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RESOURCES

The Economics of Exhaustible Resources

Report on a Meeting

by Horst Siebert, Mannheim*

Are natural resources getting scarcer? How should the limited reservoir of non-replenishable raw materials such as metals and fossile fuels be utilized by successive generations? What possible solutions are proposed by economics in the face of diminishing reserves of raw materials? These are the questions which occupied German and foreign economists at the meeting of Gesellschaft für Wirtschafts- und Sozialwissenschaften – Verein für Socialpolitik – in Mannheim on September 24-26, 1979. The following report on the crucial issues raised at the meeting is not claimed to cover the full range of the discussion.

In his paper before the plenary session on "The scarcity thesis – Founded assumptions or assumed facts?" Streissler (Vienna) followed up the question which concepts of scarcity can be distinguished and whether there is historic evidence of growing scarcity. "The empirical evidence suggests that the only basic resource scarcity is that of energy and that the encumbrance of the environment arises fundamentally on the one hand from energy generation, e.g. large-area solar mirrors or unforeseeable atomic accidents, and on the other hand from what may be described as by-products of energy, the heating of the atmosphere and the origination of an excess of carbon dioxide".

In regard to scarcity concepts Streissler distinguishes between three kinds of scarcity: Scarcity A is an absolute limitation applying to all members of society, e.g. the temporal limit of human life. This kind of scarcity can be interpreted as a restraint in the form of an inequality, and Streissler's further distinctions in regard to time, natural resources, human labour and divergencies between supply and demand confirm this interpretation. The technical or institutional restraints known from linear programming or non-linear optimization are thus designated here as absolute scarcity. Scarcity R on the other hand is a relative scarcity. "Goods are more or less scarce, and their price is correspondingly higher or lower". Scarcity C is a critical or political scarcity; it may be described as the temporal dimension of Scarcity R. C scarcities are "unexpected volume bottlenecks, unexpected big price jumps". C scarcities may have economic or possibly political causes and present as a rule a challenge to political authorities. Streissler asks whether economics can provide an explanation for these C scarcities. This would presuppose that the processes bringing about C scarcities are made the subject of economic analysis. Insofar as raw material crises occur unexpectedly but frequently, the theory of decision-making under conditions of uncertainty may offer a starting point, but if it does it does so mainly from the point of view of those who are confronted with these crises.

Scarcity Criteria

Which are the criteria indicating scarcity of natural resources? H. K. Schneider (Cologne) dealt with this question. Natural scientists and especially geologists,

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but also the public, stress that scarcity can be measured by the length of time for which resources known today will last at given rates of consumption. This concept does not make allowance for possible adjustment processes and therefore rules itself out as a measurement of economic scarcity. This criterion contains however the – from the point of view of economic policy essential – information to what extent adjustment processes are necessary. Rising costs of extraction, and especially the marginal extraction costs, merely indicate conditions of production but do not take into account how much scarcer the resource will become in the future. This information is contained in the *in-situ* prices of the resource (rate of return, shadow price).

Heal (University of Essex) reaches in an econometric analysis the conclusion that changes in raw material prices can be attributed essentially to the costs of extraction and changes of the interest rate and that this holds good for the period from 1870 onwards. His studies relate to copper, lead, zinc, iron, bauxite, manganese and mineral oil. He used the Barnett-Morse data, brought up to date however. The extraction costs were, for lack of data, measured by the cumulative and actual outputs. Special interest attaches here to the finding that the resource price does not (as the Hotelling rule suggests) vary with the rate of interest but with the change in the rate of interest.

Fair Distribution between Generations

What use is to be made of the common raw material basis of mankind by the present generation, by the next generation and by that following it? How much consideration is to be given to the interests of future generations when this allocative decision is taken? This normative question was discussed in the papers of Heal and Page (California Institute of Technology). The normative problem manifests itself in the rate of discount and also in the basic assumptions for the maximization problem. The utilitarian approach with its well-known implications was contrasted with Rawls' approach. According to the latter the members of society find themselves behind a "veil of ignorance" about their own position in society, and especially also in regard to their generation. It is Rawls' thesis that the principle of fairness is realized when individuals are uncertain of their own position. This fairness or mini-max criterion, posed similarly by Page, may also be circumscribed as the outcome of a negotiating process (social contract) between generations (including unborn ones).

The contemplation of scarcity in the future (or the interests of future generations) requires a shadow price of the natural resource. This shadow price (user costs) is the indicator of the future scarcity and reflects the opportunity costs of present resource utilization, i.e. loss of utility to future generations. It varies with, amongst other criteria, the rate of discount or the ethical assumption basic to the decision.

It is a direct consequence of the inclusion of such user costs that the price of the resource is not determined by the extraction costs (plus profit margin) alone. The notion that the price corresponds to the costs of production as assumed in the static theory does not apply to the dynamic theory. The price of a resource corresponds to the extraction costs (plus profit) and a scarcity indicator. The price of a resource can thus rise purely because the user costs have risen. Applied to everyday discussion this means that price increases may be due, not solely to cartellization tendencies, but to an increase of the user costs.

If intertemporal fairness or consideration for the interest of future generations demands the payment of a user price by the present generation, it has to be asked in the light of the contemporary distribution problems to whom this user price, this special rate of return on the resource, is to accrue. There thus exists an interrelation between intertemporal distribution fairness and static distribution problems. Put differently it may be asked: If we are to conserve resources today in the interest of future generations, who is to bear the opportunity costs of this abstention from present resource utilization?

Hotelling Rule

A number of papers both at the plenary sessions and in the working groups dealt with the theoretical question how the utilization of raw material resources can best be distributed over periods of time and which time path of raw material prices corresponds to this time profile of extracted raw material quantities. This discussion revolves round the Hotelling rule.

In regard to non-replenishable resources the Hotelling rule states that the resource price develops in time in accordance with the rate of discount (rate of interest). This statement follows simply from the assumption that the resource owner has the choice of either selling his resource today and earning interest on the proceeds or leaving the resource in the ground

and selling it in a later period. If the current rate of interest is high and the owner does not expect the price to rise very much, he will sell today. If on the contrary the rate of interest is at present low and the resource owner expects the price to rise considerably, he will leave the resource in the ground[1].

This result can be developed further in a number of directions: If the extraction costs are taken into consideration, the marginal profit rises with the rate of discount. If the resource is a capital asset, the marginal productivity of the capital equals the rate of change of the marginal productivity of the resource (Heal); for the marginal productivity of the capital represents an option on resource utilization: an asset (capital asset) is produced with which more goods can be produced. The alternative option is to postpone the resource utilization to the subsequent period. As the resource input has an impact on the marginal productivity of the resource, this option involves a consideration of the change of the marginal productivity of the resource in the course of time[2]. Finally, in the case of regenerable resources, the effect of existing stocks on the regeneration has to be taken into account. The Hotelling rule follows in all cases from the equality of yields from alternative uses, namely the rates of return to be derived from the resource in nature (in situ) or after extraction.

Importance of Expectations

In the reality it is not only the rate of interest of a capital asset which matters but in the case of a resource-offering country importance attaches also to the internal rate of return attainable in the long run by own investments (industrialization). As shown by the petro-dollar recycling, resource-offering countries may not even be able to make sensible use of their revenues for their own development. This is bound to reduce (in extension of the Hotelling criterion) the resource supply. Allotment of utilization rights, changes in such allocations and expectations in regard to such changes also have an influence on the inter-temporal raw material supply. H. K. Schneider stressed that the rise of the oil price is a result of changed crude oil utilization rights.

The Hotelling rule also draws attention to the importance of expectations, for the present resource supply will be reduced by expectation of high resource prices in the future. It is seen here that a backstop technology, i. e. a technology based on a virtually inexhaustible resource, plays an important role in the emergence of expectations. If a backstop technology is in prospect, the resource owner is faced with the danger of a depreciation of his resource reservoir, and he will offer larger quantities of his resource now. The very simple Hotelling rule shows besides that the resource market and other markets, in particular the capital market, are interdependent. A high rate of interest in the capital market is an incentive for additional resource offerings today and neglect of the interests of future generations. If for instance the state drives up the rate of interest through loan issues to cover a public accounts deficit, he provides an incentive to make larger resource offerings today. As the backstop technologies (e. g. the solar technology) are as a rule capital-intensive, the state lessens the attractions of introducing a backstop technology when it seeks finance by means of loans.

The question broached by Schneider whether the real resource price follows a U curve according to Pindyck because the producing costs of the resource will, as a result of exploration successes and economies of scale during extraction, first fall and later rise, raises an interesting problem. In this case the Hotelling rule would not apply to falling real prices either. Gottinger (Bielefeld) also concludes that the resource price will follow a U curve: for purposes of market strategy the consumers are at first being accustomed to low prices.

Special Aspects of the Allocation Theory

In the working groups a number of papers dealt with factors exercising an influence on the inter-temporal allocation. Dasgupta (London School of Economics) and Grout (University of Birmingham) examined the effect of the market structure on the inter-temporal resource allocation. A specific problem in this context is how the allocation is influenced if for example the resource owner is a monopolist and the same monopolist or another enterprise is the backstop technology inventor or innovator. The possible variants have an influence both on the time profile of the utilization of the raw materials and on the discovery and realization of the backstop technology, so that, in Schumpeter's formulation of the question, the technical progress is endogenized. This problem of the endogenization of technical progress was also

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[1] If p_o is the price in the zero period, p_1 the price in period 1 and i the rate of discount, the equation in an equilibrium (optimum) is: $p_o (1 + i) = p_1$. From this follows: $\frac{p_1 - p_o}{p_o} = i$, i. e. the price increases with the rate of discount.

[2] $F_k = \frac{d(F_r)}{F_r} = \frac{\dot{p}}{p}$, for F_r is the real price of the resource.

discussed by Pethig (Oldenburg). Sauter-Servaes (Constance) dealt with the introduction of a synthetic product.

Other authors argued on theoretical questions of resource allocation, such as different extraction costs and deposits (Kemp, University of New South Wales), recycling (Jaeger, Berlin) and the influence of institutional factors (von Böventer, Munich).

The question of the extent to which growth can be maintained in the long run occupied Heal as well as H. K. Schneider. Heal discussed the Hartwick rule which ensures a constant consumption level if the returns from exhaustible resources are reinvested. Schneider refers to processes of capital formation and technical progress which allow growth to be maintained over the long term with a given resource equipment. Theoretical considerations therefore do not implicate the conclusion that the growth objective must be abandoned when the resource is limited.

Finally, the question of how uncertainty is brought into the analysis, which Schneider broached, is also of theoretical interest. In the studies of Heal and Kemp the size of the resource reservoir is regarded as uncertain whereas to Pindyck its size is certain but its future development uncertain. From this ensue mutually contradictory implications in regard to the inter-temporal resource allocation.

Markets and the Principle of Substitution

Granted that there is a need for adjustment processes to counter growing scarcities which are manifesting themselves, what are the measures to be employed? Von Weizsäcker (Bonn) and H. K. Schneider dealt in their final addresses with this question which others also discussed. Markets play a cardinal role in this context. They express relative scarcities by price signals and thereby initiate adjustment processes. These processes take the form of substitution and innovation. If the supply and, possibly, the substitution elasticities are low in the short term, they may be expected to be higher in the long term. Hesse, the president of the Gesellschaft für Wirtschafts- und Sozialwissenschaften (Göttingen), emphasized when summing up: "There is a need throughout the economy for adjustment processes combined with relative price changes. These adjustment processes are already taking place." It may be noted in passing that it was the general belief at the meeting that the substitution principle is the relevant principle for the solution of the resource problem, that markets – however imperfectly – give effect to this principle, and that this substitution principle makes in the long term a decisive contribution to the solution of the resource problem.

Ideal Optimum and Real Market

The question of market imperfections was broached in a number of papers. Market distortions by monopolies for instance in the sphere of extraction, uncertainties about property rights, fears of erosion of risk capital profits by taxation, cartellization, non-convex development of production potentialities in the event of endogenization of the resource reservoir (Heal), external effects of the generation of new knowledge (von Weizsäcker), inadequacy of forward and risk markets and lack of stability in resource markets were mentioned as factors. It also emerged clearly that markets do not function with common property resources, that they do not operate efficiently if utilization rights are not allocated, or cannot be allocated, in a suitable manner.

The discussion about the efficiency of markets is proceeding on two levels: The welfare-economic line of argument sets out an ideal state of allocation and compares it with the results of an actually existing allocation mechanism. The more politically oriented line of argument compares the market, which is an actually existing allocation mechanism, with other actual allocation mechanisms as for instance one with a greater measure of state planning. The two approaches pose different questions and are therefore bound to lead to different answers. There would perhaps be a stronger consensus among economists if this difference in argumentation received attention.

The welfare-economic analysis starts with a definition of an ideal state of perfect market, follows this up by pointing out market imperfection, deduces therefrom the thesis of market failure and bases on this the need for intervention by economic policy. Von Weizsäcker called this ideal state a nirvana: "The real alternatives of the market may be as remote from the ideal state as the 'real socialism' of Eastern Europe from a socialist utopia". In assessing market processes from the point of view of economic policy one must therefore aspire at a comparison between the real market and the real political decision-making process. There seems to have been a basic consensus at the meeting that the market compares rather well with other real allocation mechanisms by virtue of its capacity to solve problems and its

coordination potential and in regard to the substitution principle and to competition as an innovation potential for the operation of long-term adjustment processes. On such a comparison of real allocation systems impinge such questions as that of the efficiency of economic policy, the "tyranny of little decisions" by bureaucracies, and the practical experience with state intervention as for instance in the energy price regulation in the USA.

Extent of Adjustment Processes

The operation and dimensions of adjustment processes were discussed in a number of papers although the agenda did not include a paper explicitly referring to this subject.

☐ Adjustment processes need time. "The market mills grind slowly . . ." (von Weizsäcker). It takes time to transform the in the short run low supply and substitution elasticities and the import dependencies into over the long term more favourable parameters. As time is needed for the adjustment to take place, the politician must have the patience to let the substitution and innovation forces develop long-term effects. This involves a hazard as the politician is as a rule inclined to take a different attitude, namely to tackle the solution of the problem: a problem is seen to exist, possibly pointed out to the public and then "solved" by the politician. Long-term market processes act however as a substitute for political action and deprive the politician of the opportunity to show his mettle and justify his existence.

☐ The willingness of politicians to let long-term adjustment processes operate through the market dwindles when volume bottlenecks form suddenly or unexpectedly, i. e. when, in Streissler's terminology, C crises occur. In this case the politician tends to prescribe adjustments of short-term expediency whereas he should consider it his task to avoid C scarcities, anticipate them if possible, and set the appropriate adjustment signals in advance.

☐ As adjustment processes are of necessity long-drawn-out, they can only operate if sustained over a long period, for "those who take the adjustment and substitution decisions need a certain measure of certainty . . . This requires at the very least an enduring schedule for the set of data on which these decisions depend . . ." (Hesse). This confirms – in an inter-temporal context – Eucken's demand for constancy in economic policy.

☐ Deferment of adjustment processes through failure to pass on scarcity signals, assisted by intervention with the means of economic policy such as subsidies, rationing or artificially depressed prices, heightens the adjustment pressure and makes for more extensive adjustment processes later on. As the example of the US energy policy shows, it often happens that the prices, if taken away from the market, are exposed to the interplay of the most diverse vested interests. Enmeshed in such a political web, prices become rigid and can no longer exercise their functions.

☐ The processes of adjustment to resource scarcities will be capital-intensive because exploration, extraction and development of a backstop technology or other substitution processes (e. g. insulation of houses) are all capital-intensive. Streissler points out that as far as the capital requirements are concerned to task resembles that encountered with railway investments in the last century; finance can therefore be found to cover the capital requirements. Schneider expresses the view that the problem of procuring the necessary capital could be solved by halving the newly incurred state indebtedness.

☐ The repercussions of adjustment processes on sectoral and regional structure, price level, employment and balance of payments situation were not broached as central discussion subjects but did not pass unnoticed. Another question which was apprehended in the background concerns the social containment of the adjustment processes required over the long term. It involves the international distribution problems between North and South on the one hand and on the other the observation that adjustments impinge on the lower income brackets in a special way. This poses the question whether the adjustment processes needed in the long term are politically feasible with due regard to questions of distribution. A tax on energy (von Weizsäcker) was propounded as a possible approach to a consideration of these aspects[3].

☐ It will be a priority task for the industrial nations to inaugurate the adjustment processes as for instance the implementation of an alternative technology, for this will bring relief to the Third World countries (Schneider). If the industrial nations postpone the adjustment processes, the developing countries will have to bear a heavier scarcity burden.

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[3] It should be noted that the Hartwick rule, which says that returns must be reinvested in order to maintain a level of consumption over the long term, has received no attention as yet in economic policy.