Cogeneration of Electric Energy: the Case of Pulp and Paper Mills

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This paper uses applied welfare economics to analyze the phenomenon of cogeneration of electric energy. It defines the optimum levels of energy use (and of cogeneration) by industrial firms, and shows the efficiency costs of various possible deviations from the optimum. The analysis is rooted in the case of pulp and paper mills and deals with alternatives that are realistic for that case. Data from 29 Canadian paper mills suggest that it would be both wise and prudent to mandate the purcahse by Canadian utilities of the "excess energy" (i.e., energy produced in excess of their own usage) of Canadian mills, at a price that reflects the utilities' long-run avoided cost.

Cet article utilise l'économie de bien-être appliquée pour analyser le phénomène de la co-génération d'énergie électrique. Il définit les niveaux optima d'utilisation énergétique (et de co-génération) par les sociétés industrielles et présente les rapports coûts-efficacité de diverses déviations possibles de l'optimum. L'analyse se base sur le cas des usines de pâtes et papiers et traite des alternatives qui sont réalistes dans ce cas concret. Les données retirées de l'étude de 29 fabriques de pâte à papier au Canada suggèrent qu'il serait à la fois sage et prudent de rendre obligatoire l'achat par les entreprises de service public canadiennes de "l'excès d'énergie" produite par les fabriques de pâte à papier (c'est-à-dire l'énergie produite en excès de leur propre usage) à un prix qui reflèterait les coûts évités par les entreprises de service public dans le long terme.

Historical and Institutional Background

In the past few decades we have witnessed, on a quite significant scale, the linkage to national or regional electricity networks of private power plants installed by firms whose main output is something other than electrical energy. While some such linkages surely existed, as isolated cases, much earlier, I do not feel at all reluctant to call the recent tendency in that direction a "new" phenomenon. Testimony to the fact that things have changed, with respect to the linkage of independent producers to the regular electricity networks, can be found in the spate of new legislation, in many countries, governing the terms and conditions of such linkages. The term "cogeneration" refers to the use of a common energy source (such as natural gas or wood waste) to produce sequentially both electricity and heat for industrial processes. The electricity generated is either used to displace electricity purchases at the host plant or sold to an electricity network, as conditions permit.

In the United States, for example, Federal

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law (the so-called PURPA legislation), requires any public utility company that enters into a cogeneration arrangement to pay for the energy it buys (from outside producers) at rates which reflect its (the utility's) own avoidable costs for new baseload capacity. One can easily understand the motivation for such a provision. A society that is conscious of its energy problems (now and in the future) will want to see to it that its growing energy needs are met from the lowest-cost sources. A provision like the one described seems to be an easy way of ensuring that potential cogenerators will have an incentive to supply energy to the general network whenever their long-run costs are below those of the utility. This is indeed how the US PURPA legislation would work out in an idealized, simplified case where all cogenerators were genuinely independent producers, where utility rates were set in accordance with the economic principles of electricity pricing, and where, consequently, no overt or disguised subsidies or similar distortions existed. Unfortunately, this idealized case is far from what we observe in the real world.

This paper is the fruit of an examination of real-world conditions, as they bear on cogeneration of electricity by pulp and paper mills. It was based initially on the circumstances surrounding cogeneration by paper mills located in the northeastern United States, but as the analysis developed it was also thought of as being of possible assistance in the design of potential future cogeneration rules in Canada.

Central to the story is the fact that in many United States jurisdictions, the regulatory authorities have established what amounts to preferential or subsidized rates for industrial users. (As US utilities are mostly private corporations, having to compete for incremental investment funds in the capital market, they can only give preferential rates to one class of users if another class is charged more. Such cross-subsidization is a common feature of electricity rates, not only in the 50 states of the US, but also in many other countries).

One particular case served as a sort of springboard for this paper: it assumed a long-run marginal (avoidable) cost for new base-load capacity equal to 9¢/kWh, side-by-side with a standard industrial rate of 5¢/kWh. It is important to realize that the 5¢ industrial rate applies (in this example) to all industrial users, and that the public utility somehow manages to cover its historical costs and earn a normal rate of return. Thus other (e.g., residential and/or commercial) users would have to be paying more than 9¢/kWh in order to round out the picture.

"Subsidies" like that implied by a 5¢ industrial rate in the above example have existed for a very long time (easily more than half a century) in many places around the world. And on the whole they have not given rise to allegations of unfair competition, or to cases brought against the offending country for violation of the GATT rules, etc. Such problems may have emerged when a special rate was offered to one or two fairly narrowly-defined industries (like textiles or rubber products), but not when the rate in question was a general industrial rate. And it would be my guess that over the bulk of the 20th century, Canadian pulp and paper mills did not make a practice of complaining of unfair competition from their US counterparts, just because the latter enjoyed the benefits of a favourable electricity rate, applicable to industrial users generally.

But now we enter the new era of cogeneration. The pulp and paper mill in Maine can now sell energy to the local utility company. If such sale were governed by the requirement that only "excess energy" could be sold in this way, I again doubt that Canadian producers would have reacted. (The sale of only "excess energy" means that the energy generated by the pulp and paper mill could be allocated for its own use up to the point where its energy needs were fully met. Only then would it be able to sell any incremental production, above and beyond its own usage, to the local power company.) In such a case the pulp and paper company might not find it interesting to enter into cogeneration operations at all, because of its being able to buy energy at a rate as low as

5¢/kWh. But no serious problem would be likely to emerge vis-a-vis, say, Canadian pulp and paper companies.

The critical real-world cases came, however, from a different setup — one that was characterized by "crosshauling." With crosshauling, the US pulp and paper companies would continue to meet all their energy requirements with electricity purchased from the local utility at 5¢/kWh (in our example), and they would simultaneously sell all the output of their cogeneration operation at the long-run-avoidable-cost rate of 9¢/kWh. Owing to the nature of pulp and paper operations (which generate lots of sawdust and wood chips for use as fuel in cogeneration activities) the amount of crosshauling was typically quite large, with sales of cogenerated energy at 9¢ (in our example) often exceeding the total amount of industrial energy purchased (at 5¢) and used by the pulp and paper mill. It is no wonder, when their US competitors are operating under this sort of setup, that some Canadian mills should rise up and cry "foul."

It is natural, under these circumstances, for the Canadian mills to see the difference between 9¢ and 5¢ as a straight-out subsidy to the US producer, and to raise their voices in complaint. However, this too may be a hasty and not altogether justified reaction. Consider the case where the US mill was always operating using 5¢ energy, and without complaint from its Canadian competitors. Now comes the PURPA legislation, inviting the company to cogenerate and sell at 9¢. Suppose that it can in fact do so and that its full incremental costs of cogeneration are 8¢/kWh. It is economically sound for the US mill to engage in cogeneration, if we take its previous situation as the base, and accept the 5¢ industrial rate as a "given" for the analysis.

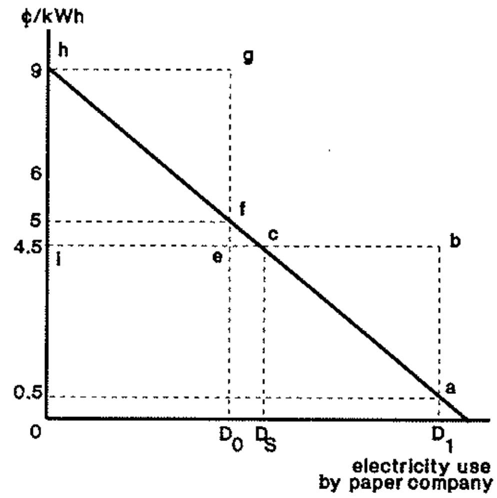
What happens in the case just presented is that the US mill continues to enjoy the implicit 4¢ subsidy that was always there. What is new is the activity of cogeneration, on which it makes a profit of 1¢/kWh. Should it be denied the possibility of earning this profit? Does the existence of this profit pose a threat to Canadian and other non-US producers? Seen in this light, the phenomenon of crosshauling does not look bad at all. One should realize, of course, that in the presence of the "subsidy" to industrial energy use, the pulp and paper mill would in all likelihood simply forgo the option of cogenerating if crosshauling were not allowed. Thus we have here a case where, in the presence of the subsidy to industrial energy, society is better off with crosshauling than without crosshauling.

This does not, however, make it any easier for Canadian pulp and paper mills that are called upon to compete with New England mills enjoying such treatment. There can be no doubt that the "crosshauling profit" leads to a reduction in the effective cost of the energy used by the firm. The reasoning is quite simple. Each extra unit of energy consumed by the pulp and paper firm gives rise to the (actual or potential) production of α units of energy through cogeneration. The profits that the firm makes on the sale of these units have to be taken into account (as an offset to its direct costs) as it decides on the scale of its operations — more specifically, as it decides on the level of its energy use. Without cogeneration, the firm equates its own electricity demand price to the industrial electricity rate that it has to pay. With cogeneration, the firm equates its demand price to the industrial rate minus the full profit that it makes by selling α kWh of cogenerated energy to the utility at the relevant rate (in our example, a rate of 9¢ /kWh).

Suppose that the firm's direct cogeneration cost is in fact 8¢ and that α is equal to 1.5. For each extra kWh that the firm demands (at 5¢) it gets to sell 1.5 kWh at a profit of 1¢ each. Thus its effective marginal cost per incremental kWh is reduced from 5¢ to 3.5¢.

This same example can be used to show how crosshauling can lead to very extreme results. Suppose the paper mill's direct costs of cogeneration were 6¢ instead of 8¢. Then its profits on the sale of cogenerated energy would be 3¢ (= 9¢ - 6¢) per kWh, and since it gets 1.5 units of cogenerated energy for each extra unit it demands, it has a cost saving of 4½¢/kWh demanded. Thus, its effective marginal cost is only 0.5¢ (= 5.0¢ - 4.5¢)!!

A case as extreme as the one just presented would surely give Canadian paper mills plenty of cause for complaint. But, perhaps surprisingly to some, there is still an overall social gain involved, using standard techniques of applied welfare economics. The true social marginal cost of energy demanded by the paper mill is in this case 4.5¢. This comes from a direct cost of 6¢ together with an "externality" of 1.5¢. This "externality" in turn comes from the sale of excess energy of 1/2 kWh for each kWh demanded by the paper mill, at a profit of 3¢/kWh. The social optimum is reached when the paper mill uses cogenerated energy up to the point where its marginal demand price is 4.5¢. When, with crosshauling, the paper mill's energy use is carried to the point where its marginal demand price is 0.5¢/kWh, there is an inefficiency cost (triangle *abc* in Figure 1) associated with carrying demand beyond the point of a 4.5¢ demand price. However, the gain from cogeneration consists of a rectangle (*eghi*) whose base is equal to energy consumption without cogeneration (marginal demand price = 5¢/kWh) and whose height is the 4.5¢ (= 9¢ - 4.5¢) saving in social cost of generating this amount of kWh. In addition there is a gain of a triangle of benefit (*fec*), entailed in carrying demand from the point where demand price is 5¢ to the point where demand price is 4.5¢. Typically these social gains from cogeneration will exceed the triangle of loss induced by carrying demand from the point of a 4.5¢ demand price, up to the point of a 0.5¢ demand price. Note that the maximum social loss on each of these units is 4.0¢, while the social gain on the pre-existing amount demanded is 4.5¢ for each and every unit.



Utility's avoidable cost = 9¢/kWh
Paper mill's direct cost of cogeneration = 6¢/kWh
Subsidized price at which paper mill can buy energy = 5¢/kWh
Social marginal cost of electricity demanded by paper mill = 4.5¢/kWh
Social optimum demand = D_S
Paper mill's demand with no cogeneration = D_0
Paper mill's demand with crosshauling = D_1

Figure 1: Cogeneration with crosshauling

The Social Dilemma (with a Subsidized Industrial Rate)

The two simple examples that we have just gone through are quite sufficient to delineate the dilemma that faces policy makers who are aiming at achieving the best result possible, from the social point of view. We will return later to the case where these policymakers face no constraints or restrictions, but for the moment let us stick with the (quite realistic) case of a subsidized industrial rate (5¢ in our example).

In this case, it is quite easy to recognize that the true cost to society of cogenerated energy is its direct cost to the pulp and paper firm plus the "externality" that comes from the sale of "excess energy" to the utility at a price that reflects the utility's own long-run avoided cost. This is what we calculated in the immediately preceding case (with direct cost = 6¢) to be 4.5¢/kWh. The task of the policymakers, assuming they seek the social good, is to make the owners and managers of the pulp and paper firm perceive *this* cost as their own. This is easy to accomplish for the case at hand; one simply rules out crosshauling and allows the paper mill to sell only its "excess energy" to the utility. Then, for each extra kWh of energy that it uses, it perceives the direct cost of that energy plus an "externality" from the sale of $(\alpha-1)$/kWh to the utility firm at a price (here 9¢) which we presume to reflect long run avoided cost. (It does not matter if the utility actually delivers 4 million kWh to the paper firm, and receives, say, 6 million in cogenerated energy from that firm; the important thing is that in this case the effective payment would be 9¢/kWh on the *net* amount (here 2 million kWh) received.)

Actually, giving pulp and paper mills free rein to cogenerate subject to only two constraints (that they are paid only for net deliveries, and when they are paid it is at a rate reflecting long-run avoidable cost) turns out to be a *generally* optimal policy, so long as no other distortions are present. In particular, it would be the optimal policy if there were no subsidized industrial rate.

The subsidized industrial rate creates trouble in two important classes of cases. First, there are cases like the one just examined (direct cost = 6¢) where when joined with crosshauling it leads to the paper firm's carrying energy use beyond the socially optimal point. And second, there are cases like the first one examined (direct cost = 8¢) where, in the absence of crosshauling, the pulp and paper firm simply decides to stick with the subsidized rate and avoid cogenerating altogether. This is an unfortunate decision from the social point of view because in this case the effective social marginal cost of cogenerated energy is 7.5¢.

The social policy dilemma is that by allowing crosshauling one avoids the problems posed by the second class of cases, but at the cost of generating potentially huge transfers from the rest of society (either the utility itself, or its customers, or the taxpayers) to the pulp and paper firm in the first class of cases.

The Essence of the Problem

The easiest way to look at the analytical problems connected with cogeneration-cum-subsidy is to think in terms of the "externality" provided by cogeneration. We are assuming here that the industrial processes of pulp and paper making are such that there is a link between the energy consumed by a process and the amount of cogenerated energy that can economically be extracted as a "by-product" of that process. Let the amount of by-products of energy produced be α per kWh of energy demand by the process in question. Simultaneously, let P_c be the direct cost per kWh of such by-product energy.

A firm with $\alpha > 1$ has the potential to be self-sufficient in energy and simply sell its excess energy. If it can effectuate such sales at a price P_v, it will view its effective cost of energy as $P_c - (\alpha-1)(P_v-P_c)$. For the energy it uses it incurs a direct cost of P_c, but it has an offsetting gain from the sale of $(\alpha-1)$ units at P_v.

A firm with $\alpha < 1$ will see its cost of energy as a weighted average of its cost per kWh via cogeneration (P_c) and the price (P_b) at which it can buy the supplemental energy it needs. This weighted average is $\alpha P_c + (1-\alpha)P_b$.

Society faces a certain cost of providing energy by expanding its standard energy facilities. Suppose this is also P_v (i.e., the price at which cogenerators can sell energy to the utility network). For most users, the social cost of the energy will be simply P_v. But for cogenerators the social cost must be reduced by the "profit" $\alpha(P_v-P_c)$ that is created when energy is sent to a user that can thereby generate a multiple α of that energy at a direct cost of P_c per kWh.

Our first observation is that, under all circumstances, the firm with $\alpha > 1$, selling just its "excess energy," will have a perceived cost equal to the social cost. That is:

$$P_c - (\alpha-1)(P_v-P_c) = P_v - \alpha(P_v-P_c).$$

Our second observation is that the firm with $\alpha < 1$ will also perceive its cost as being equal to the social cost, but only if the price at which it buys its required supplementary energy (P_b) is P_v. Thus we have

$$\alpha P_c + (1-\alpha)P_v = P_v - \alpha(P_v-P_c).$$

We therefore have three different ways of defining P_d^*, the demand price that reflects the true social cost of cogenerated energy.

(i) $P_d^* = P_v - \alpha(P_v-P_c)$

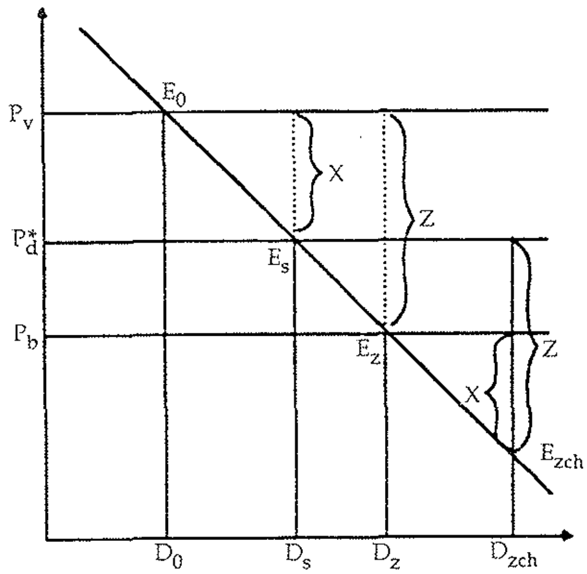
(ii) $P_d^* = P_c - (\alpha-1)(P_v-P_c)$
(iii) $P_d^* = \alpha P_c + (1-\alpha)P_v$.

I am aware that saying the same thing in different ways can be regarded as redundant, but in this case each way has its own interpretation, its own meaning. (i) tells us that society sees its energy cost as its avoided cost, corrected by the "profit" that comes from cogeneration, when it is a cogenerator that takes the energy. (ii) tells us that when a cogenerator with $\alpha > 1$ looks at the cost of providing its own energy, it comes to the same answer, so long as it can sell its excess energy at society's price P_v. (iii) tells us that a cogenerator with $\alpha < 1$ will also go to the social optimum point, but only when the price that it pays for purchased energy is equal to the social cost P_v.

The fact that we can look at P_d^* from so many angles is a great help in simplifying the analysis of cogeneration in the presence of an actual or implicit subsidy, through an industrial rate or an otherwise defined buying price P_b at which the cogenerating firm can buy energy from the utility network. Viewed in this way, we have two key prices, P_v and P_b, which presumably do not vary from one cogenerating firm to another, within the market area of a single electric utility. The difference between these two prices is the subsidy Z.

Matters are different when it comes to P_d^*, for it does vary from firm to firm among the actual and potential cogenerators in an area, depending on their specific characteristics, as embodied in P_c and α. It is convenient to think of the quantity $X_j = \alpha_j(P_v-P_{cj})$ as the "social externality" which is perceived when energy is used by cogenerator j.

With the aid of these few concepts, I believe that all relevant cases can be summarized in two simple diagrams. Figure 2 and Figure 3 differ in that in Figure 2 the subsidy Z is greater than the social externality X. This implies that P_b is less than P_d^*. Under these circumstances no cogeneration will take place if only excess energy can be sold at P_v. This is true regardless of whether X is small because α is well below unity, or because P_c is close to P_v with $\alpha > 1$. It is not the individual characteristics of α and P_c that matter, but only the



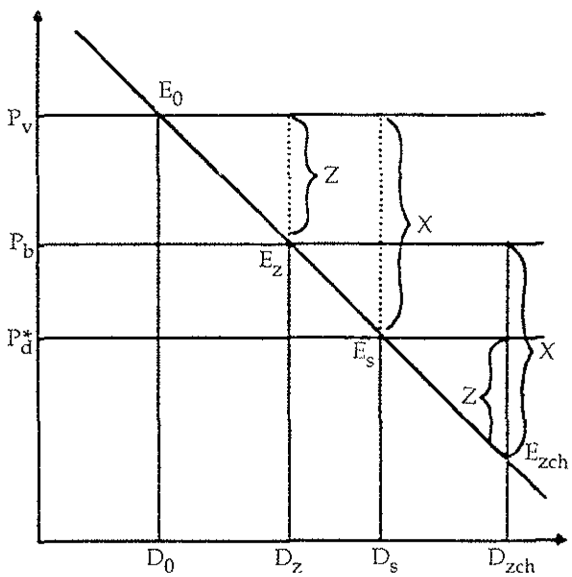
Equilibrium with no subsidy, no cogeneration= E_0
Social optimum with cogeneration = E_s
Equilibrium with subsidy, no cogeneration = E_z
Equilibrium with subsidy and crosshauling = E_{zch}
Subsidy = Z
Social externality = X

Figure 2: Four equilibrium positions, $P_b < P_d^*$

"package," $\alpha(P_v-P_c)$. This is the critical feature that enables the analysis to be simplified.

Figure 2 shows four potential equilibrium positions: E_0, which is the no subsidy, no externality equilibrium; E_s, which is the socially optimum point in the presence of the externality X; E_z, which is the equilibrium with subsidy but with no cogeneration, and E_{zch} which is the equilibrium with the subsidy when crosshauling is permitted.

The analysis here is straightforward. If crosshauling is not permitted, cogeneration will not take place. This is because the subsidized price of energy to the firm is below its effective cost of energy P_d^*, when only excess energy can be sold. Thus the equilibrium will either be at E_z (if crosshauling is not allowed) or at E_{zch} (if crosshauling is allowed). It is important to note that, with a linear demand for energy curve, the efficiency cost entailed in



Equilibrium with no subsidy, no cogeneration= E_o
Social optimum with cogeneration = E_s
Equilibrium with subsidy, no cogneration = E_z
Equilibrium with subsidy and crosshauling = E_{zch}
Subsidy = Z
Social externality = X

Figure 3: Four equilibrium positions, $P_d^* < P_b$

being at E_z versus E_o is identical to that of being at E_{zch} versus E_s. What is different is (1) that society perceives a gain in moving from E_o to E_s (equal to $P_vE_oE_sP_d^*$) and (2) that society ends up paying a greater subsidy/ transfer to the cogenerating firms at E_{zch} than at E_z. The extra subsidy is simply Z times (D_{zch}-D_z). From an efficiency point of view E_{zch} is therefore always preferable to E_z, but E_s is naturally always preferable to E_{zch}.

Figure 3 is based on an externality X that is larger than the subsidy Z. Here P_d^* is below P_b, guaranteeing that cogeneration will take place even if crosshauling is not allowed. Huge gains are attainable by going from E_z to E_s. These stem from the elimination of the welfare cost of the subsidy, plus the cost-saving trapezoid $P_vE_oE_sP_d^*$. If, now, crosshauling is allowed, the firm will go to E_{zch} and society will once again incur the triangle of welfare loss due to the subsidy. In addition, those who pay the subsidy will be worse off in the amount Z times D_{zch}, a vast sum considering that, in spite of the existence of the subsidized price P_b, no subsidy at all is paid at the equilibrium point E_s, which is completely achievable simply by the utility's buying only "excess energy" from the cogenerating firm (i.e., by ruling out crosshauling).

Some Evidence from Canada

In this section, I examine some evidence from Canada, assembled by the Special Projects Branch of Industry and Science Canada.[1] First, consider the size of the implicit subsidy Z (the difference between the long run avoided cost of energy (P_v) and the industrial rate (P_b)), at which pulp and paper mills can buy energy from the network. These rates are shown in Table 1 for seven provinces.

It is clear that, with the exception of New Brunswick, Canada's subsidies to industrial users are far less than that (40 mills) of the example presented in section one of this paper, which may be representative of some operations in some of the northeastern US states). Since US utilities pay taxes, while their Canadian counterparts do not, the subsidies implicit in the Canadian industrial rates are not strictly comparable to the US subsidies. Adjusted for the taxes that the utilities could pay if taxable, the Canadian subsidies are: Alberta, 12.3 mills; British Columbia, 23.2 mills; Manitoba, 17.1 mills; New Brunswick, 36.9 mills; Ontario, 10.6 mills; Quebec, 21.8 mills; and Saskatchewan, 2.0 mills. This creates a presumption that for Canada the case illustrated in Figure 3 may be more common than the case in Figure 2.

A survey of 29 pulp and paper mills shows that this is indeed so. Of the 29, a total of 23 had potential output of cogenerated electricity that was greater than their own respective

1/ Further details are provided in Burns *et al.* (1993), *Cogeneration: Potential Impacts on the Competitiveness of Canada's Pulp and Paper Industry*, see below, pp. 107-13.

Table 1: Industrial Rates (P_b) vs. Long-Run Avoided Costs of Energy (P_v) in Seven Canadian Provinces (mills per kWh)

	P_v	P_b	Z (=Subsidy)
Alberta	35.0	29.7	5.3
British Columbia	47.5	38.6	8.9
Manitoba	35.0	28.4	6.6
New Brunswick	62.9	38.6	24.3
Ontario	50.0	49.4	0.6
Quebec	45.0	36.7	8.3
Saskatchewan	42.5	49.0	-6.5*

* In Saskatchewan, industrial users pay more than long-run avoided cost, thus effectively subsidizing some other types of users.

demand. For these cases, we have $\alpha > 1$, and are thus assured that a policy of allowing cogeneration without crosshauling (i.e., permitting only the sale of **excess** energy to the utility network) would lead to a socially optimal allocation of resources (providing the firm in question found it profitable to cogenerate). An examination of the estimated cost of cogeneration shows that, in these 23 cases, all but one of the pulp and paper firms would indeed find cogeneration profitable. Thus, we have 22 cases in which a policy focused on cogeneration without crosshauling would lead to optimal results.

The Special Projects Branch Survey found that there were six cases with $\alpha < 1$. Nonetheless, in all of these cases the direct costs (P_c) of cogeneration were low enough to provide a weighted-average cost of energy (P_d^*) that was less than the subsidized industrial rate (P_b). So in all of these cases the firms would willingly take on the business of cogeneration. They would not, however, find it in their private interest to go to the socially optimum point E_s. Rather, they would end up carrying production beyond this point, but not as far beyond as they would go if crosshauling were allowed.

To see this, recall that firms with $\alpha < 1$ perceive their energy costs to be $\alpha P_c + (1-\alpha)P_b$. They will go to the optimum point when $P_b = P_v$, but this condition is not met in the six cases at hand. By adding and subtracting $(1-\alpha)P_v$ to the above expression, we can rewrite perceived energy costs as $\alpha P_c + (1-\alpha)P_v + (1-\alpha)(P_b - P_v) = P_d^* - (1-\alpha)Z$. Since we know that with crosshauling the firms will go to the point where demand price is $P_d^* - Z$, we conclude that the six sample firms in question will go beyond E_s, but will not go as far as E_{zch}. A triangle of efficiency cost will be present; its height will be $(1-\alpha)Z$, hence it will be smaller than the triangle of efficiency cost (of height equal to Z) that emerges without cogeneration.

Evaluating the situation that would emerge in the 29 pulp and paper mills included in the survey, we have first, that 22 of them would move from a present situation of significant efficiency cost (subsidy triangle of height Z) to a situation of zero efficiency cost (corresponding to E_s in Figure 2). For all these firms there would also be a gain of a trapezoid (of type $P_vE_oE_sP_d^*$) stemming from a reduced cost of producing energy. Second, we have six firms that would also produce a trapezoid of gain from reduced costs of generation. They would not, however, go to the optimum point E_s, but to a point somewhere between E_s and E_{zch}. For them the triangle of efficiency costs would not be eliminated, but it would be reduced vis-a-vis the starting point at E_z (with no cogeneration).

One lone firm of the 29 would stay at the starting point E_z. For that firm there would be no change, either plus or minus, as a result of allowing cogeneration without crosshauling. The score card for adopting this policy is thus 28 cases of gain, together with just one of no change, compared with the starting point at E_z. There are no cases in which one ends up in a worse position, from an efficiency point of view, than the starting point.

The Issue of Crosshauling

It thus appears that the policy dilemma described earlier is not a very serious case for the Canadian authorities as they contemplate the possible implementation of a set of rules governing cogeneration. Considering the no-crosshauling equilibrium as the new starting point, we have nothing but net social losses as we move from there to E_{zch}, in all cases except one. Only in the case of the lone plant that stayed at E_z would there be a gain in moving to E_{zch}. That gain would be the trapezoid of cost reduction $P_vE_oE_sP_d^*$ for the plant in question.

Looking in the opposite direction, the move to crosshauling would generate 22 full efficiency triangles (of height Z), plus six trapezoids (created by enlarging six triangles of height (1-α)Z into six larger triangles of height Z).

An added argument against permitting crosshauling concerns the implicit transfers involved. These transfers generate benefits for the pulp and paper mills, at the expense of the electric utility, and/or its other customers, and/or the general taxpaying public. Let us start again at the "present" position E_z, then move to an intermediate (and preferred) position of cogeneration without crosshauling, and finally contemplate the further step of permitting crosshauling.

Starting out at the initial point Z, we have for the 29 sample firms 29 subsidy rectangles, each equal to ZD_z. As we move to cogeneration without crosshauling, we totally eliminate 22 of these rectangles, as 22 firms move to D_s and stop buying subsidized energy. One rectangle (that of the firm which chooses not to cogenerate under these rules) remains the same, while six others may get either larger or smaller as the firms move to a point on their demand curves somewhere between E_s and E_{zch}, but now buy only a fraction of their energy at the subsidized price.

At the next step, as crosshauling enters the picture, all 29 firms move to E_{zch}. The one rectangle that stayed put at the earlier step now jumps to a size equal to ZD_{zch}. The six rectangles whose bases equalled α times a quantity somewhere between D_s and D_{zch} now also get bigger. Finally, to cap it all, the 22 firms whose transfer receipts were reduced to zero at the previous step now see them mushroom all the way to ZD_{zch}.

Weighing the merits and demerits of transfers is not part of the business of applied welfare economics. In standard efficiency analysis we simply view A's gain as offsetting B's loss. Gains are attributed to society only when the winnings of the winners more than offset the losses of the losers. The gains dealt with in the preceding section were net gains of this type. Implicit in the analysis was an attitude of implicit neutrality with respect to the transfers involved. They were, in short, given neither merits or demerits.

Here we must consider whether we want to step back from the neutrality of standard applied welfare economics and "take a view" (be it favourable or unfavourable) of the transfers involved in the cases we have studied. My view is that these fall in the category of arbitrary and capricious transfers, in which no substantial case can be built that society wishes to benefit the specific beneficiaries involved, to the detriment of those who are called upon to pay.

In other setups, I have suggested that we as economists might assign a sort of "shadow cost" to arbitrary and capricious transfers. This might be very large (as it appears to be in society's demonstrated attitude to the transfers generated by criminal activity), or quite modest (say only 10 or 20% of the amount involved) in cases where the transfer emerges simply as the outcome of otherwise unexceptionable public decisions. My own inclination is to think in terms of a relatively modest "shadow cost" of this type as being acceptable in the present case. Taking such a shadow cost of transfers into account further reinforces the strong case that one can make on pure efficiency grounds, in favour of a policy fostering cogeneration but ruling out crosshauling.

Comment: JOSEPH A. DOUCET

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Introduction

I am very pleased to have this opportunity to comment on Professor Harberger's paper. My remarks are organized as follows. The first section highlights what I see as the important contributions and main conclusions of Harberger's paper. In the second section I make a few technical comments concerning his modelling of industrial cogeneration. The third section presents a very brief overview of Hydro-Québec's cogeneration policy and the current status of Québec's cogeneration market. This is used in the fourth section to suggest some policy considerations for the future development of the Canadian (and Québec) markets.

1. Overview of Harberger's Paper

Cogeneration is a process by which steam and electricity are produced in tandem. This process offers the potential for expansion of generation capacity and increased energy efficiency for industry, and has been the object of a great deal of interest over the last 10 years. Increased energy efficiency, short construction lead times, and increased use of natural gas are a few of the factors that have contributed to the interest in cogeneration.

At least two facets of the cogeneration problem can be highlighted. First, the development of cogeneration potential raises the question of the efficient expansion of electricity generation capacity. Over the last decade non-utility power producers have begun to play an ever increasing role in electricity supply in the United States. This evolution has not been as pronounced in Canada, though utility and industry interest is increasing.

The second important issue is the question of subsidies and industrial policy, which is especially relevant for the pulp and paper industry. Because of the energy input in pulp and paper, subsidies through reduced industrial energy prices are very important in maintaining the competitiveness of the industry.[1]

These two facets of the problem are brought together in Harberger's paper in a compact analysis. In light of the Public Utility Regulatory Policies Act (PURPA) passed in 1978 in the US, this focus is entirely appropriate.[2] Note that the two facets of the problem described above are necessary conditions for Harberger's analysis. I.e., as clearly stated in the paper, the problems do not arise if there are no subsidies. In this case, crosshauling can be allowed without any loss of efficiency.

What really should be retained from Harberger's analysis is the interaction that exists between the opportunity to crosshaul and incentives to cogenerate. In effect, the problem faced in the US is the distortion of energy use created by the opportunity to crosshaul in the presence of a subsidy. Crosshauling can simply amplify the efficiency loss of a subsidy. In order to remedy this, Harberger's solution is to choose to either (a) allow cogeneration, even with a subsidy, but don't allow crosshauling; or (b) allow crosshauling, but eliminate the subsidy. This will in effect eliminate any incentive to crosshaul.

The above, it should be noted, is the solution for the situation where cogeneration exists, as in the US market. Harberger notes that if subsidies are present, and must be kept in place for political reasons, it may be neces-

1/ In the case of Québec, a much more important target of subsidized electricity has been the aluminium industry (Bernard and Bélanger, 1991). However, this industry does not represent cogeneration potential. The pulp and paper industry in Québec does not benefit from preferential electricity tariffs over other industries.

2/ See Bolle (1991) for an overview of the economics of PURPA.

sary in some cases to allow crosshauling in order to preserve the incentive to cogenerate. This is because the loss of efficiency from higher than optimal consumption (due to the subsidy) is more than offset by the benefits of cogeneration, which is undertaken because of the opportunity to crosshaul.

In other words, cogeneration with crosshauling can be *welfare increasing* as compared to a situation with no cogeneration at all. This point is important for two reasons. First, it offers some insight into the potential benefits of PURPA with respect to the development of the US cogeneration market. Oft criticized, the incentives contained in PURPA may be justified in light of the analysis provided by Harberger. Second, in terms of the Canadian context, where cogeneration markets are less developed, the message might be that crosshauling could contribute to growth in cogeneration and increased social welfare. This last statement would have to be analyzed more carefully in light of the data gathered by Industry and Science Canada, to which Harberger referred, that seem to suggest that this case is not empirically relevant for Canada.

2. Technical Comments

This section provides a critical discussion of some modelling issues related to Harberger's paper. Note first that both facets of the cogeneration problem mentioned above, expansion of generation capacity and industrial electricity subsidies, relate to *long-run* decision making. This is also the framework of Harberger's paper, in the sense that a pulp and paper company does not face a capacity constraint. Hence, it must choose the optimal plant size or equipment capacity, as well as the optimal utilization factors for the plant. These issues are not dealt with in Harberger's model.

Since the model is one of long-run decision making, and the cogenerator's decision variable is energy use, there is an *implicit* relationship between energy use and plant size or capacity. The first question that comes to mind is whether or not this modelling assumption might hide some of the subtleties of cogeneration or pulp and paper production. For instance, consider the demand curve in the graphs. This is the demand for energy use and its height is the "value-in-use" to the pulp and paper company of any particular unit. Of course, the curves in the figures are drawn for expositional purposes, but it would be interesting to consider how well behaved the demand curve is when various elements of long-run planning (plant size, cogeneration technology, fuel choice, etc.) are varied. Also, it would seem that P_c, the unit cost of energy cogenerated by the pulp and paper company, might not be constant over all values of energy use.

Another illustration of the above preoccupation concerns the technical coefficient α. This is defined as the ratio of the number of units of energy cogenerated to the number of units of energy used. α is treated as a technical coefficient (possibly different from one plant to another) which remains constant as energy use varies. What are the implications of the assumption of a constant α?

At least four different factors are affected by this assumption, namely: the energy use and the steam use of a pulp company, and in terms of cogeneration outputs, energy production and steam production. The assumption of a fixed technical coefficient really means that energy use and energy production both have to vary proportionally, but this requires that the pulp company's production, and plant size, vary proportionally with the cogeneration plant's size. One reason that this might be the case, alluded to in the definition of α, is the use of biomass (wood chips and sawdust) as a cogeneration fuel. Under some circumstances availability of this fuel could be a function of a pulp company's production, and hence cogeneration production could vary proportionally with production. However, this need not be the case. For instance, availability and use of natural gas should allow more flexibility in the selection of cogeneration plant size. This might "unbundle" the proportional link between energy use and cogeneration production.

The incentives in PURPA lead us to believe that in the US cogeneration plant size might not vary proportionally with pulp and paper plant size. These incentives have at times led to overproduction of electricity, at the expense of the potential high conversion efficiency of cogeneration. In the case of "PURPA machines," cogenerators produce minimal amounts of steam and achieve profitability through electricity sales to the utility. It has also been suggested that some pulp and paper plants cogenerate more than is necessary for their internal needs (in effect "wasting" the steam), in order to profit from the sale of electricity to the utility through crosshauling. A constant α does not capture this type of situation.

What is important in the above discussion is the idea that accounting for a variable α might enrich the model and better reflect the optimal plant capacity decision underlying the long-run planning process of interest to policy makers. The qualitative results may not change, but there could be modifications to the areas of welfare losses and gains that would alter the quantitative conclusions. More careful analysis would be necessary to bear this out.

3. Cogeneration in Québec

This section will briefly outline Hydro-Québec's current policy regarding cogeneration and suggest how some of Harberger's policy conclusions should be viewed in this market.

Hydro-Québec considers cogeneration to be one form of independent power production (IPP). Hydro-Québec's selection of IPP is based on its capacity expansion plans; electricity produced by IPP must be cost effective vis-à-vis the utility's alternative expansion plans (i.e., the utility's long run marginal cost). In addition, the utility requires that cogenerators sell to it **all** of their energy production. In effect, crosshauling is mandatory.

The result of this policy is a decoupling of the two markets of cogeneration production, steam and energy. In practice, cogeneration projects are often proposed by an independent developer with a firm contract for the sale of its steam to a third party. Cogenerators are therefore not themselves large consumers of electricity, and the crosshauling is not completely analogous to the cases in Harberger's paper.[3]

Independent power production for sale to the public utility is a relatively new phenomenon in Québec. Hydro-Québec first adopted a policy of electricity purchase from IPPs in 1987. The 1990-1992 corporate plan (*Plan de développement*) called for IPP capacity of 390 MW by 1995. A first call for proposals in 1991 resulted in 87 projects being submitted, with a total capacity of 8,253 MW. The goal has now been increased to 760 MW for 1996, of which 140 MW is small hydro and 610 MW is cogeneration and waste incineration. To put this into perspective, Hydro-Québec's planned generation capacity in 1996 is approximately 37,000 MW so IPP still plays only a relatively small role.

The current status of IPP (as of May 5, 1993) is as follows. There are 7 IPPs operating for a total of 43 MW. One of those involves a 30 MW plant, run by a subsidiary of a pulp and paper mill in the Eastern Townships. There are 17 signed contracts, two of which are cogeneration, for a total of 279 MW. Projects in the negotiation phase number 68 IPPs of which 9 are cogen, but the latter represent 1,034 MW out of a total of 1,436 MW[4] (Hydro-Québec, 1992; Hydro-Québec, 1993). Clearly, cogeneration dominates (in terms of capacity) current IPP projects in Québec.

It may seem curious, especially given the US experience, to note the absence of cogeneration in the pulp and paper industry in

3/ The one cogeneration project currently in operation in Québec is a wholly owned subsidiary of a paper mill, with the mill as its only steam client. The cogeneration facility is operated independently of the mill. Most of the other projects currently being evaluated have been proposed by independent producers.

4/ The total capacity of projects under consideration is larger than the utility's objective as past experience has shown that not all projects will be undertaken.

Québec. In fact, none of the provinces 60 pulp and paper mills is directly involved in cogeneration. Several reasons can be given. First, the absence of any PURPA-like legislation is fundamental. In fact, there is no legislation (federal or provincial) favouring or encouraging the development of cogeneration capacity. Second, although Hydro-Quebec is willing to pay the long-run avoided cost for cogenerated power, that cost is roughly in the neighbourhood of 4.5¢/kWh. At this rate, it is not surprising that cogeneration capacity is not as developed as in some areas of the US. Third, natural gas, a fuel of choice in many cogeneration applications, is less available in Québec than in many US markets. Fourth, a lot of pulp and paper mills in Québec traditionally developed their own sources of hydroelectric production. The pulp and paper industry in Québec is currently studying cogeneration in the hope of using this to stimulate the economic revival of the industry, especially in the face of US competition.

The growing interest in cogeneration, as evidenced in the number of project submissions to Hydro-Québec's IPP program and the pulp and paper industry's potential, makes Professor Harberger's analysis especially relevant in Québec.

4. Policy Considerations and Future Research

For Canadian policy makers the question of interest is how can Harberger's analysis and the US experience help define or direct policy here? In this light, it is useful to reiterate the point made in section 1. Harberger's most important contribution in this paper is probably the observation that, all things being equal, cogeneration with crosshauling is superior (socially) to no cogeneration at all. Given what has been said about the developing cogeneration market in Québec, and Hydro-Québec's policy of "mandatory crosshauling," Harberger's conclusion might be seen as reassuring.

By decoupling the production and usage issues related to cogeneration, Hydro-Québec avoids some of the incentive problems that PURPA has engendered in the US. Specifically, Québec's policy will not result in the phenomenon of "PURPA machines." By treating cogeneration as another supply resource and paying the utility's long-run marginal cost Hydro-Québec does not provide incentives for the over-use of energy. Through its policies, however, Hydro-Quebec has fostered a market structure that will result in having cogeneration undertaken, not by the pulp and paper mills, but by third parties. If PURPA has resulted in too much cogeneration in the US, then could Hydro-Québec's policy result in too little? It is not at all obvious that the pulp and paper mills will be able to catch up, in the sense that they would hope, to the US mills. It may be necessary to search for some middle ground that would benefit the pulp mills yet avoid the PURPA excesses.

Another aspect of the pricing issue concerns the underlying philosophy of utility tariffs. PURPA basically obliges the utility to buy energy from the cogenerator at the cost of new base-load capacity (i.e., **long-run marginal cost**). However, even in the absence of explicit subsidies to industry (i.e. cross-subsidization through tariffs), most North-American utilities set tariffs based on **average cost** of installed capacity. Since these utilities are in the position of increasing average costs (this is certainly the case for Hydro-Québec), it is clear that marginal cost will be higher than average cost, and hence the incentive to crosshaul will be present. A more efficient structure for the cogeneration market might then be one more argument in favour of a move towards marginal cost pricing.[5]

Conclusions

Harberger's paper, in spite of the apparent simplicity of the graphical analysis of welfare results, is in fact a very compact treatment of both individual cogenerator and social welfare

5/ Other arguments in favour of marginal cost pricing can be found in Bernard and Chatel (1985).

results. This in itself is a significant contribution. In addition, the paper highlights the inter-relationship between the incentives of subsidies and crosshauling. It is especially interesting to understand how society can benefit from crosshauling, even in the presence of some subsidies, because of the resulting benefits from cogeneration. This is probably the most important conclusion of the paper as it relates to the developing Canadian cogeneration market.

The most important questions for Québec relate to the market structure that will result from Hydro-Québec's policy of mandatory crosshauling and treatment of cogeneration as an IPP. It is not clear how this policy will affect the pulp and paper industry in the province, but it does not appear that the industry will benefit from cogeneration in the same way as has been the case in the US.

References

Bernard, Jean-Thomas et Gérard Bélanger (1991) 'Aluminium ou exportation: de l'usage de l'électricité québécoise.' *Canadian Public Policy — Analyse de politique* XVII:2:197-204.

Bernard, Jean-Thomas and Josée Chatel (1985) 'The Application of Marginal Cost Pricing Principles to a Hydro-Electric System: the Case of Hydro-Québec,' *Resources and Energy* 7:4:353-75.

Bolle, Friedel (1991) 'On the Economics of PURPA Auctions.' *Energy Economics*, April, pp. 74-80.

Doucet, Joseph A. (1992) 'Incentives for Cogeneration Dispatchability: A Priority Purchase Approach,' Cahier 92-20, Groupe de recherche en économie de l'énergie et des ressources naturelles, Université Laval.

Harberger, Arnold C. (1992) 'Economic Analysis of Cogeneration: The Case of Pulp and Paper Mills,' mimeographed paper.

Harberger, Arnold C. (1993) 'Cogeneration of Electric Energy: The Case of Pulp and Paper Mills,' *This Volume*, pp. 90-98.

Hydro-Québec (1990) *Conditions d'achat de l'électricité des producteurs indépendants.*

Hydro-Québec (1992) *Suivi du plan de développement 1990-1992, Horizon 1999; Rapport Particulier: La production privée d'électricité.*

Hydro-Québec (1993) Communiqué de presse: 'Hydro-Québec poursuivra ses négociations avec les producteurs privés jusqu'au 15 décembre 1993.'

Reinsch, Anthony E., Ellen F. Battle (1987) *Industrial Cogeneration in Canada: Prospects and Perspectives*, Canadian Energy Research Institute Study No. 24.

Comment: MEL KLIMAN

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Formal modelling in economics, despite its analytical power, has always suffered from a large gap in the space between generic models of production/consumption and large detailed models of the sort used in macroeconometrics, programming, or computable general equilibrium analysis. In applied economics, one often wants a model that takes account of some specific facts not contained in the generic models, but which remains familiar and intuitively comprehensible. Professor Harberger's application of microeconomic and welfare theory has been situated in that in-between position and has shown itself to be highly useful in understanding various important issues, such as the economics of cogeneration.

The essence of Harberger's analysis of cogeneration is familiar: a subsidy, in this case the pricing of industrial power at less than marginal cost, results in a net loss of economic welfare. The payoff of the analysis is in how it shows that the particular structure of the cogeneration market has implications for the welfare outcomes. In particular, if the cogenerater produces electricity at lower cost than the utility does, it is important that the utility's selling price to industrial customers be above the cogenerated cost. Also interesting, I think, is the demonstration that familiar predictions do not necessarily apply in a second-best world. In professor Harberger's presentation we saw first that if energy can be cogenerated at a unit cost less than the subsidized price of electricity, this will eliminate the deadweight loss — an intuitively reasonable result. It says simply that if it is possible to produce electricity at or less than the subsidized price, substituting this low cost service for the subsidized higher-cost service will save resources and the decision maker will now be responding to a real price rather than an artificial one.

Then we saw that cross-hauling introduces a second subsidy and therefore brings back a deadweight loss. However, another case shows that the welfare loss of a very large initial subsidy ($P_b<P_d^*$) can actually be reduced by allowing cross-hauling. That is, in this case the existence of the second subsidy due to cross-hauling actually improves rather than worsens the outcome. Harberger points out that the configuration of parameters producing this last outcome is probably unlikely. Nevertheless I think it's useful to know of that kind of result. We tend to throw around the concept of "second-best" in very general ways without working out its implications in specific cases.

Another example of a potential 'second-best surprise' arises in the cases Harberger considered in an earlier draft of his paper in which the cogeneration purchase price is arrived at in an auction process. One assumes that society will always gain from having the price bid as low as possible. But Harberger shows that there may be an efficiency loss if that occurs. In other words, you can have a price that is too low, because you may lose the gains that can come from cogeneration.

Despite the enjoyment that one can take from this analysis, it is important to be aware of its limitations. For instance, I found somewhat baffling its lack of consideration of what happens outside the pulp mill. The impact of cogeneration on a pulp company is depicted in a straight-forward fashion in the diagrams, and Harberger asserts that the gains and losses for all of society can also be inferred from these same diagrams. In one respect this argument is convincing. When $\alpha>1$, cogenerated energy is delivered to the utility and, by implicit assumption, sold to other customers at the same prices they have paid in the past. Since these customers do not move along their demand curves, there are no triangles or trapezoids of gain-or-loss to be accounted for.

In another respect, however, there is something left out: the implications of the financing of the subsidies provided to the pulp mills. Harberger alludes to cross-subsidies from other customer-classes. If, for instance, residential customers are paying more than marginal cost for their electricity, they are suffering some loss-triangles that need to be accounted for in the analysis of the initial case, which considers the subsidy associated with P_b. The point is also relevant for the case of cogeneration without crosshauling, where $P_b>P_c$. Here the utility is no longer providing a subsidy to a pulp company on the electricity it consumes itself, which reduces the size of the total subsidy to industrial customers to be financed. This change — which occurs only for the cogenerator — may appear to be so small that it would not affect the rates charged to other customer classes. However, if one hypothesizes a case in which all of the pulp mills in Canada cogenerate their own power, it no longer looks so obviously negligible.

My own view of this as an analytical issue is that it is unnecessary to invoke the assumption of a cross-subsidy. The standard regulatory model in use involves average cost pricing, and there are jurisdictions in which regulators attempt to apply it even-handedly across customer classes. Average cost pricing often results in the utility's marginal cost being greater than price (though right now in Ontario we're in a period when that's not true). When MC>AC, an implicit subsidy is paid (to the extent that it needs actual financing) either by complicated transfers from government or by increases in debt and electricity prices over time as marginal generation capacity comes on stream. This would show up in Harberger's model as an increase in P_b, and in terms of static analysis would avoid the welfare effects associated with a cross-subsidy.

A second issue to keep in mind is that Harberger's analysis is one, admittedly substantial, chunk of the economics of cogeneration, his focus apparently motivated by an interest in the problem of crosshauling. Another part of the picture has already been referred to by Professor Doucet.[1] As a problem in long-run decision making, the pulp firm would in principle approach its cogeneration investment in a larger context, as a joint-product problem, simultaneously setting its output of steam and electricity in the context of both the pulp and electricity markets. Although Harberger does not explicitly analyze this long-run problem, his analysis seems to relate implicitly to that context as a result of the assumption of a fixed α. When a pulp company considers alternative points along its energy use demand curve, if it is also cogenerating, it must be increasing the size of its generation unit in order to keep α constant (no mention is made of the availability of excess generating capacity).

As a practical matter, this may be reasonable. I presume that much of the interest in cogeneration in the pulp-and-paper industry is based on the retrofitting of existing pulp mills. Thus, one can think of a pulp company's energy-use demand curve as being based on a plant of a given size, it then chooses an appropriate generating unit to go along with that plant, and α is then set. What is not allowed in the analysis, however, is any short-run movement along the curve due to price changes or any shifting in the energy demand curve due to changes in the pulp market.

Finally, I would like to refer to another issue raised by Professor Doucet, the emerging market structure for cogeneration. Since Ontario Hydro purchases only the net power from the non-utility generating units that are on line, it effectively does not allow crosshauling. However, as in Quebec, something new is emerging, namely third-party developers of cogeneration plants. In the present context, the power is sold to the utility, and steam is sold to a pulp and paper company. To my mind, there is a natural tendency for this type of arrangement to emerge, especially in the case of large generating units, because of the inclination of many entrepreneurs to think mainly in terms of their primary business. A pulp and paper producer may be inclined to say, "What do we know about electricity? Let somebody else worry about that." Since the firm that is actually producing the electricity does not have a direct need for most of the energy that it produces, the surplus can be sold to Ontario Hydro. In these cases, crosshauling is implicitly allowed.

Comment: ROB ABBOTT

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I would like to provide a few comments on Professor Harberger's paper from the point of view of an engineer and a utility representative.

1. Because cogeneration as a process involves the simultaneous production of electricity and process heat, typically using natural gas and wood wastes, the economics of just the electricity production cannot be singly isolated, particularly if you are looking at overall societal costs. The implication on fuel, taxation, avoided waste disposal and avoided process energy costs must also be considered.

2. In reality, the cost/price versus demand curves are anything but linear. The shapes are very complicated and are likely to include various step functions and limits. I assume costs will balance out according to the appropriate integrated areas, but because of the shapes, the actual prices and the ability and incentive to move from one

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1/ See above, pp. 99-103

point to another along the curve could be significantly different from the linear model.

3. The legislated NUG purchase rate P_v is based on long term future forecasts while the industrial retail rate P_b is usually based on existing average costs. It is somewhat of an "apples and oranges" exercise when trying to compare societal costs/benefits.

4. Many of the problems are the result of short-term fixing of artificial subsidized/incentive prices for P_v and P_b. We are beginning to see, and expect in future, that these prices will become much closer and will be established more and more by market conditions.

5. Ontario Hydro does not allow crosshauling for customer-owned generation projects, but requires it, in a sense, for those owned by a third party.