Models for natural resources management

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Abstract: Natural resources are not homogeneous in nature, having certain features in the productive process that require grouping them into different categories by different criteria. Consequently, natural resources cannot be addressed all at once, but only distinctly, according to relevant criteria selected based on the proposed goals. This criteria selection process requires special mathematical models and features that form the main object of the present paper. Furthermore, the paper also intends to cover the social importance of understanding resources misuse, which is based on the social opportunity cost and the total economic value. These concepts, alongside the types and sources of inefficiency in resource management, will subsequently be analyzed, in order to gain a complete and informed picture, while also understanding the market and government failures in this respect.

Key-words: economic management principles, mathematical models, mining industry, natural resources market, scarcity, property rights regime, social opportunity cost, total economic value.

1 Introduction

Economic analysis of extractive industry is fundamentally different from the analysis of agriculture, manufacturing and services. The main reason is that mineral resources are exhaustible resources; in other words, in the mining industry an initial stock of reserves will exhaust over time. Consequently, if we start from the premise that the owner of a resource, like any other owner, is seeking maximum gain, we must then take into consideration multiple factors specific to the mining industry.

Until now, economic analysis in general, and especially that related to the natural resources market, has been characterized by the concept of natural resource scarcity, much of the methodological concepts being closely related to resources allocation problems at micro and macro-economic level.

Based on these considerations, it should be noted that in the economic literature, the idea of resource reserves depletion has been often accredited to the extent of economic and demographic development. But it must be taken into account that natural resources are not homogeneous in nature. They have features in the productive process, which requires grouping them into different categories by different criteria.

Therefore, because of their diversity, natural resources can not be addressed all at once, but only distinctly, grouping them according to relevant criteria based on the proposed goals. And such special features will be revealed in the first parts of this analysis.

It has also been noticed that, in terms of economic management of natural resources, the social importance of the analysis of resources misuse is facilitated by the study of two related concepts. The first is the social opportunity cost of resource use. This cost represents the optimum level at which resources can be used. The second concept is that of the total economic value. This value looks at the elements that compose the value of the sustainable conservation process of natural resources. The analysis of both concepts is also extended at the end of this paper.

2 Natural resources market

Research in the area of natural resource market involves a comprehensive analysis according to several criteria: requirements of economic growth, future potential of environmental factors (as mentioned above), scientific and technological progress and demographic change; these factors affect both demand and supply rate, as well as substitution rates, specific consumption rate reduction, etc.

The economic literature contains a comprehensive analysis of most of the aforementioned issues, which is why in this paper we shall dwell only on the following matters: limited character and scarcity of natural resources (supply) in relation to the development of demand; mechanisms and economic laws that describe the supply-demand ratio of natural resources determined by economic and social factors.

Until now, economic analysis in general, and especially that related to the natural resources market, has been characterized by the concept of natural resource scarcity, much of the methodological concepts being closely related to resources allocation problems at micro and macro-economic level. In this sense, natural resources (raw materials and energy) are scarce, according to, on one hand, the growing supply-demand ratio on the market, and on the other hand, the manner in which these resources are found in the production process.

Consequently, natural resources appear to be scarce because, as inputs required for production processes, they are not available without limit during the production process. *Taking into account given restrictions on the temporal scarce character of certain resources, the theory of optimum allocation of resources is a combination of production factors in such a way to achieve maximum effect.*

In the dynamics of productive processes, production factors are reproduced in increasingly larger quantities. However, when using natural resources, their scarce nature remains on the market [29], varying in time, due to the different intensity of external factors (technical progress, direct action of man, the economic mechanism). The scarce character of natural resources supply on the market in relation to society needs is gradually fading as economic development and increased contribution of technical progress to economic growth improve opportunities to supply resources [1].

Although the geological map of mineral reserves in the world is quite rich and will continue to enrich through new geological discoveries and technological tuning, the real supply often remains under the reserves potential, not because of their physical exhaustion, but mostly for economic reasons. For example, research development and geological prospecting, extraction and preparation, and haulage of substances to the place of consumption, require huge investments which any country, and especially developing countries, find difficult to sustain. Furthermore, foreign capitals are often reluctant to some projects due to increased investment risk and price fluctuations on global market.

In achieving a balance between market supply and demand of resources, the scarce character of natural resources that is of raw materials and energy should be revealed through their prices: the scarcer these resources are, the higher their price would be [16, 22]. Prices must reflect both the amount of labor and material expenses, and the current and future market situation (supply and demand), the status of natural resources etc.

In building mathematical models of resource allocation optimization, scarce (or abundant) character of resources is outlined by optimal prices. Nevertheless, in reality, a time lag usually appears between the actual consumption of natural resources, the effect in prices and the correlation between solvent supply and demand. Usually, such a match occurs post festum. A solution to this problem is the stock exchange.

In the case of the natural resources market, a rise of prices would lead directly to rationalized consumption (reduction or substitution of specific consumption of resources), to increased production, and especially to the introduction of new technologies for extraction and preparation, as a more effective way to reduce production costs and achieve greater profits.

Since the economic mechanism is based on maximizing immediate profits, spontaneous action of demand and supply on natural resource market, as well as of the technical progress, is not designed to guide national economies to protect natural resources to avoid their rapid exhaustion or depletion. On the contrary, this very non-consumer mechanism encourages overuse of natural resources, hence their irrational exploitation [16].

Therefore, comparative studies of national economies profile with different degrees of endowment in natural resources reveal the correlation between the relative endowment of production factors and the traditional economic structure, in particular the manufacturing industry.

At the same time, there are opinions that trade with raw materials would depend on differences in factor endowment. As such, testing the Heckscher-Ohlin theorem would be unnecessary for the producer of resources [18]. Of course, the reasoning is not correct, since, on one hand, economic activity in this sector calls for capital and labor in different proportions to produce different quantities of products, and on the other hand, rational economy is a solid system, with influence and direct and indirect links between branches.

A thorough analysis of the relationship between export and import of resources in their natural status, and resources incorporated into final products, can be made only by taking into account all branches in one economy. In terms of computer technology, it is the extension of applying Leontief's method to the new production factors: energy and raw material resources [18]. This provides an extension of the Heckscher-Ohlin theory testing [35].

For example, according to some economists, in Romania, in relation to other countries, the highest deficit level is recorded for energy resources, followed by human capital and some mineral raw material resources [21]. For physical capital and normal labor, the situation is generally more relaxed. Taking into account this situation and according to the extended Heckscher-Ohlin theorem, the existence of the following comparative position of the factors (the ratio of total export factors and import factors) would appear to be normal:

$$\frac{L^e}{L^m} > \frac{K^e}{K^m} > \frac{R^e}{R^m} > \frac{K_h^e}{K_h^m} > \frac{E^e}{E^m} \qquad (1)$$

where: L = normal labor;
K = physical capital;
R = raw material resources;
K_h = human capital;
E = energy resources;
e = index for export;
m = index for import.

For mining units, the most important supply market is the deposit bearing mineral reserves, not only those exploitable, but also those identified and possible to use in conditions of effective existing technology at a certain time. Deposits identified without knowing the possibilities of economic recovery are only "a stock of future opportunities", but may be considered as a supply source since a method through which they could be exploited effectively is not known yet.

Mining units participate as bidders in several markets, but only to a limited extent do they meet on these markets the latest mining products consumer, the contact taking place with other industries which, in turn, modify and process the mining industry products (crude or prepared). These units operate on the market as "intermediaries" between the mining industry and end users.

Moreover, mining units transfer their special products through specialized units to ensure haulage of mining products to intermediaries. From this point of view, mining activity takes place under certain conditions:

- any commodity price increase to end user is not caused only by the sales price of the mining product, but also by the price of all activities taking place upstream of the final consumer;
- in order to maintain price stability to the final consumer, any of the intermediaries can supply local or imported mining products or substitute products;
- any change or renewal in transformation technology (processing) that applies to any of the intermediaries influence parameters to which mining units are able to extract their products (price, quantity, quality); conversely, any technological innovation in the mining units leads to price changes of the mining products and affect the chain of intermediaries to the final consumer.

Thus, achieving availability of raw materials or mining products should be considered as part or parts of a complex scheme with several interrelated steps. In these circumstances, valuing mining products with superior efficiency, enhanced in order to meet the final consumer needs, involves understanding that all parts of this flow represent a whole.

3 Exploitation of natural resources and factors affecting the reserve depletion level

There are many factors that affect the price-production trend in the mining industry, the most important being: fluctuations in profit rates; fluctuations in extraction cost; taxes introduced by the Government. Some, such as taxation and the profit, can be treated as variable pricing policy introduced by the government to influence the extraction of non-renewable mineral resources.

3.1 Changes in profit rate

Profit level fluctuations may have strong effects on the price-production trend in the mining industry. To start, let us suppose that the profit market rate increases. This means that the revenue rate obtained from an alternative investment project, say term cash deposits, increases. If owners do not undertake any changes of the originally conceived plan, the reserves stock will lead to achieving sub-optimal rates of income over time.

The way to avoid these losses is to move production today. This means that the owners will extract and sell more now, which will lead to a lower price asked on the market. Therefore, the less is extracted, the higher the net price of the remaining reserves could rise. This means that reserves would be exhausted in less time than it would take the profits to increase.

Figure 1 illustrates this situation. The curve “ab” is the price-production trend before increasing the profit rate. Immediately after the increase, owners should make an adjustment by increasing production, and then prices start to fall at moment t(0) to the “a” level. For the remaining time left the owners will extract less so that the annuity/rent of the reserves left would grow at a higher rate. This will shorten depletion time from “T” to “T '”. The new price-production trend "a'b” will be steeper than the previous one "ab".

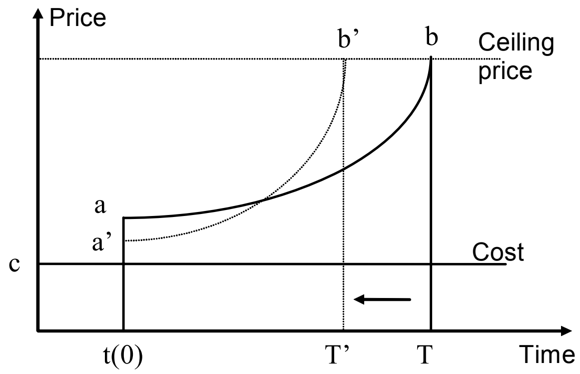

Fig. 1 Effect of profit rate growth on production and price trend, and on deposits depletion time

If the profit rate falls, the opposite phenomenon will occur. Original price will increase as owners push their production into the future by reducing current extraction.

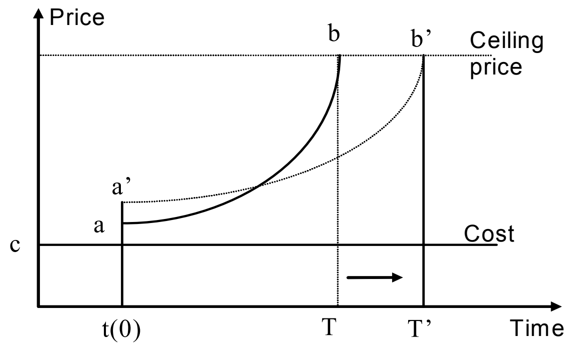

Fig. 2 Effect of profit rate falling on production and price trend, and on deposits depletion time

This is because lowering profit rates makes stocks return more attractive than current production. This is obvious also in that a lower profit rate would show a lower growth trend than in the previous case. This means that depletion time increases, as shown in fig. 2.

3.2 Fluctuations in extraction cost

To begin, let us assume that extraction cost increases. This can happen for a variety of reasons such as lack of skilled labor, wage growth in the mining industry and basic resources decline as owners start extraction from fields with difficult access.

An increase in mining costs will reduce the current production level and therefore will increase the starting price, but will reduce future prices. This situation, in turn, will reduce the demand in the near future while increasing the future demand. The net effect will be the increased depletion time. The situation is shown in fig. 3. As the cost of extraction increases, the rent will be reduced. In response, resource owners will reduce the current production and will increase, at moment t(0), the initial price “a” to the new price “a'”, so that the new price-production trend will be "a'b'”.

Conversely, a decrease in the extraction cost will have the opposite effect, by increasing the initial value of the rent. If no adjustment is made, it could lead to a situation in which the cancellation price would be reached faster than desired, leaving owners with unsold stocks.

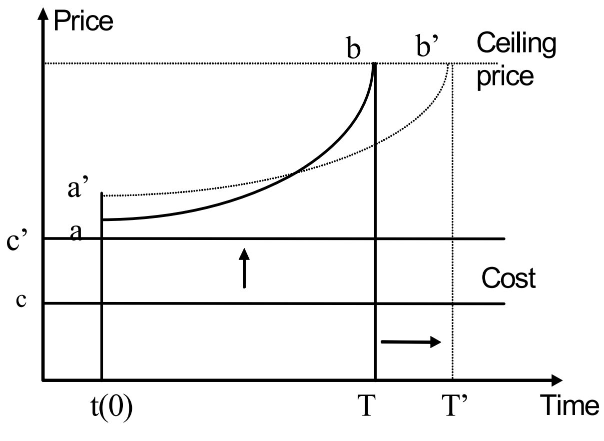

Fig. 3 Effect of extraction cost on production and price trend, and on deposits depletion time

To avoid such a situation, the owners should lower the starting price. The gain will be that when extraction costs fall, the immediate production level increase, which in turn will reduce the initial price and depletion time (as seen in fig. 4).

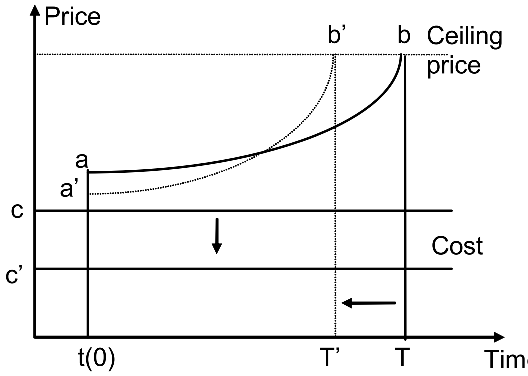

Fig. 4 Effect of extraction cost lowering on production and price trend, and on deposits depletion time

3.3 The charging system

The charging system may have strong effects on the policies used in the mining industry. In this respect we can mention several charges:

3.3.1. Excises

Taxing the value of mining production will increase costs, which will have an effect similar to that shown in fig. 3. For a mine owner, a tax on income is a cost that will reduce the current extraction and enhance deposits depletion time. Moreover, this type of charge will cause mining companies to postpone extraction so as to delay (or suspend) payment of taxes. Therefore, they prefer to keep reserves in deposits, where there are no taxes to be paid.

3.3.2. Ad-valorem tax

This is a fixed tax on the price of each unit of production, usually a certain percentage of the value of extracted production. The effect of this tax is to reduce the deposits depletion rate and increase their depletion time. Therefore, there is a difference between the effects of ad-valorem tax and excise tax, in that the depletion rate reduction is lower in the first taxing case.

Let us suppose that the owners are proposing to postpone payment of taxes by lowering the rates of extraction. Where ad-valorem tax is chargeable, it will be observed that as sales prices are higher, taxes paid on these sales will therefore be higher. Hence, in the case of ad-valorem tax, the depletion rate reduction is not preferable to the one from excises.

The difference between specific and ad-valorem taxes can significantly influence decisions in the mining industry. If the government feels that the country's natural resource reserves are depleting too quickly, then a strong measure as excise tax may appear appropriate for a moderated depleting reduction of deposits. An action with a lower impact is the use of ad-valorem tax, as an opposite alternative to taxing through excises. This is the main reason for which conservatives prefer excise tax in the mining industry.

3.3.3. Property Tax

This kind of tax will reduce the depletion time of deposits. From equation (2) inherently results that the stocks value on the capital market is the present value of future net profits to be obtained by the extraction and sale of these stocks. This equilibrium value will increase in time at the level of profit market rate, thus providing incentives to owners to keep them.

$$\frac{\delta L}{\delta Q(t)} = [P(t) - C](1+\gamma)^{-t} - \lambda = 0 \qquad (2)$$

where: L = Lagrange multiplier;
Q (t) = amount extracted at time t;
P (t) = resource price at time t;
C = cost of extraction, is constant;
t = time in years;
r = rate of return;
λ = absolute mining rent, is constant.

Ceteris paribus, an annual tax on the value of the resources will strongly reduce this incentive because the longer the deposit is kept intact, the greater the taxes to be paid on it. One way to avoid paying this tax on all future periods would be extracting as quickly as possible and investing money in areas where there is no charge similar to this.

Other economic considerations. A model for testing the basic economic principle applied to the mining industry

Operating with the basic economic principle is restricted by numerous real world constraints. For example, fluctuations in profit market rates; if these increase, ceteris paribus, the extraction will increase, and conversely, if rates fall, then there will be a slowdown in the mining extraction rhythm. It is well known that the profit market rate may increase or decrease quite rapidly in a short time. In this case, do we expect an automatic adjustment of the output whenever the profit rate changes?

It seems quite unrealistic to expect that resource owners will have an automatic response to profit rate changes. Let us consider that the profit market rate increases sufficiently enough to constrain owners to increase the extraction so that the accrued money would be invested in deposits with high interest. In general, an increase of income production in mining, petroleum and natural gas extractive industries requires an expansion of production capacity, which requires time. Moreover, the period with high profit rates may not be so long, leading resource owners to think twice before engaging in the costly action of extending the production capacity.

A similar problem may occur in connection with the tax system. In many countries, national level fiscal policies change with the change in government leadership. Therefore, resource owners cannot be certain of the sustainability of a particular fiscal policy. If production capacity and production levels in the extractive industries are based strictly on current tax law, when this suddenly changes, resource owners may remain with excess capacity or inadequate structures with which to operate in an optimal way.

Another important factor is the technological change related to natural resources. A change in technology can reduce dependency and hence the demand for a particular resource. For example, let us compare solar energy with fossil fuels energy. A rapid technological development in capturing and storing solar energy can result in substantial demand decrease for fossil fuels.

This type of uncertainty is always in the attention of resource owners when they set the depletion plan for their deposits. Alongside the fundamental economic principle, resource owners are also guided by the rule which says: "Sell reserve stocks at the moment when the demand exists for them." When depletion time (“T” in our analysis) is high, it is necessary to develop a technological breakthrough.

Last but not least, an important issue is the time factor – that is, impatience - which can exert a strong influence on depletion time for natural resources deposits. For various reasons, a resource owner can be strongly determined to have money in cash, which may be obtained either by selling their property rights over resources, or by speeding up the extraction regardless the fundamental economic principle rules. When fields are owned by the state, selling property rights may not be politically possible in most cases, and the government remains with only one alternative: fast depletion to obtain immediate cash resources. This happens quite often nowadays.

The mining economic literature shows that prices of natural resources as raw materials for the manufacturing industry have been declining for a long period of time [1, 2, 32, 41]. There were some exceptions, such as timber which presented an upward trend, or the oil price that has rapidly increased during 1973-1982, although after 1982 and until 1988 was in decline.

On the other hand, the economic fundamental principle shows very clearly that, ceteris paribus, the price of mined ore and fossil fuel should increase linearly with the market rate of return. This raises the question whether or not a contradiction between the economic theory of natural resources and the situation observed in the real world is manifested.

Once again we emphasize that in Hotelling model [19] we considered the net increase of reserves of fossil fuels and mining products in time - that is, the market price less extraction costs - all expressed in real terms. However, it is known that, with the exception of short time periods, the real rate of return has been positive in many countries over time. In this case, there was a sustained reduction in extraction costs that can explain the current trend of prices within the meaning of Hotelling's rule. This has been tested by Slade [39] who tried to reconcile the theoretical predictions of actual price increases in natural resources and raw materials for manufacturing industry with the above-mentioned empirical findings of lowering prices.

Slade's model assumes exogenous technological improvements and endogenous changes in state deposits, parameters that are used to predict price trends for all metal mining products and fossil fuels in the U.S. If equation (2) is slightly amended in that it allows the extraction cost to change in time, then:

$$P(t) = C(t) + \lambda(1+r)^t \qquad (3)$$

Slade allowed a reduction in price stating that, although $\lambda(1+r)^t$, which is the resource rent, is normally growing, if technological progressions are substantial, then C(t) that is the extraction cost may decrease substantially and may induce a trend in resource price decline. In the early stages of research, a decline in cost may offset the increase in rent, but later its intensity decreases the likelihood to obtain a U-shaped price trend.

However, Slade notes that his model is simple and naive, because it neglects the important issues facing mining industry as environmental regulations, tax policy, price controls and market structure; models related to the latest issues will be further discussed in the paper.

4 Models for market structure

It has often been discussed the fact that market imperfections, especially in the case of extreme monopoly, are "the best friends of conservatism", says Hotelling [19]. It should be emphasized that monopoly can exist in the mining industry as well as in the manufacturing industry, affecting depletion rates and thus the cost/price of fossil fuels and mining products.

In this sense, we need to understand in what ways a monopolistic behavior may differ from a perfectly competitive behavior in the mining industry. It should be once more underlined that the objective of any business is the extraction of resources in a manner which maximizes the present value of profits over time. When this happens, the market rate of return will be one of the determining factors of both monopolistic and perfectly competitive firms. This is inherent in the economic fundamental principle.

To begin, let us consider that a monopolist owner is the sole owner of a set stock that can be extracted at zero cost. The market demand curve which the owner must satisfy remains stationary in time.

The owner then needs to find an extraction scheme to bring maximum profits discounted over time until all original stock (inventory) is depleted over time.

The marginal income increase from two consecutive moments of time will be:

$$\frac{MR(t+1)-MR(t)}{MR(t)}=r \qquad (4)$$

that is the percentage change in marginal revenue equals the time rate of profit, “r”, or:

$$MR(t)(1+r)=MR(t+1) \qquad (5)$$

meaning that at any point in time the monopolist owner’s marginal revenue amounts to the market rate of return.

Figure 5 represents the situation in which production at any point in time meets the conditions in equation (5). In figure 5(a), an output level at time t, “Q_t”, corresponds to the price level, “P_t”.

In the next period, t+1, price, and thus marginal revenue, must increase linearly with the market rate of profit, which may be obtained only by reducing production, namely: $Q_{t+1} < Q_t$

When marginal revenue is discounted to market rate of profit, it remains constant in different time periods. Last unit of extracted production will produce the highest undiscounted marginal income, which corresponds to the price limit “p*”.

As the monopolist owner shifts the marginal revenue curve upwards, the numerous traders that are competing on mining markets will also shift the demand curve upwards at every point in time.

In both market structures, the economic fundamental principle must meet the same profit rate. Since the marginal revenue curve is steeper than the demand curve, that is:

$$slopeMR > slopeD \qquad (6)$$

the monopolist owner will have to make a lower decrease in production than the competing firms, at any one point in time.

Thus, the monopolist owner will use its reserves more slowly than firms performing on the competitive market.

Considering two different price trend on the two markets, because the monopolist owner has a lower initial production their initial price must be higher.

Because marginal revenue is lower than the price (see fig. 6), then the monopolist price trend will be flatter than the competitive price, meaning that the price is growing more slowly.

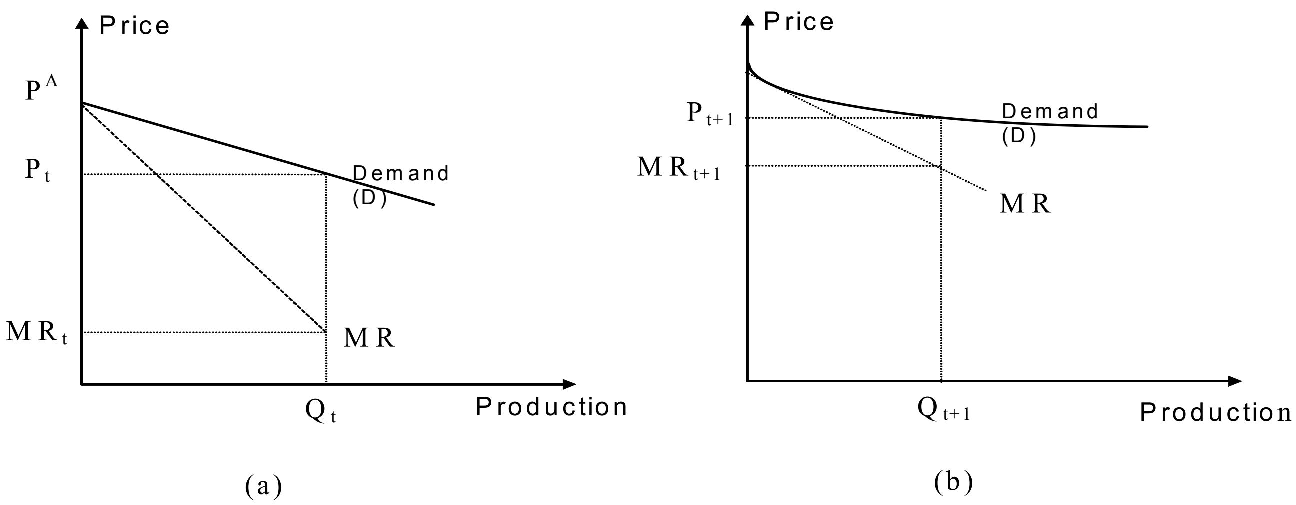

Fig. 5 Stock depletion in monopolistic situation, with (a) time = t and (b) time = t+1

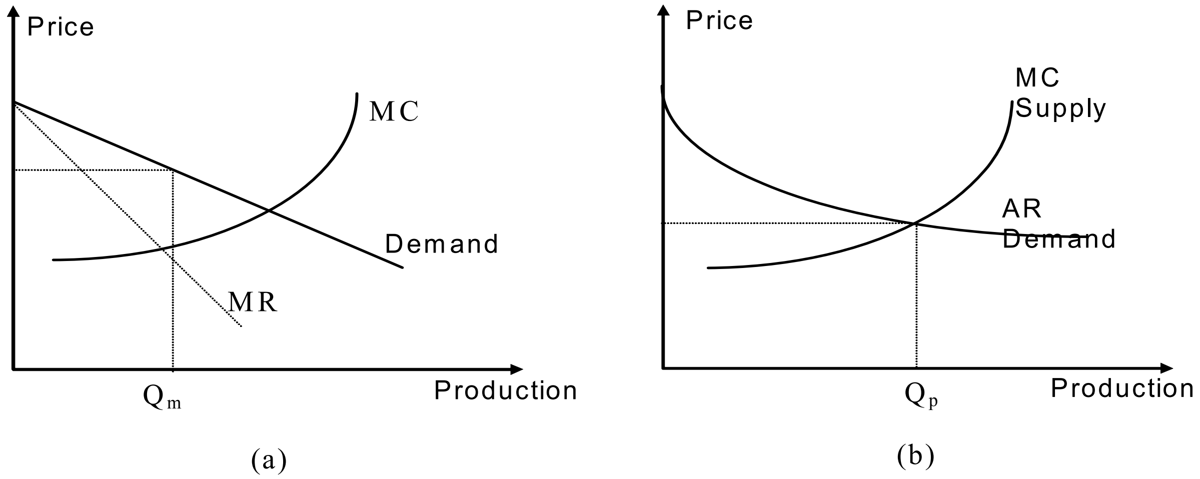

Fig. 6 Price and production levels in manufacturing industry, with (a) monopoly and (b) perfect competition

This situation is shown in figure 7. In the monopolistic situation, the initial prices are higher, but their growth rate is lower. Assuming there is no change in demand for natural resources, then, in the monopolistic situation the reserve stocks will last for a longer time period compared to a competitive situation in the extractive industry.

It was stressed that when depletion time (T) is long, then many changes can occur related to natural resource extraction technology and their use, which will affect the demand curve. It can be argued that as long as the competitive market prices are growing fast, this situation will encourage the users of these resources to seek new sources of alternative raw materials.

In a monopolistic situation, however, demand for natural resources and raw materials for the manufacturing industry cannot be avoided as long as their users are accustomed to the slow growth of resource prices and thus will maintain their constant demand. With a constant demand, the ultimate depletion will take place in the competitive market, and if users gradually shift to substitutes, it is possible that part of the stock of reserves to remain in deposits.

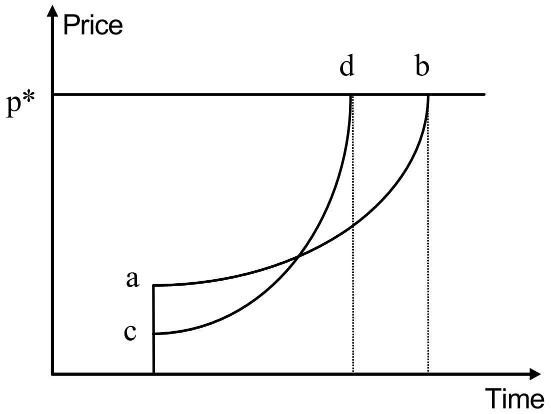

Fig. 7 Price trend in the situation on (ab) monopolistic and (cd) competitive market

In this assertion it is also inherent the fact that monopoly rent, which includes both the resource rent and excess profits, exceeds the resource rent obtained in the competitive market [6].

It is therefore understandable why independent owners of natural resources are willing to form a cartel whereby they believe they can act as a collective monopoly.

Indeed, a cartel is a group of independent owners who are trying, by common understanding, to act as a firm. In a cartel case, each owner agrees to produce less than they would produce under competitive market conditions. The expected effect of the cartel is to increase the market price so that producers can earn excess profits.

Figure 8 shows the production levels both in a competitive market and in the situation of a cartel. To simplify the calculations let us assume that we analyze the case of a zero rate of profit. Figure 8(a) provides competitive price “$0P_p$” and production competition “$0Q_p$” by intersecting supply and demand curves.

A competitive market firm considers the market price as a given and produces at a level where price equals marginal cost, which then becomes the marginal revenue and so the firm will schedule its production at this level. Its market segment covers only part of its total sales.

Let us now consider that in order to achieve excess profits all competing firms would join together to form a cartel.

In this case, their production “0Q” would fall so that market prices are rising to “$0P_c$”. We need to emphasize here that the ability to offer is not diminishing as production level reduces artificially.

Each cartel firm receives such a share so that the reduced rate of production on the market can be maintained.

The individual company depicted in figure 8(b) is told to reduce production to “$0Q_c$”.

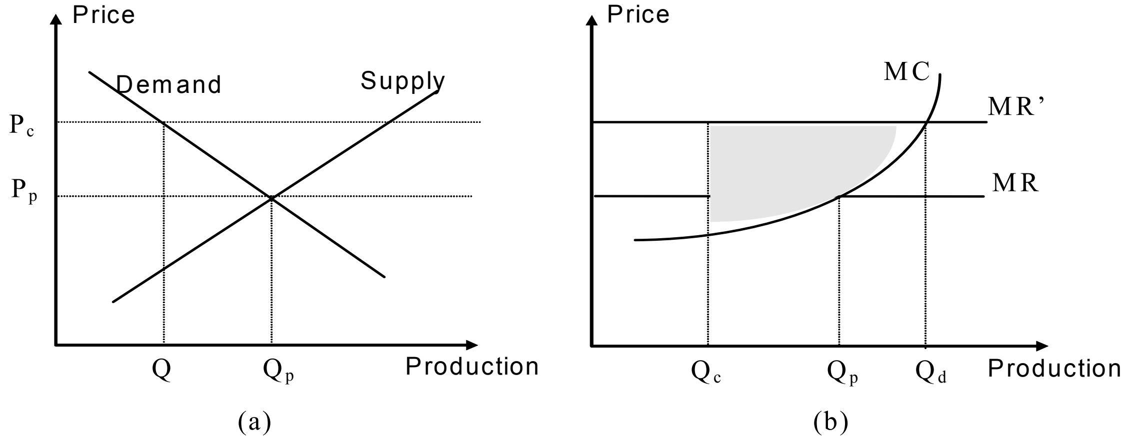

Fig. 8 Incentives "to deceive" in terms of a cartel

In this new situation created there is a great temptation "to deceive". By reducing its price just a little (slightly below the cartel price), the individual company may sell more, "$0Q_d$", at the same expenses as other members. For production "$0Q_d$", the firm's marginal cost equals the new marginal revenue, "MR'", and the shaded area shows over-excess profit that can be achieved "through cheating" the cartel. In fact, all firms are tempted to do likewise. If all are "cheating" the cartel, then the market output will be much higher than pre-cartel level and therefore the price will be much lower. In other words, a cartel may also cause disasters to its members.

To conclude this part of our analysis, we must point out that a cartel may increase prices only by reducing its production. However, at higher prices, members forming a cartel are tempted to produce even more than in the competitive market equilibrium. As the cartel situation has more success, the temptation "to deceive" will grow. To be successful, a cartel requires some measure of group domestic policy to ensure that each member takes care of their share. In natural resources depletion terms, in a cartel case, the amount extracted at any point in time will be lower than in the competitive situation and therefore reserve stocks will remain in their deposits for longer.

And this is both helpful and desirable for a sustainable development in the mining industry.

5 Models for natural resources approach

In order to better define the nature and development of resources in their close connection to the entire system evolution, we reproduce in a Forrester-type graph the dynamic interrelations of the main variables of the productive system in which resources are represent a central component (fig. 9).

This graph highlights productive relationships between system elements, namely the effects of increasing volume of required resources (including the total quantity of pollutants) on production volume.

Based on these considerations, it should be noted that the economic literature has often accredited the idea of resource reserves depletion to the extent of economic and demographic development [13]. But it must be taken into account that natural resources are not homogeneous in nature. They have features in the productive process that require grouping them into different categories by different criteria [24].

Therefore, because of their diversity, natural resources can not be addressed all at once, but only distinctly, grouping them according to relevant criteria based on the proposed goals.

Consequently, in terms of their use duration or of reserves availability, natural resources are classified into: non-renewable or exhaustible (deposits of fossil fuels, metal ores and non-metallic minerals) and renewable (soil, water, air, as these are environmental factors for organic production - plant and animal -, and for economic and social life).

In terms of available exploitable reserves volume, as related to consumer demand, resources can be classified as abundant and poor.

A feature of some resources is that they can be reused or recovered, therefore counteracting their depleting trends. Subsequently, in terms of opportunities for recovery or reuse in production processes and consumption, natural resources can be classified into: recoverable, including a wide range of resource materials; partially recoverable, comprising especially biological resources, which, through successive reuses, gradually degrade; and unrecoverable, representing especially those resources used for energy purposes.

In principle, the general relationships between economic outcomes, on one hand, and natural resources - interpreted as flows and stocks - and other primary resources, on the other hand, may be emphasized more clearly by using mathematical symbols and relations [20].

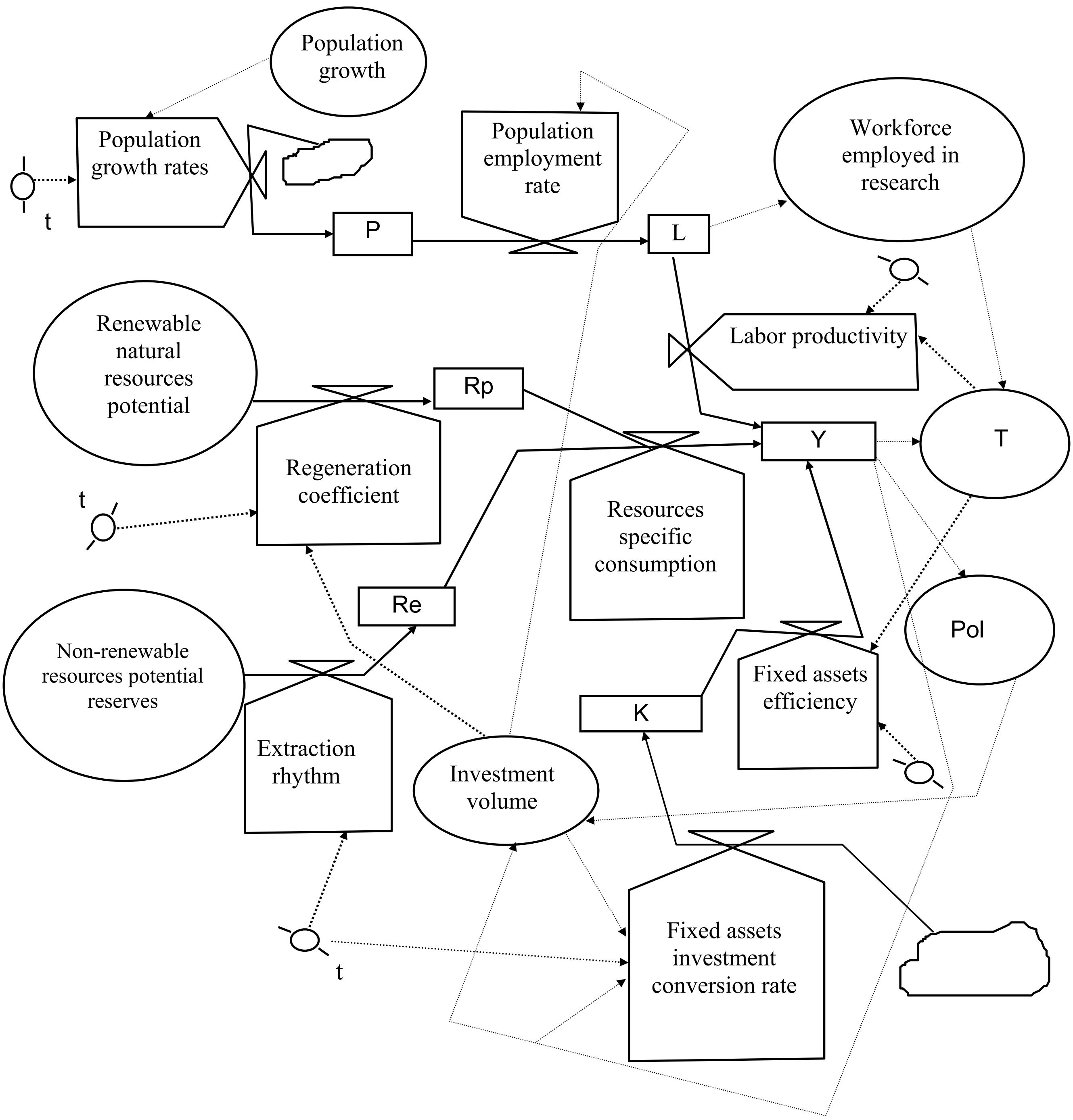

Fig. 9. Dynamic interrelations between the main variables
(Source: FORRESTER, J. (1961), Industrial Dynamics, Pegasus Communications, Waltham, MA.)

Legend:

Y - the final output of goods and services;
P - population;
Rp - renewable natural resources represented by the farming exploitable land (agricultural production and forestry), water and the production yield by their use;
Pol – Pollution, whose intensity depends on the production volume;
L – labour force;
Re - non-renewable or exhaustible natural resources (fuelling minerals and metallic and non-metal minerals, the latter being generally recyclable);
K - fixed capital or fixed funds accumulated, represented by machinery, buildings and special constructions;
T - stock of scientific and technical knowledge and their application in economic practice

Thus, to achieve the final output of goods and services Y(t), the national economy uses, as primary resources, the labor force $L_0(t)$, production funds $K_0(t)$ and natural resources $R_0(t)$:

$$Y(t) = f\left[L_o(t), K_o(t), R_o(t), t\right] \quad (7)$$

Natural resources $R_0(t)$, represented by the flow of raw materials and primary energy used in production, are achieved, in turn, from the stock of material resources, as a result of mining, forestry and agricultural use of water richness etc., which require labor resources and capital assets to be allocated. Taking into account the so-called existing stock of natural resources in the period t, noted by S(t), labor $L_1(t)$ and fixed capital $K_1(t)$ available in period t, production of raw materials and energy $R_0(t)$ is represented by the relation:

$$R_o(t) = f\left[L_1(t), K_1(t), S(t), t\right] \quad (8)$$

The more resources are extracted from the reserve stocks, the more difficult and expensive it becomes to recover the resources from nature. Therefore, the stock S is an upper limit which can be reached in terms of given technological and economic conditions. But even the stock has a dynamic character, as it may be over time through different methods depending on the resource nature. In the case of non-renewable resources prospecting and geological research can help to increase the identified and known reserves category. In the case of renewable resources, stocks can be improved through natural processes (rain, wind, solar radiation), works to improve and protect soil and forests, such as planting of forest, and researches to create technologies necessary to highlight the stocks' natural potential.

Increasing stock of natural resources noted by G(t), as a result of human activity, requires an appropriate amount of labor noted by $L_2(t)$ and capital or fixed capital noted by $K_2(t)$:

$$G(t) = f\left[L_2(t), K_2(t), S(t), t\right] \quad (9)$$

Considering the initial stock of resources noted by S_0, the exploitable stock increased due to geological research and soil improvement G(t), as well as the raw materials and energy production flow R(t), which leads to resource stock decreases, the resource stock state at the end of period t can be expressed using the relationship:

$$S(t) = S_0 + \int_0^t \left[G(\tau) - R(\tau) d\tau\right] \quad (10)$$

or in terms of a discrete time model:

$$S(t) = S(t-1) + G(t) - R(t) \quad (11)$$

This simplified model illustrates the links between variables and how labor resources and fixed capital should be allocated for the production of raw materials and primary energy, for geological work and soil improvements required to raise the resources stock to an optimum level.

This level should allow the maintaining of raw materials and energy flow amounts required to achieve production growth of final goods and services.

To encourage the promotion of renewable and/or recyclable resource consumption and the diminished consumption of non-renewable resources, E. Dolan [8] suggested the use of a tool for calculation and analysis of the development expenditure of resources, which he called gross national cost (CNB) which is subdivided into two categories: Type I, which is the CNB fraction produced from renewable and recoverable resources; and Type II, which is the CNB fraction produced from exhaustible resources.

In terms of economic management and conservation of natural resources, the problem is to maximize Type I CNB fraction (produced from renewable and recoverable resources) and to minimize Type II CNB fraction (obtained with exhaustible and non-exhaustible resources).

6 Two organizational principles for economic management of natural resources

In terms of economic management of natural resources, the social importance of analysis of resources misuse is facilitated by the study of two related concepts.

The first is the social opportunity cost (SOC) of resource use. This cost represents the optimum level at which resources can be used.

The optimum level of utilization (the optimum utilization price) is the point where resource use benefit minus the cost of social opportunity is maximized.

The second concept is that of the total economic value (TEV). This value looks at the elements that compose the value of the sustainable conservation process of natural resources.

This concept includes the commercial or recreational use of resources, their value for future consumers and their value in a sustainable state for people who simply use the resource for their own existence.

The analysis of both concepts is extended in the subsequent part of this paper.

6.1 The Social Opportunity Cost (SOC) of resource use

The special feature of the social cost of resource use is that it covers all costs of natural resource use. These costs will tend to include three components:

1) Direct cost of extraction, harvest or use.

2) Any costs which current use of resources impose on their future uses, the so-called "user cost". For a tolerable administration of renewable resources, such user costs are not usually significant as long as resources are regenerated (hence they are known as "stock effects").

However, if a resource is used irrationally (unbearable) the user cost will occur when the resource cannot be quickly regenerated in the future.

For mixed renewable-exhaustible resources, user costs can certainly occur, as well as soils that are severely depleted. For lands that are non-renewable and are depleted under "their minimum safety standard" user cost always occur. For any future year, user cost is the difference between costs that are currently made by users and the costs that the users would otherwise do if the resource was not used now. Total user cost is therefore the sum of these differences in discounted costs over time.

3) Any external costs associated with use; for example, any adverse effects on soil and water quality, etc., occasioned by the removal of protected forests, special use of water etc., effects that are not "internalized."

External costs will arise whether the resource is used bearably (rationally) or not, but will be especially significant if the resource is used in an irrational manner. Essentially, the irrational (unbearable) use means that the stock of that resource is diminishing, and it allows an increase in external costs.

SOC concept can therefore be summarized as follows:

$$SOC = Harvesting\ Cost\,(Ch) + UserCost\,(Cu) + \\ + ExternalCo\ sts\,(Cs) \qquad (12)$$

In symbolic terms we can rewrite the formula as follows:

$$SOC = Ch + Cu + Cs \qquad (13)$$

The presence and importance of cost components are depicted in the following table (see table 1).

6.2 Total Economic Value (TEV)

A natural resource is worth using. Trees are assessed as raw materials, the soil is evaluated as an agent of plant growth, and water is valued for direct consumption, irrigation or other purposes. We call it the consumer value.

Table 1
The social cost of resource use by its components and their importance

Costs	Resource use	
	Bearable	*Unbearable*
Ch	*	*
Cu	Stock effects	* *
Cs	* *	* * *

Source: Authors own evaluation

Additionally, many people will want to retain their ability to have an option for future use of the resource. This option can be maintained only if there is a resource in its natural state. This value is the optional value.

There is a third component of value, the existential value, which appears to people who want to preserve (keep) a resource in a rational way, as they assessed its existence without wanting to consume it (consumption value) or they reserve the choice right of using it (optional value).

These three components make up the total economic value (TEV), a concept that can therefore be summarized as follows:

$$TEV = ConsumerValue(VC) + OptionalValue(VO) + \\ + ExistentialValue(VE) \qquad (14)$$

In symbolic terms we can rewrite the formula as follows:

$$TEV = VC + VO + VE \qquad (15)$$

6.3 The relationship between SOC and TEV

If a renewable resource is rationally used, its SOC of use is determined by harvest costs and any external costs (we ignore the famous "stock effects" for simplification purposes). By definition, an exhaustible resource cannot be rationally used because its stock will decrease over time regardless of the consumption rate.

For any exhaustible resource, the SOC includes three components of cost and its use is irrational. On the other hand, if a renewable resource is used irrationally, the outcome is that the harvest rate will exceed the natural or controlled resource efficiency, i.e. we always have costs Cu and Cs.

We can now identify the first source of inefficiency of resource management. If there is no incentive for taking into consideration user costs (external costs), or they are inadequately considered, there will be a tendency to over-use.

This conclusion must be combined with property rights regime. We distinguish, for example, two statements: income in a free access regime (open access user rates will be inflated compared to an optimal rate of use in open access), or income in a solitary owner scheme. But resource owners within the solitary owner scheme will tend to utilize the resource in a less intensive manner than those within an open access scheme, suggesting that "privatization" is a possible policy measure created to conserve the resource.

Thus, the externalities in question are not those that arise from over-allocated rights to an existing resource, but those that arise from rights of activities that lead to resource use. How much of them can be taken into account by simply defining the rights over a source is difficult to answer, even if we believe that solutions will arise from negotiations amongst users, like Coase proposes [7]. However, as literature up to Coase has proven, this situation is more improbable than not [11].

Furthermore, it is unclear what source rights have to say about values such as "the existential value": are there any representative agencies, say the government, to bid for them? In any case, even the sheer presentation of the situation as a matter of redefining rights surfaces the question regarding equitability in the distribution of rights.

The relevance of TEV concept policy can be seen in context of non-marginal decisions for development or maintenance of wildlife areas, say a place under water. The question is whether or not to drain the land for agricultural uses. Strictly, the decision must be based on a comparison between costs and benefits of drainage. For drainage to be socially necessary, then:

$$[Bd - Cd - Bp] > 0 \quad (16)$$

where: BD = agricultural benefit obtained by draining;

CD = cost of drainage;

Bp = benefit value set for the land under water (we ignored the cost of maintaining the land).

We note immediately that the requirement that drainage is needed is stricter than a purely private decision in terms of cost and benefit to the farmer, that is, just comparing Bd to Cd. Bp is the effect of the external costs of development. As long as it will be ignored in most market conditions, we say that under free market conditions there will be a tendency to over-develop the environmentally valuable land held by private owners.

Now, Bp is measured in this formulation, in fact, by TEV. In short, we rewrite the equation as follows:

$$[Bd - Cd - TEV] > 0 \quad (17)$$

The important predicament here is that TEV may be considerably more comprehensive than the preservation (maintenance) value based on typical rates of recreational use. By ignoring or underrating the optional or existential components of TEV development decisions will be directed to favor over-development of that land.

The same is true for the issue of preservation of specific areas; hence, too little land will be preserved. The analysis can be used for the cases of removal of hedges (natural green curtains); then, Bd would be the agricultural productivity gains claimed by their removal, while TEV would be the loss of both life and aesthetic value.

6.4 Types of inefficiency in resource management

TEV and SOC are related. We noted that if a resource is used rationally, the external cost of resource use is likely to be lower than if the resource were to be used irrationally. If the resource is used irrationally, the stock will decline. As long as the threat exists, in general, over non-commercial uses such as recreation, future use values (optional value) and non-use values (existential value), TEV loss will occur. This means that TEV enters in SOC's formula as "observer" of external cost.

Another source of inefficiency in resource use may occur in the government market intervention. Thus, subsidies may exist, accelerating non-optimal depletion of exhaustible resource or irrational use of renewable resources. At the inefficiency that may occur due to neglecting external environmental costs in a free market, we add these inefficiencies inspired by the government, even if the interaction of the two sources of inefficiency is not always cumulative.

Consequently, the previous section can be synthesized in non-technical terms as follows:

1) External costs and future user costs occur even when a resource is used rationally or irrationally, but they will be much higher in the second case.

2) Different property rights regimes (e.g., private property over common property) can be compared in terms of relative efficiency of use.

3) As long as a renewable resource is used irrationally, its stock will tend to diminish and perhaps it will cause losses occurrence in TEV.

4) Because the market system has a significant potential to neglect the preservation value (TEV of resource preservation) there is a clear preference for preserving ecologically valuable land for development purposes.

5) Government intervention in the market of natural resources often has the effect of increasing

the resources inefficiencies identified on private markets.

6) Redefining property rights clearly provides a more significant potential for minimizing conflicts costs for resource multi-use. Notably, attempts may occur to adopt this solution that requires addressing the objective function towards strictly limited bureaucratic goals. This avoids the extending of the fuzzy phenomenon that appears in the standard neoclassical definition of the objective function, but at the cost of possible significant potential for ignoring value components.

6.5 Assessing inefficiencies

It is therefore important to identify sources of inefficiency and, as far as possible, to see which are the most important. This action requires a methodology for evaluating the degree of inefficiency. As long as *externalities* are concerned, we may follow the *monetary evaluation* process as much as possible.

In the term *"government inefficiency",* the Organization for Economic Co-operation and Development (OECD) studies suggest that water pricing policy often fails to recover development costs and to reflect environmental costs of water supply, which is also true for forestry. This suggests a review of various incentive mechanisms for water and forest management in OECD countries.

6.6 Market and government failure

Despite the distinction made by some authors between market and government failure, it is advisable to use here this situation in organizational purposes only. The exact mode in which a market that has no consideration for externalities, on one hand, and a government that intervenes upon resource use, on the other hand, can simultaneously exist cannot be known with certainty.

This is because resource depletion may be lower in an imperfect market, as with "monopolies", which means that we expect monopolist owners the level to which a resource is extracted or harvested. This situation occurs because monopolist owners can get profits from such activities.

7 Conclusions

Economic literature has often promoted the idea that resource reserves depletion is significantly affected by the extent of economic and demographic development. Economic and population growth lead to increasing consumption of natural resources. Given that natural resources are limited, their stock volume must be known in order to determine the duration of their use until complete exhaustion, for non-renewable resources, or their decrease level of stocks per capita, beyond subsistence level assurance, for renewable resources.

In conclusion, as related to natural resources management, we can in fact distinguish three potential sources of inefficiency in resource use, not all acting in the same direction. These are:

1) *externalities:* neglection of over-failure costs of resource use. This allows us to tend towards *too high* current rates for use of resources.

2) *monopoly:* restrictions on production due to profit. This makes the current rates *too low* for use of resources.

3) *government intervention:* the use of subsidies and tax laws. This leads to *excessive* current rates of resources use only if they occur to correct the type (1) inefficiencies.

With this analysis we have made a perfect analogy to the pollution situation. Here we know, for example, that a pollutant load that takes into account only externalities cannot produce optimal results if significant imperfections exist on the pollutants producing market (Bulearca *et. al.*, 2010/1).

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