IIASA International Institute for Applied Systems Analysis www.iiasa.ac.at

Electricity for Aluminum in the Era of Expensive Energy: The Economic Principles

Gordon, R.L.

IIASA Collaborative Paper
June 1983

NOT FOR QUOTATION
WITHOUT PERMISSION
OF THE AUTHOR

ELECTRICITY FOR ALUMINUM IN THE ERA OF EXPENSIVE ENERGY

THE ECONOMIC PRINCIPLES

Richard L. Gordon

June 1983
CP-83-32

Collaborative Papers report work which has not been performed solely at the International Institute for Applied Systems Analysis and which has received only limited review. Views or opinions expressed herein do not necessarily represent those of the Institute, its National Member Organizations, or other organizations supporting the work.

INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
2361 Laxenburg, Austria

ABSTRACT

Cheap electricity has long been the basis for locating aluminum smelters. However, a limited number of sources of cheap electric power are available around the world. Such sources consist of the best hydroelectric sites and possibly sites near gas field and low grade lignite and subbituminous coal deposits--unfavorably located to compete on world markets. A few additional aluminum smelters might be located at the remaining sites of this low cost power. However, critical limits exist to extensive relocation of industry near cheap energy or even the persistence of cheap electricity. Electricity is difficult but not impossible to transmit over long distances and a time may come, where it becomes profitable to integrate the low cost facility into a national or international generating system (grid). Moreover, given the limited number of available sites, only a limited number of plants seeking low cost energy can be accommodated. Moreover, cheap energy is not the only consideration in plant location and high nonenergy costs may eat up any energy cost savings. The long run prospect is that the margin aluminum smelting will be based on nuclear generated electricity. However, there may well remain unexploited low cost sources and excess capacity so that it will pay to locate several more smelters near cheap energy.

ELECTRICITY FOR ALUMINUM IN THE ERA OF EXPENSIVE ENERGY

THE ECONOMIC PRINCIPLES

Richard L. Gordon

Electric power long has been an important input into aluminum smelting. The importance, in fact, has been sufficiently great that smelters often have been located at sites near a cheap source of energy that may have been remote from raw materials, markets, or both. Changing energy market conditions in the 1970s have drastically altered the economics of aluminum smelting. Many producers, particularly those located where electricity costs were high, have endured severe cost pressures. Some areas, notably the U.S. Pacific Northwest, have exhausted surpluses of low-cost sources of energy for electricity generation.

Attention, understandably, has turned towards determining what adjustments, if any, in the location and other characteristics of aluminum production might be made to alleviate the cost difficulties.

This paper seeks to appraise the basic conceptual issues associated with the electricity problems of the aluminum industry. While the discussion draws upon knowledge of the actual characteristics of electric power supply around the world, the stress is on providing an analytic framework. The primary concern is in explaining the determination of the social marginal cost of electricity in different regions.

The discussion begins with an analysis that ignores the problem of load variation--the temporal fluctuations of electricity demand. Then, the concept of load variation and its implications are examined. Finally, note is taken of how governments around the world have imposed policies to hold the price of electricity to many consumers, including aluminum smelters, below its social cost.

The most critical point about electricity market conditions follows directly from basic economic principles, that should be, but probably are not, recognized in all appraisals of aluminum. In any region, cheap sources of energy for generating electricity are in limited supply. Thus, sufficient demand growth will exhaust these supplies. Any search for cheap energy, therefore, must include evaluation of demand growth prospects.

Another critical consideration is whether the areas of cheap energy have high costs of other key inputs that offset the advantage of low-cost electricity. A final question is the economics of electric power in those countries dependent on coal or nuclear power for increased electricity output. It is argued that the prevailing economics can keep the costs well below those of oil-generated electricity.

The discussion begins with a review of the concept of social cost. Then, the economic principles relevant to analysis of electricity availability are noted and employed to develop the basic arguments about cheap electricity. Then, the other issues are examined.

The Concept of Social Cost

Economic theory stresses that social efficiency is attained when the social marginal cost associated with the level of activity maintained equals the price being paid for that output. The theory proceeds to discuss the problems of attaining such an equality. The usual concerns are that monopoly will cause prices to exceed marginal costs or that public policy will fail to make firms liable for the environmental damage that they cause. As suggested above and reviewed more fully below, the problem in electric power is quite different from the usual concerns of theorists (but far from an unusual practical problem). Electricity has become one of the many goods that politicians have decided should be sold at prices below the marginal cost of current output.

These rules for attaining efficiency are such basic elements of economic theory that their comprehensive review is not appropriate here. It is presumed readers either are familiar with the concepts or will seek explanations from the many available discussions.

However, a few points should be recalled. Noneconomists need to be told that the marginal cost is a measure of the sacrifice of resources needed to produce a change in the output of something. Even economists may have to be reminded that this cost varies with the level of output and that this variation is a critical concern.

Moreover, although electric power historically has been considered a natural monopoly--an industry in which marginal costs fall with output, the modern realities of at least generation economics are quite different. It is clearly an increasing cost industry.

In fact, it is the eventual run-up of marginal costs as electricity output expands in any region that is the core of my arguments about the cheap-power issue. In particular, it is this increase that eliminates the advantage of regions with some supplies of cheap power. The usual further consequence is another development familiar to the analysts of the economics of political intervention. Increasing cost industries generate economic rents--the differences between the price that equals the marginal and average costs of the highest cost entity operating and the lower average costs of the superior resources. Politicians inevitably view such rents as fair game for reallocation--unfortunately not necessarily to those who would readily be considered particularly needy or deserving.

In any case, the *raison d'etre* of economic transactions is to effect production and trade that produce benefits in excess of the cost incurred. Where an increase in producing and selling something produces a marginal benefit in excess of its marginal cost, the increase should be made. This is a self-limiting process because marginal benefits tend to decline as availability increases. (The more we have to begin with, the less valuable are additional amounts of a given commodity). The end point of expansion occurs, then benefits decline to meet costs. Any further expansion would cost more than it is worth and would not be made.

Thus, economic theory argues that the output of all commodities should be set the level at which the (social) marginal cost of production equals the amount consumers are willing to pay for that quantity of that commodity. So long as the problems of decreasing costs and public-good externalities do not arise, it is possible for firms in competitive industries to satisfy these rules.

The Principles Applied—the Search for Cheap Electricity.

Discussion of aluminum smelting (and other industrial processes in which energy is a major cost element) often includes inquiry about the availability of low-cost energy in special locations. The marginal-cost principle implies that the relevant costs are those of the highest-cost energy sources needed to satisfy demands. Many regions have some low-cost energy resources such as the cheapest-to-exploit available hydroelectric power and natural gas in areas in which markets are limited.

Historically, significant amounts of aluminum smelting capacity were located in areas such as remote parts of Canada and the formerly hydropower surfeited Pacific Northwest of the United States. However, this situation eventually will cease because no region has unlimited amounts of energy available at the marginal cost that happens to prevail at any moment.

Therefore, demand growth, if it occurs, eventually absorbs the supply of cheaper power and forces resort to higher-cost alternatives. Historically, the critical influence for sites adopted for aluminum smelting has been the availability of low-cost water power sufficient to supply all the electricity needs then existing. Such sources, however, are classic examples of the concept of the scarcity of natural resources associated with David Ricardo. Water-power resources are limited in quantity and differ radically in quality. Use will proceed from the best water resources to successively more costly ones. Long before all these supplies are utilized it will become economic to introduce the use of fossil-fuel or nuclear-fired plants.

Fossil-fuel and nuclear generation are also subject to increasing costs. It is undesirable for any one unit to comprise a significant enough proportion of production capability that its loss causes a high probability that demands cannot be met. Thus, the optimum at any moment involves employing many units. The needs of these units for land possessing characteristics such as adequate space and access to cooling water essential for a power plant produces increasing costs because the same principle of limited quantities and different qualities applies here as well as in the water-power case.

Obviously, the same problem of increasing costs applies to a country with only a mineral-fuel-based electricity sector. Moreover, the extensive development of electric power based on cheap fossil fuels also ultimately will produce cost increase because of the notable effects of the expansion on the supplies of cheap fossil fuels.

All of this indicates that at any point in time the marginal cost curve for electric power is upward sloping. It should further be recalled that it is this type of increasing costs that is relevant to the viability of a competitive industry. The much reviewed question of whether a firm can at least break even with prices equal to marginal cost is resolved by viewing the shape of the marginal cost curve at each point of time. Where the marginal cost curve for each product is upward sloping and the firms are operating at each moment of time in the range of increasing costs, Euler's theorem for homogeneous functions, the basic rule by which viability is evaluated, indicates that sufficient return on investment can be earned. (The theorem, as presented in numerous texts, shows that when there are diseconomies of scale, total payments to the factors of production including capital will fall short of revenues and revenues exceed costs only if there are economies of scale--represented in the single product firm case by decreasing average cost.) The only problem is that the industry must be foresighted enough that it restricts capacity to levels that produce high enough revenues to permit adequate profits.

It should be noted further that the industry long had been subject to a phenomenon of steadily downward shifts over time in the marginal cost curve. This was produced by a combination of technical progress and the effects of demand growth.

The historical phenomenon (that unfortunately seems to have ceased in the 1970s) of steady cost reduction arose from shifts in the supply curve due to technological progress. In addition, demand growth alters the optimal plant size. The probability of lost ability to serve customers depends upon the *proportion* of sales represented by an individual unit. With larger demands, the same level of relative dependence on any unit implies a higher absolute size. Thus, larger units are possible for larger systems. These larger units, in turn, have lower production costs than smaller ones.

These considerations interact. One way to increase the size of a system is to connect previously independent utilities. One way this might be done is to merge companies. Historically, interconnection began by merging small companies that served areas as small as part of a city. Throughout the world, eventually a move was made to nationalize electric power. This served to provide an integrated national system

North America is a major exception. Canada has government-owned power, but only at the provincial level. In the United States, private power coexists with power owned by federal, state, and various types of local government and with cooperatives. In the 1930s, failures occurred in the complex network of holding companies that arose to amalgamate the ownership of utilities. This inspired federal legislation placing severe limits on such amalgamations. As a result, existing companies were radically restructured, and mergers were subjected to what proved to be the highly unsympathetic scrutiny of the Securities and Exchange Commission. However, the industry was still able to extend interconnection by developing a wide range of arrangements for intercompany exchanges of power. These exchanges, moreover, involve cooperation between U.S. and Canadian utilities.

However, shifts of this sort still make possible revenues in excess of cost at each point of time even with prices equal to marginal cost. Thus, the shifts do not create the classic natural monopoly problem but instead merely lower the amount of return on investment to justify a given level of output.

For these reasons, electric power is in the sense critical for public policy an increasing cost industry. This is becoming increasingly recognized by specialists in the U.S. electric power industry. Some go on to argue that the same proposition applies to long-distance transmission of electricity. Thus, the deregulation of at least generation and perhaps transmission has been widely proposed.

(I have argued elsewhere, Gordon, 1982, that the dangers of only deregulating generation and transmission are an undesirable restructuring of a well-established industry and the prospect that the continued regulation of distribution will defeat the goals of deregulation. Power to control buying prices will effectively maintain the regulation of generation and transmission. I further argue that regulation does so little good that total deregulation may be the preferable option and regulatory reform may be preferable to partial deregulation. The skepticism about regulating distribution arises from doubts about both whether the local monopolies are as potent as supporters of regulation assume and whether regulation helps.)

This, of course, contrasts with the vision of electric power as a decreasing cost industry and renders irrelevant to the case all the policy propositions related to decreasing-cost industries. As discussed further below, the real problems are the economic rents associated with ownership of lower-cost energy resources. I return to this point again, as already noted, at the end of this paper. The immediate need is to reiterate the points made earlier about the consequences of increasing costs.

The specific need is to recall the forces that tend to prevent the continuation of low prices. One critical point has already been made. If there is steady prolonged growth of demand, eventually resort to higher-cost resources will arise.

Demand growth, in turn, can occur in many ways of which the most important to consider is the movement to the areas of industries dependent on cheaper power.

Other developments are also possible. As power or the fuel to generate it become more expensive, incentives arise to increase trade in low-cost energy or power. Alternatively, improvements in energy transportation or electricity transmission can stimulate exports. Capacity can be built more rapidly than is profitable. This situation has arisen in the electric power industry in some parts of the United States, France, Brazil, Canada and perhaps other countries in which plans for expansion were made before rising energy costs drastically slowed industry growth. Aluminum producers can perhaps get bargain power from these overbuilt systems. However, this situation cannot persist because demand growth and capacity retirement will eliminate the excess capacity. All this, of course, is warning that what happened in the Pacific Northwest United States eventually will occur elsewhere.

To be sure, the length of that time period is a critical concern. If low-cost persists long enough, it can be profitable to locate a plant in an area of low-cost power. In the very long run, differential power costs may be irrelevant to the location of aluminum smelters. However, this may be a very prolonged long-run. In fact, the periods involved may be of sufficient duration that relocation of smelters to take advantage of the interim situation may be profitable. In certain countries marginal costs may long remain well below the cost of nuclear-generated electricity. Location of a smelter in such countries could be profitable. The present value of the cost saving during the transition period may, given large enough cost reduction over a long enough period, suffice to repay the investment in a new smelter.

Two or three subcases can be distinguished. First, a country may possess large supplies of low-cost difficult-to-transport energy as water power or natural gas in locations far from industrial centers. There simply may not be enough demand from either local industry or foreign companies locating to take advantage of the cheap energy to absorb the entire supply of low cost energy until many years have passed.

Second, the mass of energy shocks of the 1970s has caused capacity in many countries to have been built far in advance of demand growth. As I argue in the next section, the rise of oil prices appears to be the *least* important of the many cost-raising pressures. For reasons that are not well understood, real construction costs for electric power facilities of a given design have risen sharply during the 1970s. Moreover, increasing concern with nuclear safety, the pressure to reduce emissions of pollutants from fossil-fuel burning, and the desire to reduce the discharge into natural waterways of waste heat from power plants has made it necessary to build more elaborate, more expensive to operate plants. Generally, pressures of these sorts rather than the rising price of oil have been (with exceptions noted later in this section) been the main source of rising electricity costs.

A graphic illustration of all this is provided by the United States. A surge of power cost increases did coincide with the 1973-1974 oil price shock. Some analysts claim that actually quite different considerations such as weather conditions conducive to abnormally high electricity use, tightening environmental regulations on coal burning, the passage of a stringent federal law regulating mining practices affecting workers health and safety, labor unrest in mining, and delays in completion of nuclear plants were the true problems. For example, in some fashion that no one has managed satisfactorily to untangle, the health and safety laws and the labor unrest caused U.S. coal mines output per man day to decline sharply throughout of the 1970s. However, coal prices were unaffected by the second oil shock. What did happen was that the movement towards increased oil use (which never exceeded 18 percent of generation) in electricity generation reversed sharply. (Oil generation declined almost 60 percent from 1978 to 1982).

In any case, whatever the causes, the effect was a sharp reduction in growth of electric-energy consumption. Facilities have long leadtimes and plants became available that had been designed to meet the much higher demand when construction began. This has produced a second source of low cost power--the non utilized capacity built in anticipation of demand growth that did not occur. Moreover, cases *may* arise in which the available capacity and the growth prospects are such that in some locations such as Quebec, cheap power again may be available for a sufficiently long period that it pays to locate an aluminum smelter.

A possible third case is that in which a country has been overly influenced by the portions of the economic development literature that stress that creation of Infrastructure--transportation, power, communications, and similar basic facilities--is the key to promoting growth. Hydroelectric dams built under the guidance of this theory may have such limited demand prospects that again it may pay to locate a smelter near them.

A converse of the argument is that those countries, notably Japan, with heavily oil-based electric power were most severely hurt by the oil shocks. Their problem is ultimately to replace oil-fired capacity with lower cost plants. This too can be time consuming and it may pay, as the Japanese have chosen to do, to shift much smelting away from Japan.

The ultimate concern is the extent to which process of relocation is selfdefeating. The capacity of attractive areas must be large enough to absorb the entry of aluminum smelters and similar activities without eliminating the unused supply of low-cost resources.

In sum, one must carefully steer between the Charybdis of belief in perpetually cheap energy and the Scylla of neglecting extended opportunities to take advantage of excess in supply of sufficient endurance to justify investment. My concerns tend to stress the capacity depletion problem. Many overly enthuiastic sales people are trying to convince energy users of the virtues of cheap power. Few people are discussing the underlying economic and the limits to perpetually cheap power. Good deals probably do exist but care must be taken not to underestimate the dangers that, as occurred in the U.S. Pacific Northeast, the low prices will vanish sooner than expected. As discussed below, smelters, as any activity, can be chosen as the beneficiary of subsidy and opportunities of this sort also must be considered.

Still another concern is whether the areas of cheap energy are truly attractive to industries to which energy costs are an important consideration. Other characteristics of the area such as political instability, poor location, or lack of critical human and natural resources may outweigh the energy advantages. Development of energy-using industries in the Middle East as of 1983 has been negligible. Extravagant plans seem never to be realized.

The Limits to Electricity Rates--the Constant-Load Case

Another point to keep in mind is what actually sets the limits to electricity prices. In particular, it appears that for reasons that we must examine, the limit for most countries is well below the cost of oil-generated electricity. The economics of interfuel competition appears to be such that everywhere rival fuels will undersell oil in electricity generation.

The critical point here is one made earlier that what matters is not just the equality of costs at the margin, but also the quantities at which the equality occurs. In inter-fuel competition, the rivalry of alternatives involves *both* spatial and end-use differences. The spatial aspects have been much more thoroughly analyzed than the end-use questions. Examination of the geographic pattern of oil prices long has been a standard element of economic literature on world oil (see e.g., Leeman or Adelman).

The standard exposition indicates that somehow prevailing f.o.b. prices are established in every supply area. Delivered prices then are the sum of the f.o.b. price and transportation costs. Markets are divided among suppliers by the basic economic principle that everyone pays the lowest available price. In the world oil case in which the concern is with ocean shipments, it can be validly assumed that transportation costs depend only on distance. Delivered prices are a steadily increasing function of distance. Given two supply areas, the *delivered price* from each then rises steadily as the distance from the supply area increases. At some location, termed in literature as the watershed, the delivered prices from the two areas will be equal. The world is then split into two regions. In each, all consumers between the watershed and a given supplier get their oil from that supplier. The market at the watershed is split between the two suppliers.

This analysis neglects many critical issues. First, distance is not always the sole cause of transportation-cost differences. The volume and mode of shipment are also major considerations. Where water transportation capacity suffices to handle all the traffic, costs are much lower than when the marginal supplies are delivered by rail or truck. For example, because of the elaborate inland waterway system in the United States and particularly the Mississippi River and its tributaries, distant locations such as Tampa, Florida can be served more cheaply by water transport from Illinois than some nearer but landlocked locations.

Another important consideration is that full-train or full-ship consignments are cheaper to handle and thus produce lower rates than smaller shipments. Moreover, at least up to the limits of port capacity, larger ships involve lower unit costs than smaller ones.

Even more critical a consideration is how the f.o.b. prices are determined in the first place. As I have shown elsewhere (Gordon, 1981), the processes are generalizations of the standard economic analyses of price determination. For example, in a competitive model, a generalization concept of market clearing prevails. Each supply area's industry produces the quantity whose marginal cost equals the f.o.b. price that customers are willing to pay for that quantity. These customers consist of all buyers nearer (economically) than the watershed plus a share of the watershed market. Additionally, in all demand regions, purchases are made from the supply region(s) with the lowest delivered prices, and the purchases equal the quantity demanded at the delivered price. In short, all markets clear simultaneously.

The final consideration is that, as already noted, end uses differ in their ability to use various fuels. One source of differences already has been noted--larger-scale users can take advantage of economies of scale in transportation. As it happens, all aspects of securing heat for industrial processes involve economies of scale. The boiler, the fuel-storage, fuel-handling, and often the heat-utilizing facilities benefit from economies of scale.

More critically, these differences tend to alter the interfuel choices quite considerably. Roughly, as energy users move from gas to oil to coal to nuclear they encounter steadily higher capital and non-fuel operating costs. However, the nature of the economies of scale is such that these cost disadvantages narrow as the scale of use increases. Thus, as scale increases, less of a fuel-cost saving is needed to offset disadvantages in other costs. The largest-scale fuel users by far are electric utilities, and they tend to find that their marginal source of fuel is coal or nuclear energy.

At least through 1983, it has, in fact, proved more profitable to extend coal and nuclear use to electric utilities in more regions than to use coal in more end uses in the regions previously served. The U.S. Energy Information Administration and the International Energy Agency perennially predict resurgences of coal use in manufacturing industries. To date little has happened.

The failure of coal consumption to grow as predicted is often attributed to business ignorance of the advantages of coal use. An alternative explanation, which I prefer, is that the outside observers grossly understate the economic availability of rival fuels and are inadequately aware of the economic penalties of using coal in compliance with environmental regulations.

However, this is far less critical than the basic point that some set of marginal markets exist in which coal or nuclear power are just barely competitive with oil. These markets can be described as involving a different watershed for different uses. At the very least, many users then will secure coal or nuclear energy for less than oil parity. Those with better coal or nuclear locational or utilization economics than the marginal user will have costs below oil parity.

Discontinuities in the variation of costs among different participants in actual fuel markets can cause all actual coal and nuclear users to have costs less than oil parity. There may be few or even no consumers who actually are in a parity situation. The oil price may simultaneously be too high to attract any coal or nuclear users and lower than coal parity for all actual oil users.

This can occur because of substantial jumps in both the scale of operation and the ease of transportation. The first point seems the simpler to explain. In any given region, an electric power plant may be substantially larger than any other fuel-using facility. Thus, the premium the nonutility users are willing to pay for oil may be much greater than what utilities would pay. The outcome we observe is that the gap between coal and oil prices lies in between the critical premium levels.

For example, utilities might switch to coal for a cost saving of $2.00 per million Btu while the largest manufacturing plant would require $3.00 saving. At oil prices of $4.00 and coal prices of $1.50, we have an actual difference of $2.50. This is simultaneously more than needed to induce utilities to use coal and less than needed to cause manufacturers to use coal. There is no actual user for which a $2.50 premium induces coal use.

Geographic barriers produce similar discontinuities in space. A considerable price cut, for example, must be made to extend markets from coastal to inland markets not on waterways. To serve inland markets, a transfer from ship to inland transportation mode must be made. Thus, costs of transfer and the costs of transporting over the additional distance by a higher-cost method causes a big jump in price to occur as markets expand inland from the coast. Again the equilibrium can involve a price such that the most attractive fuel on the coast sells for less than necessary to undercut the other fuels in that market. Inland, the cheapest fuel on the coast may have a delivered price above the amount that would make it preferable to the fuel actually selected.

The practical relevance of all this is that everywhere in the world nuclear power in electric utilities seems to cost significantly less than oil-generated electricity. At least in the United States, the same is true of coal-generated electricity (which probably is why the U.S. tolerates the political pressures to burden nuclear power with costs that have aborted future U.S. investment in nuclear). This, of course, is the basis of the prior assertions about long-run power costs.

The Implications of Load Variation

The implications of load variation have long fascinated public-utility economists. The fascination, in fact, may be excessive to the extent to which it has precluded consideration of the more critical rent allocation issues discussed below. The concerns are great enough, nevertheless, to merit comment here.

Load variation refers to the significant temporal swings in electricity demand. Variation occurs within the day, the week, and the year in response to changes in the pace of electricity-using activities. In the United States, originally the dominance of lighting and cooking tended to put the annual peak in the winter and the daily peak in the early evening. The spread of air conditioning shifted the peak to summer afternoons. The rise of electric heat could cause the old pattern to return.

Given the upward slope of the electric-utility industry cost curve, the marginal cost and, therefore, the optimal price of meeting different levels of demand differs. The enormous literature on peak-load prices discusses the determination of such optimal prices. Much effort has been devoted around the world to designing methods for varying prices optimally with loads. The principal practical problem is that significant costs are incurred in administering a variable-price system. A particular problem is that metering the timing as well as the amount of use adds significantly to costs.

(A curious hiatus in the literature was analysis of the optimum pricing pattern when price change is costly. However, Gordon, 1982, provides such an analysis. The basic results are unsurprising. Price changes should occur whenever they produce efficiency gains in production that exceed the cost of administering a price change. Between price changes, the price should lie in between the range of optimums that would be charged in a world of costless price changes. Where in the range the optimum lies depends upon the nature of the demand and supply functions and the duration of different levels of demand.)

The analysis of peak load pricing is too complex to be adequately treated here (see Gordon 1982 for a fuller view). The analysis can equivalently be handled by a socalled two part tariff model in which separate demand and capacity charges are considered or by the more conventional concept of the price of electric energy at various points of time. I prefer the latter.

Under this analysis, it can be shown that at peak, all users should be charged a rate equal to the long run marginal cost of supplying peak power. Rates should go down when demand declines but a wide range of possible off peak rates could arise. The lower limit is the operating cost of the most expensive plant utilized at that moment. However, as I have shown (Gordon 1982), somewhat higher rates may be necessary to repay the portion of the capital costs not recovered by the high rates during peak period.

Given these complexities it is not clear a priori what load variation will do overall to the cost of power for aluminum producers. What is clear, is that some incentive in the form of higher charges or supply interruption clauses should be provided to encourage aluminum smelters to reduce consumption at the peaks. It should be further noted that this is less problematic than outsiders might think. Substantial peaks are rare events. U.S. aluminum smelters, for example, tend to be located near winter peaking regions and the problematic surges are the worst hours of periodic cold snaps.

However, the more fundamental question of what happens to the overall cost of power to the industry is less clearcut. However, an excellent prospect does exist that on average, an aluminum industry that is part of a grid will pay less than the long-run average cost of coal or nuclear power.

If the aluminum producers tend to respond to the surge of prices during peak by substantially curtailing electricity use it will be others who pay the peak charges and in the process make substantial contributions to recovery of the costs of peak and off peak capacity. To the extent that is true the charges to aluminum smelters for off peak power would be correspondingly lower.

Economic Rents in Electric-Power—Economic Tradition Versus Political Practice

Both economists and politicians have great interest in what to do with economic rents. It is agreed that the disposition of such rents is a value judgement to be decided on the basis of prevailing social ethics. However, political practice in this area runs contrary to a prevailing economic consensus on the issue.

The perils of characterizing the diverse views of economists or any other group are considerable. Nevertheless, a considerable amount of literature exists arguing in one way or another that the proper use of economic rents is to tax them for use to finance the general programs of governments. In particular, two alternatives are viewed skeptically. First, doubts are raised that any participants--be they consumers or producers--in a given market should receive any priority in sharing the rents. Second, a particularly disfavored use of rents is subsidy of consumption or output in excess of the socially efficient level.

Before discussing these arguments, we should recall a principal exception. It was often raised in discussions of electric-power economics that assumed decreasing costs prevailed. An elaborate theory was developed to show that the consumer surplus enjoyed by users of the output of decreasing-cost industries could be used to finance the losses incurred with prices equal to marginal costs.

The proposed expedient is a form of (second-order) price discrimination called Ramsey pricing. Consumers would face precisely the sort of declining-block-rate schedules electric utilities actually employ. An above-marginal-cost price would be charged for the highly-valued initial levels of consumption and successively lower prices for each incremental block.

The hope was that the quantity available to the consumer at the price equal to the marginal cost of optimum production would equal the amount demanded at that price. The higher prices for lower levels of consumption provided the financing needed. This argument is founded on

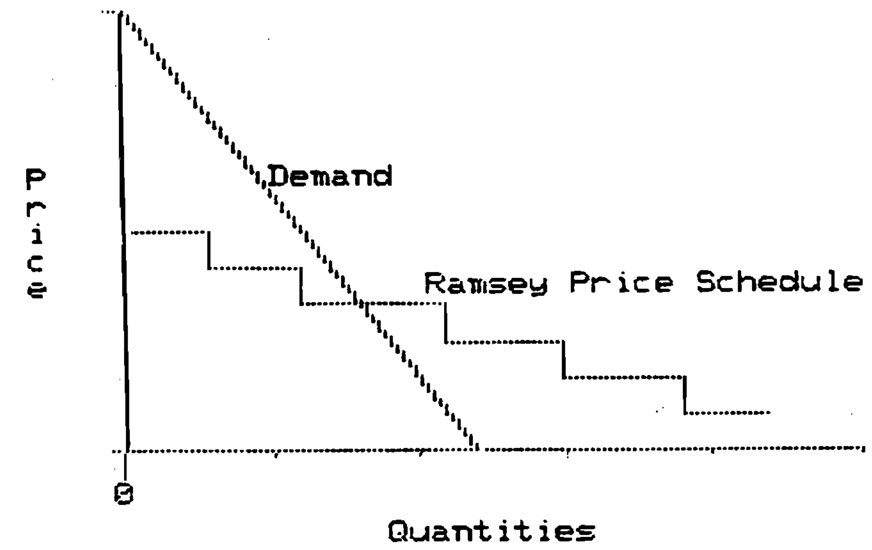

Figure 1. An Efficient Ramsey Price Schedule

the proposition that beneficiaries should finance their gains. This still leaves open the question of optimal shares in the financing.

This argument does not reverse well. Where output is already optimum, no incentive is needed to change it. Producers are certainly getting at least enough to sustain production. Consumers similarly get some surplus as well as the optimal quantity supplied. Thus, neither producer nor consumer need to be coaxed into changing actions. The resulting rents have no obvious use, and society must decide how best to employ them.

This immediately leads to the propositions stated above about the views of economists on rent use. There is no reason in theory why the producers or consumers of a commodity with which economic rents are associated should be more deserving of possessing these rents than any other group. Historical experience suggests that rent allocation that favors participants in the rent-generating market can create many kinds of mischief.

A primary problem is the confusion about the worthiness of aid of those involved in the market. Quite clearly, deserving people will trade in any widely used commodity that generates economic rents. However, it is highly improbable that the worthiness is accurately measured by indicators of the degree of participation in the market. Favoritism to suppliers or consumers is generally tied to the extent of engagement and thus implicitly assumes the existence of a high correlation between participation and merit.

The minimum problem that can arise is the prevalence of unseemly and intractable battles over who should benefit. U.S.oil policies have perennially involved battles over shares of the benefits. When the states restricted output, fights raged about what types of producers should endure the largest share of the cuts. Many groups battled for access to the rents from possessing oil import quotas. Small refineries, refineries in Puerto Rico, and petrochemical manufacturers all were favored.

Similarly, efforts to use price controls to limit economic rents in U.S. natural gas production have forced regulators into pettifogging efforts to rank consumption categories in their order of merit.

Actually, the most basic subsidy in electric power is that given to all consumers through keeping prices at average costs. Effectively, the excesses of revenues over costs when an increasing cost industry equates marginal costs price have not been allowed to occur. These profits have been eliminated by keeping prices below marginal cost thus encouraging (and meeting) additional demand. Effectively, the profits are being used to subsidize the additional output (see Gordon, 1981).

Predictably, this decision to spread around rents has opened a mass of controversy. Bitter battles are fought over how the subsidies should be shared.

Presently, the great battle is over access to the economic rents from low-cost power. The most dramatic case is in the Pacific Northwest which has depleted its low-cost hydro resources. Within the region, battles rage over who gets the rents. It dawned upon the U.S. Congress that the tradition of favoring public or cooperative utilities could have perverse equity effects. The customers of such utilities were not necessarily more or less deserving than those of privately-owned utilities. Policy was, therefore, changed to favor the household customers of all utilities.

In addition, areas outside the region continually seek access to an increased share in the rents. The leader in this effort predictably is California. A call for greater access to Pacific-Northwest power is a major element in the elaborate state strategy to avoid construction of new power plants in the state.

Similar squabbling has occurred elsewhere. New Hampshire tried to limit sharing the benefits of low-cost hydroelectric power with the rest of New England. Massachusetts threatened to retaliate by limiting access to its low-cost nuclear power. Another battle prevails over how to interpret the vague requirement for sharing with other states that conditions the rights granted New York state to utilize hydroelectric resources in the Niagara Falls region

Of course, worse problems have arisen elsewhere. The perverse income distribution effects of world oil price rises have probably been more harmful than any of my U.S. examples. The OPEC experience suggests that commodity price rigging is more likely to be a markedly inferior than a particularly good way to improve income distribution. The creation of instant millionaires of a lucky few is no more attractive in the Gulf of Persia than in the Gulf of Mexico.

The final insult to economic sensibility is that politicians are so enthralled with producing new inequities that they eagerly impose inefficiencies to attain their goals. There are supposedly realistic economists naive enough to believe that an equity-efficiency tradeoff is made. Adam Smith knew better. We should heed warnings that it is too often the powerful and undeserving who get aid. It is no wonder that the one thing on which James Tobin and Milton Friedman agree is that direct aid to the poor is better than intervention in individual markets. Thus, aid to the aluminum industry would be another inglorious episode in this saga of inappropriate action.

Conclusions on Electricity for Aluminum

The prior analysis has warned of the limits to finding low-cost locations to produce aluminum. It also has been suggested that in the absence of such options the cost of electricity will be the cost of nuclear generation with proper adjustment to the way the industry alleviates or aggravates the peak load problem. It was also suggested that the rents generated by the existence of cost differences in electricity generation could be used to subsidize aluminum production but such subsidies were unwise.

The analysis deliberately did not attempt to provide estimates of whether substantial opportunities existed to relocate the aluminum industry near cheap power. I only wanted to warn that the advocacy at relocation may have been overdone.

If I am correct, the long-run equilibrium of the aluminum market will involve marginal suppliers dependent upon nuclear or possibly coal generated electricity for the bulk of their power. As the electric power industry adapts to the changing economics of generation, international differences in power costs should diminish.

However, the adjustment will be slow and painful problems will be endured by aluminum producers. The oil prices shocks of the 1970s seem to have surprised everyone including the OPEC countries themselves, the governments of OECD countries, the major oil companies, the leading consumers, and academic energy specialists. Losses obviously were suffered by those most dependent upon oil.

Those countries such as the United States, Canada, and Norway that avoided a heavy dependence on oil-generated electricity have a significant short-term advantage over countries such as Japan and France with extensive oil generation. The eventual evolution is unclear. Canada still has significant amounts of hydro resources in Quebec that can hold down cost rises. The United States never got as heavily involved with oil as did other countries. The substantial backlog of plans to add coal and nuclear powered capacity combined with resurgence of gas availability in some regions, notably California, has enabled the U.S. to cut oil generation almost 60 percent from 1978 to 1982. The 1982 level of oil generation was the lowest since 1969. However, the barriers to electric power expansion caused by an unfavorable regulatory climate may cause the U.S. position to erode in time

The final concern is what this means for aluminum market prospects. This depends upon analyzing all the impacts of higher energy costs on materials supply and demand. Key considerations besides those cited here are changes in the supply economics of other materials and changes in the demand for materials. I can only offer conjectures such as that petrochemicals may suffer more than aluminum and other metals may suffer less on the production cost side. What the implications of the search for energy saving in consumption may be is less clear. More extensive study of the relevant markets than I have undertaken is needed to resolve these issues.

Changes thus will certainly occur in the aluminum industry, but it would be foolhardy to predict their nature without careful study. The prior discussion may not have resolved all the issues, but it should have exposed some of the misconceptions that can arise about electric power.

REFERENCES

Adelman, M.A. 1972, *The World Petroleum Market*, Baltimore: The Johns Hopkins University Press for Resources for the Future, Inc.

Gordon, Richard L. 1981. *An Economic Analysis of World Energy Problems*, Cambridge, Mass.: The MIT Press.

Gordon, Richard L. 1982. *Reforming the Regulation of Electric Utilities: Priorities for the 1980s*. Lexington: D.C. Heath Lexington Books.

Leeman Wayne E. 1962. *The Price of Middle East Oil*. Ithaca Cornell University Press.