (in the first part), and with demonstrating the relationship between the level of extraction and price trend resulted in time (in the second part).*
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Introduction

Economic analysis of extractive industry is fundamentally different from the analysis of agriculture, manufacturing and services. The main reason is that the mineral resources are exhaustible resources. In other words, in mining industry an initial stock of reserves will exhaust in time. If we start from the premise that the owner of a resource, like any other owner, is seeking for maximum gain, then it must consider specific factors, unique in the mining industry.

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One of the objectives of Hotelling's research was to examine the optimal level of extraction of non-renewable mineral resources in terms of government which wanted to maximize social welfare by exploiting these resources.

Political and economic principles of pricing in mining industry

Given the premise that the owner of a resource, like any other owner, is seeking for maximum gain, in other sectors, the profit will be maximized by operating at a level where the marginal cost of supply equals marginal revenue (see fig. 1).

Scholars in mining economics states that this type of curve policy was the base ground for "maximum recovery efficiency" programs widespread in actions of regulating the extraction of oil in the U.S., where production is recommended to be set at minimum average cost in the long term. As will be demonstrated below, this statement is valid only in the special case where the profit rate is zero.

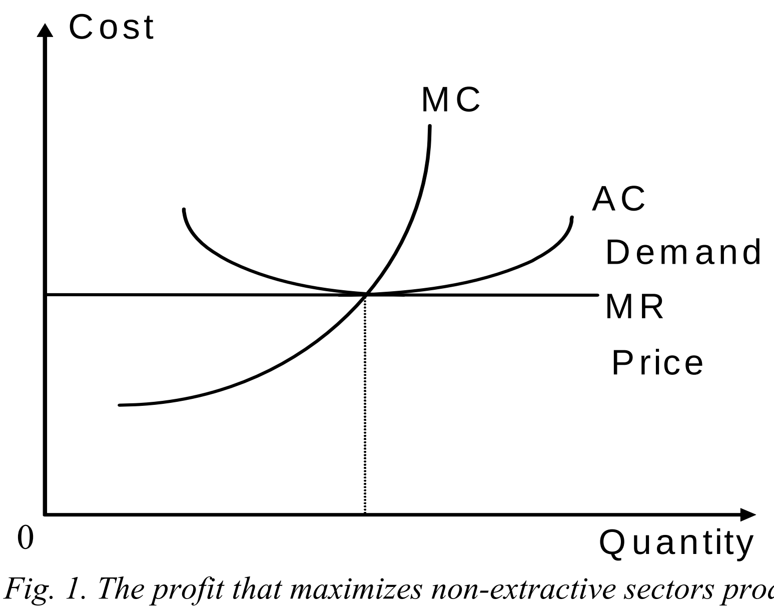

Fig. 1. The profit that maximizes non-extractive sectors production under competitive market conditions (MC = marginal cost, AC = average cost, MR = marginal reserve)

On February 3, 1977, two years before the outbreak of the second energy crisis of the '70s, the *Wall Street Journal* front page article said: "The waiting game: natural gas reserves are not operated as producer expects profitable prices”. A few weeks thereafter, U.S. Secretary of Interior had warned the companies that lease federal oil and gas that they must explain the reasons for not producing, if not, being forced to cancel their lease arrangements.

Mining economics claims that revenues that could arise from current extraction should be large enough to cover the marginal cost of extraction and the marginal cost of the user. This leads us to the law known as the "economic fundamental principle" of the mining industry stated by Hotelling. For extraction to be justified, it means that net resource market price (net cost of extraction) should grow in line with market rate of return. This principle can easily be assimilated if we imagine two situations:

- Suppose the market price minus the cost of resource extraction has a value which is lower than the market rate of return. What will be the most appropriate action for the resource owner? If it seeks to maximize profit, ceteris paribus, he will extract and sell its stock as soon as possible, investing profits elsewhere, e.g. in term deposits.
- If we assume that the market price minus the cost of extraction has a value which is higher than the market rate of return, then the best decision of the owner of the resource is that it does not exploit the reserves it held, having better returns in other investment alternatives.

Therefore, a net price which amounts to market profit rate is the equilibrium condition.

Formally, the economic fundamental principle can be obtained from a number of simplifying assumptions:

- resource owner has a fixed stock of non-renewable resources, say oil, and wants to deplete its reserves at a rate that renders maximum profit, i.e. the owner wants to maximize the present value of its income resulting from the extraction in time of its reserves;
- resource quality (here, oil) is uniform at all points of extraction;
- extraction cost is constant.

In these circumstances, the profit function to be maximized is of the form:

$$\pi = P(o)Q(o) - C + \left[P(1)Q(1) - C)\right](1+\gamma)^{-1} + \left[P(2)Q(2) - C\right](1+\gamma)^{-2} + \ldots + \left[P(T)Q(T) - C\right](1+\gamma)^{-T} \quad (1)$$

under a stock constraint:

$$Q(o) + Q(1) + \ldots + Q(T) = \bar{Q} \quad (2)$$

or as a restricted form:

$$\max \sum_{t=0}^{T} \pi (1+\gamma)^{-T} = \sum_{t=0}^{T} \underbrace{\left[P(t)Q(t) - C \bullet Q(t)\right]}_{profit} \underbrace{(1+\gamma)^{-t}}_{\substack{discount \\ factor}} \quad (3)$$

under a stock constraint:

$$\sum_{t=0}^{T} Q(t) = \bar{Q} \quad (4)$$

where:

π = discounted profit function;
P (t) = resource price at time t;
C = cost of extraction, is constant;
Q (t) = amount extracted at time t;
t = time in years;
T = number of years of reserve service, for example, horizon provided or the depletion of the reserve period;
γ = rate of return;
$\bar{Q}$ - total stock (total reserve).

By using Lagrange multiplier method, the growth function becomes:

$$L = \sum_{t=0}^{T} \left[P(t)Q(t) - CQ(t)\right](1+\gamma)^{-t} + \lambda \left[\bar{Q} - \sum_{t=0}^{T} Q(t)\right] \quad (5)$$

Differentiating compared with Q (t) being zero, we obtain:

$$\frac{\delta L}{\delta Q(t)} = \left[P(t) - C\right](1+\gamma)^{-t} - \lambda = 0 \tag{6}$$

which means:

$$\left[P(t) - C\right](1+\gamma)^{-t} = \lambda$$

or: (7)

$$P(t) - C = \lambda(1+\gamma)^{t}$$

The left side represents the net price of the reserve (net cost of extraction), and the right side is the resource rent. Equation (7) shows that price minus extraction cost increases linearly with the market rate of return, a truth we were seeking to demonstrate for the mining industry case.

Relationship between the level of extraction and price trend resulted in time

Now, suppose that the entire mining industry faces a linear demand curve downward (see fig. 2). Obviously, with higher production of that industry, the production will lower the price at any time. One must underline some aspects of it.

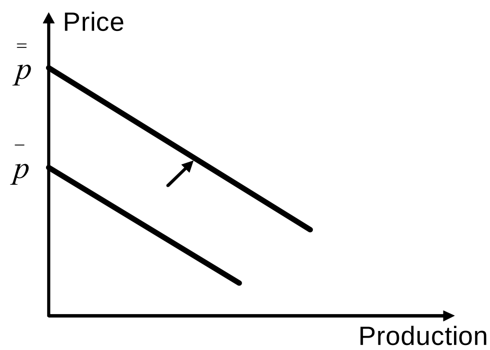

Fig. 2. Demand for mining production and the cancellation price

First, the industry must reduce the amount extracted in each moment of time to secure to obtain higher prices implied by equation (6), i.e. the net price should increase over time in linear relationship with rate of return. This happens only when the extraction level decreases. Therefore, extracting the following year must be less than the production of this year to ensure that the price will rise sufficiently to satisfy equation (6).

Secondly, with this curve type there is a price level at which nobody wants to buy production. Called the cancellation price, this means that demand for these products is zero while reaching its level.

Thirdly, if there are other reserves remaining in the ground when its price reaches its critical level, in terms of mining, they represent losses as it sells at that price or below it. Obviously, these reserves can be stored at a reduced price, where the industry will get losses.

In light of these facts, resource owners want to make sure that the reserves they own will have full-time depletion before the cancellation price is reached, for which they will adopt a plan to decrease production levels at each time point, which in time will ensure a certain tendency in price. For this, the forecasting and production level need to be established simultaneously, situation presented in fig. 3.

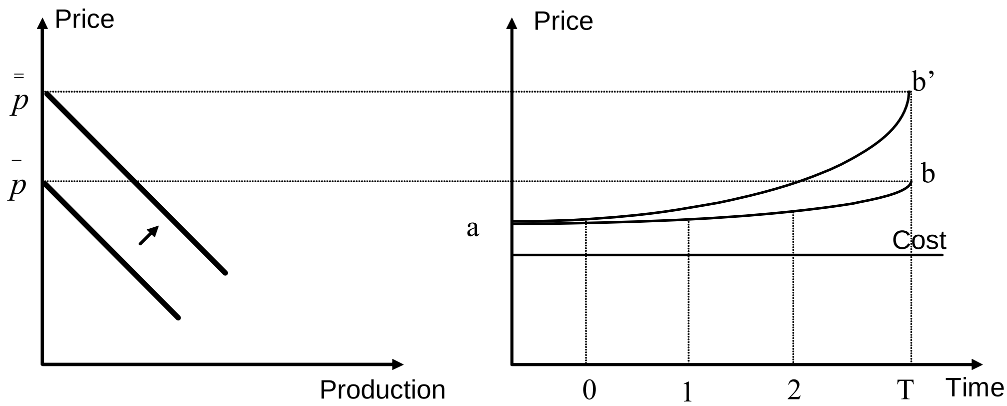

Fig. 3. Production-price trend in mining industry

Cancellation price on the left becomes ceiling for the right diagram, i.e. the price will reduce demand to zero. Therefore, the reserve will be exhausted even before it reaches this point. Justification for this claim is that when the price becomes prohibited, buyers will turn to a resource-alternative, which is a substitute.

The cost of extraction, which is constantly, is illustrated by the horizontal line "c"; "ab" is the price trend obtained by reducing production at every time point. The difference between the price line (ab) and cost (c) is the resource rent that is growing at a rate equal to market profit in a perfectly competitive economy. If the demand curve slides left to right, then right ceiling is above, allowing resource owners to obtain a higher rent in time.

We emphasize that at a given value "ca", which is the original rent, it can be a similar pattern "ab" through a process with errors. If this trend reaches the cancellation price earlier than depleting reserves, then the objective is to have higher prices at each time point and the owners will get higher royalties. On the other hand, if some owners will still have grounded stocks while cancellation price is reached, then they will be forced to reduce royalties. In this way, a trend more or less consistent with "ab" is proving to be an iterative process.

Dynamic pricing efficiency of non-renewable resources

How high can the price be set at a non-renewable resource to ensure that our future demands will be met? Although a difficult question, we can isolate some of the problems by considering the following example.

Suppose we have a limited amount of metal that will be completely replaced within two years by a cheaper substitute of plastic of the same quality. In this case, the objective is to fully use the metal in the next two years in the most efficient manner (as cheaper plastics will become available when it is no longer necessary to store any quantity of metal after that date). How should we set the price in the following year so as to accomplish the objective? The answer is shown in fig. 4.

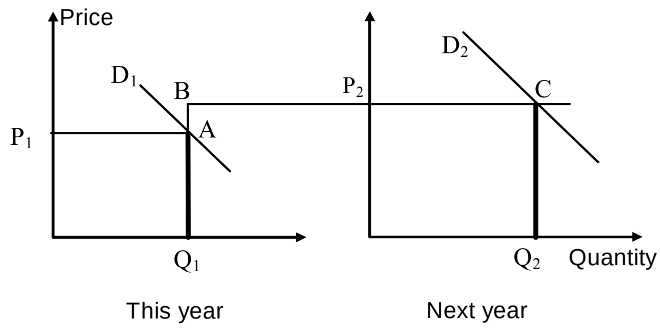

Fig. 4. Rule of effective pricing of a non-renewable resource for two years

The rule of effective pricing requires that interval AB between prices in the two years to equal the rate of profit. Efficiency also requires that the amount of resources used (Q_1+Q2) is equal to the total available quantity. Worth noting that there is no reason for D_1 and D_2 to be the same; in fact, they are almost different in situation shown fig. 5.

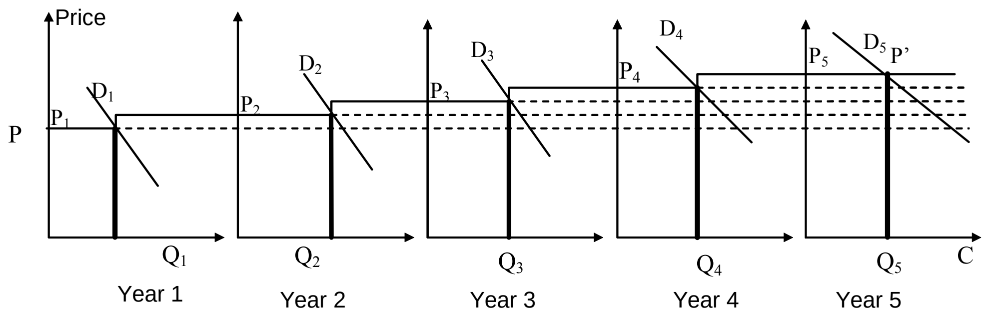

Fig. 5. Rule of effective pricing of a non-renewable resource for five years

Situation shown in fig. 5 extends the analysis presented in fig. 4. Determination of rule of effective pricing and resource utilization in time can be viewed while fitting a "price level" PP' to demand curves with the restriction that $Q_1 + Q_2 + Q_3 + ...$ to equal the amount (C) of the total available resource. As before, the scale height of each step is the rate of return.

Let choose prices P1 and P2 in the two years so that the following conditions are met:

1. The quantities used in the two years to accumulate exactly as Q = total quantity available. That is:

$$Q_1 + Q_2 = Q$$

2. Price P_2 must be greater than $P_{1,}$ by an interval AB equal to the rate of return. So if the profit rate is 5%, P2 should be 5% higher than P1.

Why this rule results in a price efficient allocation of the resources in time? Why, in particular, should the prices be lower this year and bigger next year? The answer is that there is an advantage to have assets or productive resources this year than next year. If we have productive resources this year, we can harness the capital and will allow us to produce more next year.

For example, we have the option (1) to use 100 tons of steel to produce cars, refrigerators and other consumer goods this year, or option (2) to use 100 tons of steel to produce machine tools and equipment that allow us to have 105 tons in the year. We can now choose between 100 tons and 105 tons next year. The profit rate is a measure of quantity (size) of additional assets that we have by waiting. In other words, is a measure of the advantage of having assets currently (now) than in the future.

The most effective rule of pricing will reflect this advantage of the products now compared to future products. In the particular case shown in fig. 4, where the demand curves are the same this year and next year, is more efficient to use more this year (Q_1) then the following year (Q_2). In the general case, where demand curves do not vary from one year to another, the price should increase with the size of the profit rate in order to have an efficient allocation of resources over time.

To fix the message shown in fig. 4, a fixed quantity of this resource is efficiently allocated if we use Q_1 this year and Q_2 next year. This is the situation that occurs in competitive market economy where prices P_1 and P_2 are those of the two years. We will not pretend that this is the right price rule that should prevail; it might not be so.

For example, if the supply of this resource is controlled by a small number of producers, they can, like any other oligopolists, to use their market power to set prices above P1 and P2. In fact, using higher prices, some of these resources will be exhausted by the end of year 2, when they will be replaced by substitutes. However, oligopolists can still have maximized profits due to increased prices of the quantity that they really sell now.

The analysis shown in fig. 4 assumed that the resource will be completely substituted in two years, while the analysis shown in fig. 5 extends as if the resource is replaced in a longer period.

The situation presented in fig. 5 assumed that the resource is replaced by a substitute after four years. That does not mean that a substitution eliminates all demand in the coming years. In fact, there is still a demand for metal in year five, namely D_5. However, this demand is under the price of P_5 as the cheap substitute stopped the demand for this metal.

Of course, another reason for the demand to be stopped may be that the public feels no taste for this resource; so the use of these resources could be stopped for this reason too. An example is coal. Domestic ovens were converted from coal, about 50 years ago, not only because was developing its replacement by gas and oil, but because people no longer wanted to burn coal.

Conclusions

In conclusion, we have here three serious but unpredictable influences that may affect the rule of effective pricing in mining industry:

1. If the existing reserves of a resource appears to be lower than originally estimated, will result a smaller quantity Q to be distributed (shared) in time, and the entire PP' prices "scale" will shift up (as the occurrence of the phenomenon, worth noting how the amount used in each year shall be reduced "in line" with the reducing of total quantity Q). On the other hand, if new deposits are discovered, will be a larger available amount Q and the prices "scale" will shift down.

2. If an unexpected change in demand occurs, PP' prices "scale" will shift again. For example, if future demand will be higher than expected, the price "scale" will shift up.

3. If substitutes are developed faster (or less quickly) than expected, prices "scale" will shift up (or will shift down, respectively). It is very difficult to correctly predict the exact moment for appearance of substitutes.

Therefore, we consider that in practice is very difficult capturing the specific mode to set a rule for effective pricing and allocating of any resource.

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