Modeling the Electricity Market in Ontario

by

Yin Li

(2927391)

Major Paper presented to the

Department of Economics of the University of Ottawa

in partial fulfillment of the requirements of the M.A. Degree

Supervisor Professor: Rose Anne Devlin

Ottawa, Ontario

December 2003

TABLE OF CONTENTS:

ABSTRACT:

The structure of the electricity market in Ontario is continuously changing, especially with the process of reform in recent years. But many problems still exist in the current electricity market in Ontario. This paper aims to investigate the market further and to supply possible solutions to some of these problems. In this paper, we discuss three basic aspects of the electric industry: supply, demand and trade. We then describe the electricity market structure and regulation before and after restructuring. Tirole's model (1988) is used to model the electricity market before restructuring, and possible problems are analyzed using this framework. These problems led to the reforms in the electricity market in 2000; technological developments made the reforms possible. Tirole's model (1988) is also used to look at the post-restructuring situation. All potential problems and resulting conclusions deduced from this model are analyzed. In the final section, an ideal model is introduced to tease out the problems that existed in the initial models. A brief comparison of the three models with respect to the pricing of electricity is also done; we discuss the ideal pricing model for electricity in Ontario.

Key Words: vertical market structure, electricity market in Ontario, electricity reforms,

1. INTRODUCTION

Electricity is a safe and clean source of energy used by almost every Canadian. Since 1990, several problems have plagued the electricity industry, partly as a result of faulty policies. For example, the Ontario government expected a remarkable increase in the demand for electricity in Ontario, thus instructed Ontario Hydro (a crown corporation owned by the electricity provincial government) to invest in nuclear plants to meet this need. Electricity prices were frozen in the 1990's yet it was expected that the amount of electricity used would be so vast that it would generate enough revenues to cover the cost of electricity production. But the actual demand for electricity increased slower than expected, resulting in higher average costs of production. The contradiction between expectations and reality has resulted in massive debt accruing to nuclear power plants. These problems motivated the government to implement major reforms to the electricity industry. However, the government's efforts at repairing the situation have produced new problems. Electricity prices rose abruptly after the reform process. The appearance of the electricity shortage in the summer of 2001 and the recent blackout disaster have both been attributed to the reform process.

In this paper, I will use economic theory to model the electricity industry before and after the reforms in order to reveal the advantages and disadvantages of the reforms. I also present an ideal model of the electricity industry, and discuss how the post-reform industry differs from this ideal.

The structure of this paper is arranged as follows: in section 2, I will introduce some basic facts regarding the current electricity industry, including information on the demand and supply for the electricity. In section 3, I examine the market structure and regulation before the reforms, section 4 then sets up a model describing the pre-reform structure and analyze the potential problems in this model. In section 5, I analyze the feasibility of the reform and show the reform contents about market structure and regulation respectively. Section 6 sets up the actual market model according to the facts after restructuring and show the potential problems. Section 7 outlines the ideal model. In section 8, I compare the different effects of three market models on pricing. Section 9 presents some conclusions.

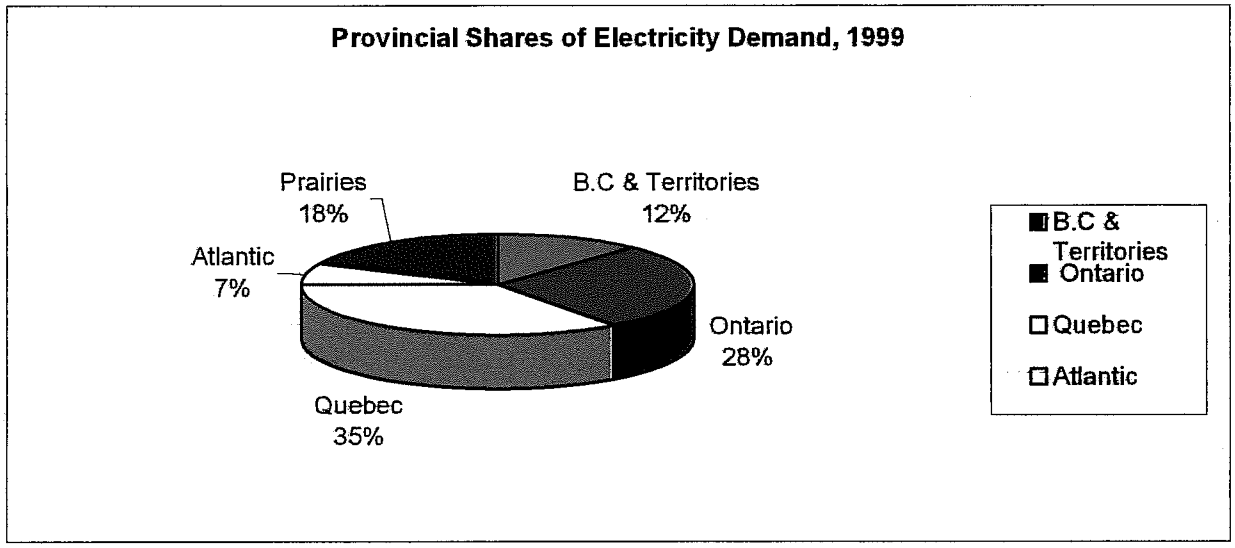
2. OVERVIEW OF ONTARIO'S ELECTRICITY INDUSTRY

2.1 Demand Side of the Market

Because of economic recession, total annual demand for electricity decreased during the early 1990's and then grew as the economy recovered. Over the period of 1986-1999, the average growth rate was about 1.4 percent annually. By 1999, the demand for electricity in Ontario reached 136 Terawatts Hour, and Ontario became second to Quebec in terms of market demand for electricity in Canada **(Figure 1)** (Independent Electricity Market Operator, 2000, 13-15).

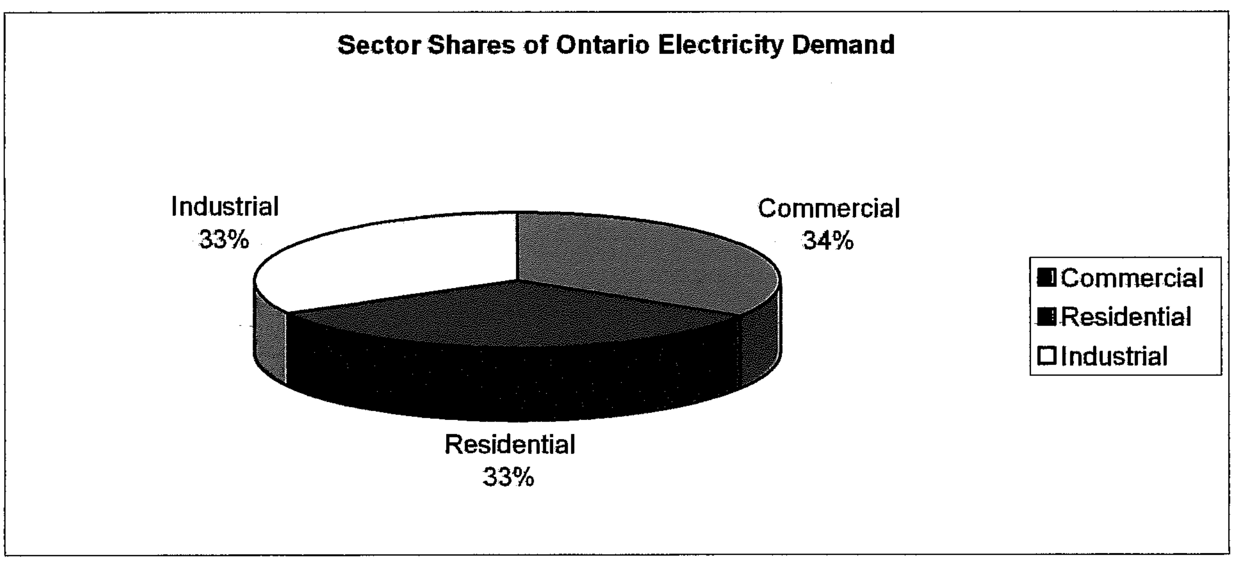
The demand for electricity can be divided into three sectors: residential demand, commercial demand and industrial demand. Over the past ten years, there have been small variations among these demands: Residential demand slightly decreased from about 47 Terawatts Hour in 1990 to 43 Terawatts Hour in 1999 due to energy efficiency regulations and the appearance of cheaper substitute natural gas; commercial and industrial demands endured a minimal shrinkage and recovered with the economy. In 1999, the three kinds of demands shared the market equally **(Figure 2)** (Independent Electricity Market Operator, 2000, 13-15).

Figure 1



Source: Independent Electricity Market Operator, 2000, 14

Figure 2



Source: Independent Electricity Market Operator, 2000, 15

The demand for electricity in Ontario is volatile due to weather fluctuations: with abnormal high temperatures in the summers in recent years, experts predict that the demand for electricity will change from having one winter peak-season, to experiencing two peak-seasons: winter and summer (National Energy Board, 2001, 32-33). Further, the Independent Electricity Market Operator (2000, 14) forecasts an annual growth of about 0.9 percent in the average usage of electricity over the period 2001-2010, and about 0.8 percent annual growth rate for the peak winter demand and 1.1 percent for the peak summer demand.

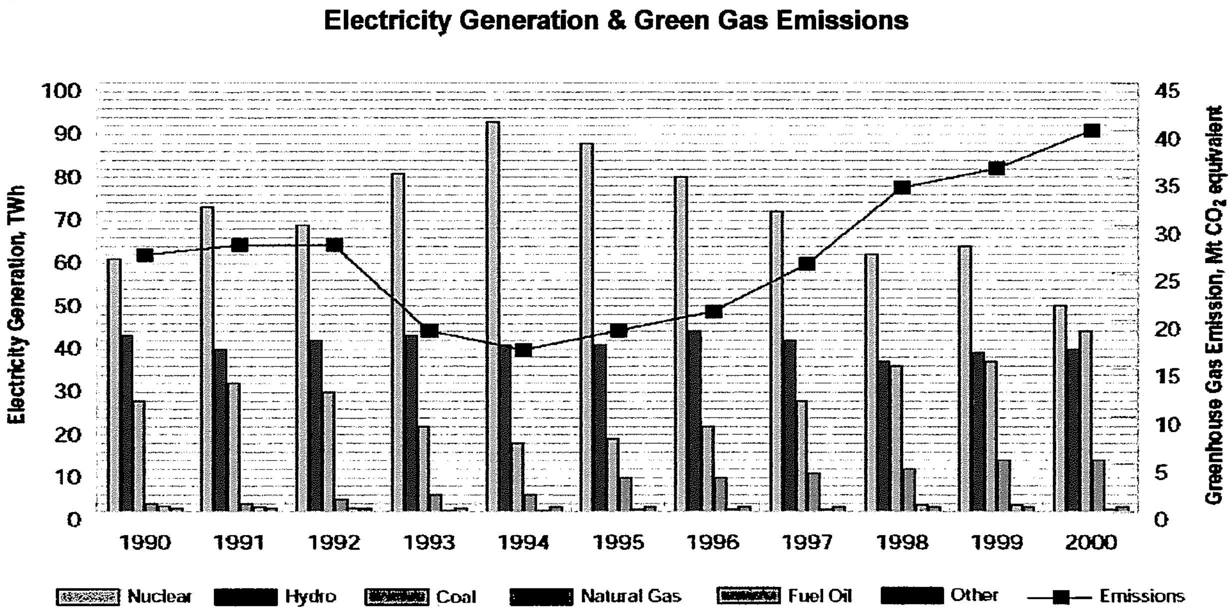
2.2 Supply Side of the Market

During the 1990's, the amount of electricity generated per year varied from 140 Terawatts Hour to 160 Terawatt Hour (National Energy Board 2001, 33-34). But the change in the relative shares of generation from different sources is large. **Figure 3** illustrates the variation in electricity generation from different resources during the whole of the 1990's. Even though nuclear generation has declined from 57 percent of the market in 1995 to 41 percent in 1999 and 34 percent in 2000, nuclear power still dominates the Ontario generation market. Hydro and coal accounted for 25 percent and 24 percent in 1999, and 29 percent and 26 in 2000. These three resources altogether account for more than 90 percent of electricity generation in Ontario. Hydro generation has remained relatively stable over the past ten years, but the use of coal is wavering against the use of nuclear. Natural gas generation has been increasing at an annual average rate of 10 percent, and now claims 7 percent of the market's share in 2000. Additional electricity generation resources include Wind, Solar, Biomass, wood waste etc and the like. [1]

[1] The data until 1999 are from National Energy Board 2001, 34; the data there after 1999 are from: Environment Canada "Fact sheet 2 - Electricity and Petroleum Industries: 1990-2000"September 2002 <http://www.ec.gc.ca/pdb/ghg/1990_00_factsheet/anchor5>

Ontario has a supply of electricity within the province to accommodate provincial demand plus a reserve in excess of peak demand. Compared with Ontario's peak electricity demand of

Figure 3



Other: Includes wood waste, spent pulping liquor and other fuel use to generate electricity
Statistics Canada, Quarterly Report on Energy Supply-Demand in Canada, Catalogue 57-003-XPB

Source: Canada's Greenhouse Gas Inventory

approximately 25,000 Megawatts under extreme weather conditions, even without all 9 nuclear plants, the province still has 26,700 Megawatts generation capacity (Case and Akman, 2001, 7-9). In addition to the current capacity, another 3,000 Megawatts of new generation capacity is set up to meet the possible growth of electricity demand; this includes building 800 Megawatts combined-cycle gas-fired facilities in Brampton and Mississauga, and the construction by

TransAlta [2] of a 440 Megawatts addition to a 210 Megawatts gas-fired co-generation facility in Sarnia (2002 start-up) (National Energy Board, 2001, 35).

2.2.1 Trade

Owing to the different seasonal needs between the United States and Canada and the different pricing levels among different provinces, international and inter-provincial electricity trades are necessary and beneficial to Ontario. Inter-provincial and international transmission connections have provided Ontario with the possibility to import lower priced electricity from hydro producers in both Manitoba and Quebec and export surplus power to higher priced markets in the United States. Since 1988, some variations of trading exist year by year. Compared with the amount of electricity generated, the amount of electricity imported and exported is relatively low: only about 5 to 6 percent of Canada's total generation is exported and imported every year (Cohen, 2002, 30-31). In 2000, Ontario imported 6.2 Terawatts Hour of electricity and exported a total of 6.4 Terawatts Hour. A total electricity of 4.3 Terawatts Hour was imported from Quebec and Manitoba, representing approximately 70 percent of total imports. The U.S. market accounted for the remaining 30 percent of the total imports; nearly 69 percent of Ontario's electricity exports went to the U.S. market (National Energy Board, 2001, 35).

In sum, the demand for electricity increased moderately in recent years, although some reductions in electricity demand have appeared since 1995. The analysis of potential generation capacity ensures us that the abundant supply within Ontario can meet not only the average

[2] TransAlta is Canada's largest non-regulated generator, which operates coal, hydro and gas generation, and high-voltage transmission.

demand but peak-season electricity demand as well. Although international and inter-provincial trade keeps increasing, they still occupy a relatively small share of the whole electricity market.

3. MARKET STRUCTURE AND REGULATION BEFORE RESTRUCTURING

3.1 Market Structure

The electricity industry has three central functions: generation, transmission, and distribution. Given these functions, there are many types of market structure, depending upon the degree of competition, the degree of vertical integration, and the mix of public and private ownerships in existence.

Before restructuring in 1998, the whole electricity industry of Ontario was mostly vertically integrated, because all parts of the industry were traditionally considered to be natural monopolies. Most of the generation, transmission, and some of the distribution and energy services were controlled and managed by one utility: Ontario Hydro. The local distribution services and energy services were performed by municipal electric utilities (MEUs). Almost all the electricity industry assets were in the hands of the provincial and local governments.

Ontario Hydro generates about 90 percent of the electric power sold in the province. Its generating facilities are comprised of 79 generating stations, which are made up of 68 hydraulic, 5 nuclear and 6 fossil fuels. Nuclear generation represents 62 percent of the total electricity supplied in the province; hydro electric generation 24 percent; fossil 10 percent; non-utility generation 3.7 percent; and purchases 0.3 percent (Daniels and Trebilcock, 1996, 2). The province-wide transmission grid is owned and operated by Ontario Hydro. It delivers about 70 percent of the total power generated in the province to 309 municipal electric utilities (MEUs). Ontario Hydro also delivered electricity directly to about 925,000 rural retail customers outside the jurisdictions of any of the MEUs, and to about 100 large industrial customers, which have demands exceeding 5 Megawatts (Yatchew, 1996, 336-338).

Except Ontario Hydro, the distribution system in Ontario also consisted of over 300 municipal utilities, which were owned and operated principally by municipal commissions. In most cases, municipal utility boundaries coincided with the municipal boundaries. About one-third of municipal utilities also administered other services, such as water, gas etc. Approximately 70 percent of the power delivered in Ontario is delivered by these municipal utilities, which serve 2.8 million customers in urban areas (Booth & Halpern, 1996, 74-76; Yatchew, 1996, 336-338).

There are also several private companies that generate, transmit, and distribute power. These companies include such companies as Gananoque Light and Power Limited, Great Lakes Power Limited, Canadian Niagara Power Company Limited, Orillia Light and Power, as well as a few large resource industry companies that generate, transmit or distribute the electricity by themselves.[3]

In sum, in the electricity industry of Ontario, Ontario Hydro dominated the generation segment, monopolised the transmission segment, and controlled the distribution segment. The whole market is not fully vertically integrated; most local distribution companies are separately owned by different regions. At the same time, the electricity industry is a "public industry" which

---

[3] The name of the private companies in the Ontario electricity industry is chosen from the list in the Ontario Energy Board website. < http://www.oeb.gov.on.ca/html/en/licences/licensedmarketparticipants.htm >

means that the provincial government owned Ontario Hydro and local governments controlled most distribution services. The electricity price was decided by the Ontario Hydro without taking the situation of the market into careful consideration. Under the pressure of the provincial government, Ontario Hydro has frozen its electricity price in Ontario since 1993, and was basically a policy tool of government.

3.2 Regulation

In 1973, the government passed a matrix of three statutes – the Power Corporation Act, the Ministry of Energy Act, and the Ontario Energy Amendment Act – that set up the basic structure of regulation of the electricity industry. In addition, the government established the Ministry of Energy and Ontario Energy Board (OEB), replacing the old Hydro-Electric Power Commission of Ontario (HEPC), to oversee the whole electricity industry. [4]

Since 1973, Ontario Hydro has been controlled by a set of "quasi-regulatory instruments" and partly self-regulated. No single regulatory agency had the responsibilities of reviewing both capital plans and revenue requirement proposals of Ontario Hydro. The investment plans of Ontario Hydro have been subject to various forms of review by select committees of the Ontario Legislature, Task Forces, Royal Commissions, and, most recently, by the Environmental Assessment Board. Under the review of the Minister of Environment and the Energy and Ontario Energy Board (OEB), Ontario Hydro can set its own rates for those customers it serves directly, set wholesale rates for the electricity selling to the MEUs, and regulate retail rates that may be charged by the MEUs. OEB did not have the "quasi-judicial power" to set electric rates

[4] The regulation part is derived from Freeman, 1996, 375-380

and the Minister of Environment and Energy did not have the power to arbitrate disputes between the OEB and Ontario Hydro.

MEUs were not only controlled by Ontario Hydro through the rate charged for retail, but they were also responsible to their local contributors. Given this characteristic, MEUs, like other municipal utilities that supply such distribution services as water and natural gas, were controlled by local governments. Municipal commissions oversaw the activities of the municipal electric utility. The majority of municipal utility commissioners are elected by municipal authorities according to the Public Utilities Act.

In conclusion, a diffusion of responsibility among Ontario Hydro, the Minister of Environment and Energy, the OEB and the Municipal Authorities is a main feature of the regulatory structure of Ontario's electricity industry. This feature impedes the external analysis through the blurring of political responsibility, leading, potentially, to implementing the wrong regulatory system.

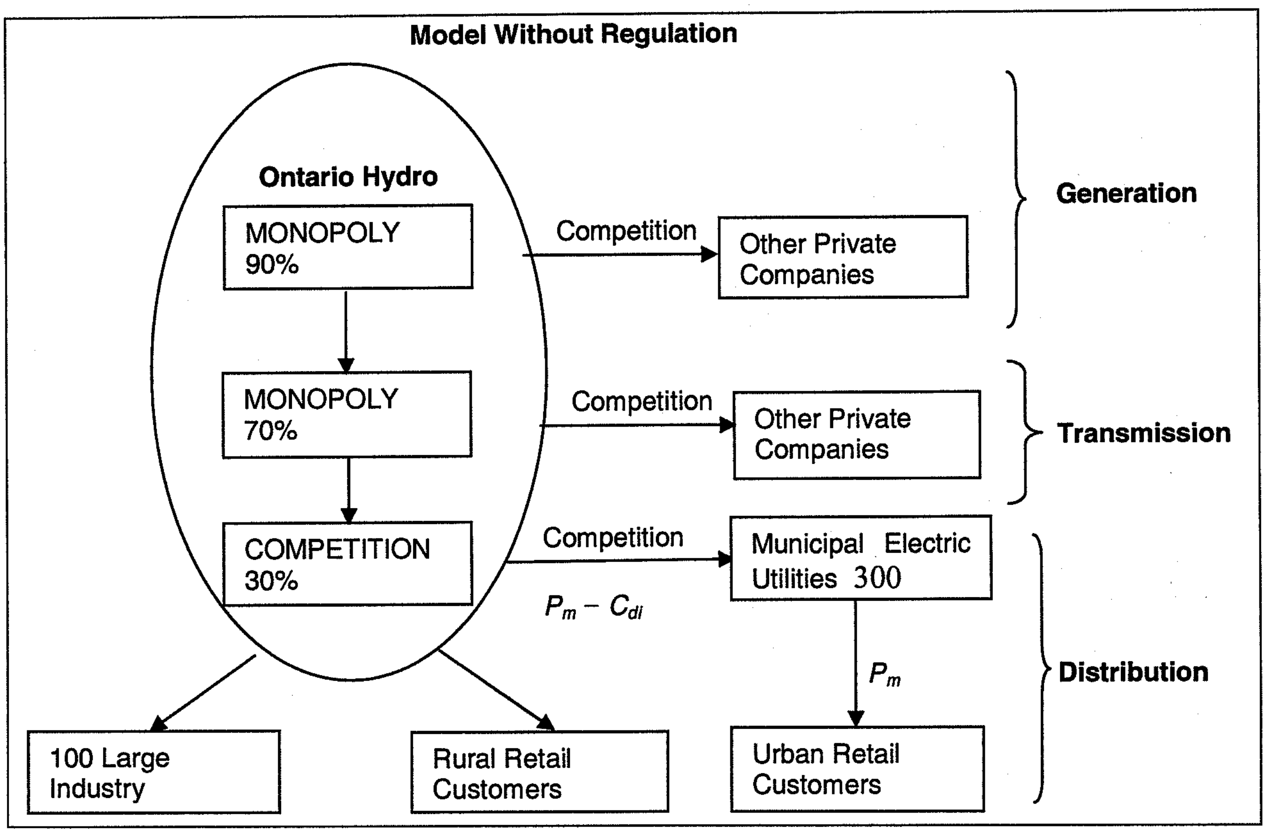
4. MODELLING THE ELETRICITY MARKET BEFORE RESTRUCTURING

The market structure can be summarised as follows before restructuring: Ontario Hydro dominates the electricity's generation segment with a 90 percent share of the province's generation capacity; it has monopoly control over the industry's transmission segment with a 70 percent transmission service in the market, it shares the 30 percent of the distribution service and has control over the distribution segment. Ontario Hydro sets wholesale rates and regulates retail rates for about 300 downstream municipal electric utilities. We depict this situation without regulation in **Figure 4**.

As Tirole (1988, 169-172) discusses, vertical control is defined such that an upstream/downstream firm directly or indirectly controls the decisions in a downstream/upstream firm made by contracts specifying "vertical restraints". There are several ways of obtaining vertical integration profit via vertical restraints:

1. A linear price: the generation company charges the price P per unit of electricity, which is

Figure 4



Source: The idea is from Tirole (1988, 172)

higher than the marginal cost C, so the total tariff is

$$T(q) = P * Q$$

2. A franchise fee: which adds a fixed fee to the linear price, the total tariff faced by retailer is

$$T(q) = A + P * Q$$

3. Resale-price maintenance (RPM): the generator sets up the choice of the final price and variation of the price in the contract; the actual price should equal or be larger than a price floor, equal or be less than a price ceiling.
4. Quantity fixing: the generator decides the amount Q to be bought by the retailer and controls variants of quantities between the quantity forcing and quantity rationing.

In this case, the "upstream firm" is Ontario Hydro that vertically controls the "downstream firms" – about 300 Municipal Electric Utilities, which supplies about 70 percent distribution service all together in the market. Ontario Hydro controlled the downstream firms by setting up the wholesale rate to the Municipal Electric Utilities (MUEs) and regulating MUEs' retail rate to their customers (like resale-price maintenance arrangement (RPM)).

In order to explain why Ontario Hydro implemented this kind of vertical control, we can set up the following model. We assume that there exists no uncertainty, the demand for electricity is a function of the retail price, and Ontario Hydro knows every segment's cost. We suppose the demand for electricity is $Q = D(P)$, the cost of generation is C_g, the cost of transmission is C_t, the average cost of retailer i is $C_{di,}$ here $i = 1, 2 \ldots, 300$. $D_i(P)$ is demand for distributor i, and total demand is $\sum D_i(P) = D(P)$. Ontario Hydro chooses the price P_m to maximum the whole vertical structure's profit

$$\prod = (P - C_g - C_t) * D(P) - \sum C_{di} * D_i(P)$$

Ontario Hydro sets the wholesale rate to 300 MUEs as $P_m - C_{di}$, and regulates the retail price as P_m. The total tariff, faced by retailer in the sub-market i, can be written into a franchise form

$$T(q) = A + P * Q = (P_m - C_{di}) * D_i(P) + C_{di} * D_i(P)$$

Here, A is equal to $(P_m - C_{di}) * D_i(P)$, $P*Q$ is equal to $C_{di} * D_i(P)$. Through vertical control, Ontario Hydro can get the vertical monopoly profit and avoid the "*double marginal problem*" (Spengler 1950).[5]

Due to market power, Ontario Hydro could charge a price to capture the whole monopoly vertical profit. To avoid high pricing, the government regulated the Ontario Hydro prices so that it could cover costs, including a normal profit. In addition, the government regulated the Municipal Electric Utilities' retail price through Ontario Hydro to cover their distribution costs, such as the wages, management costs, and so on. Thus, considering regulation, we should modify the model as shown in **Figure 5**.

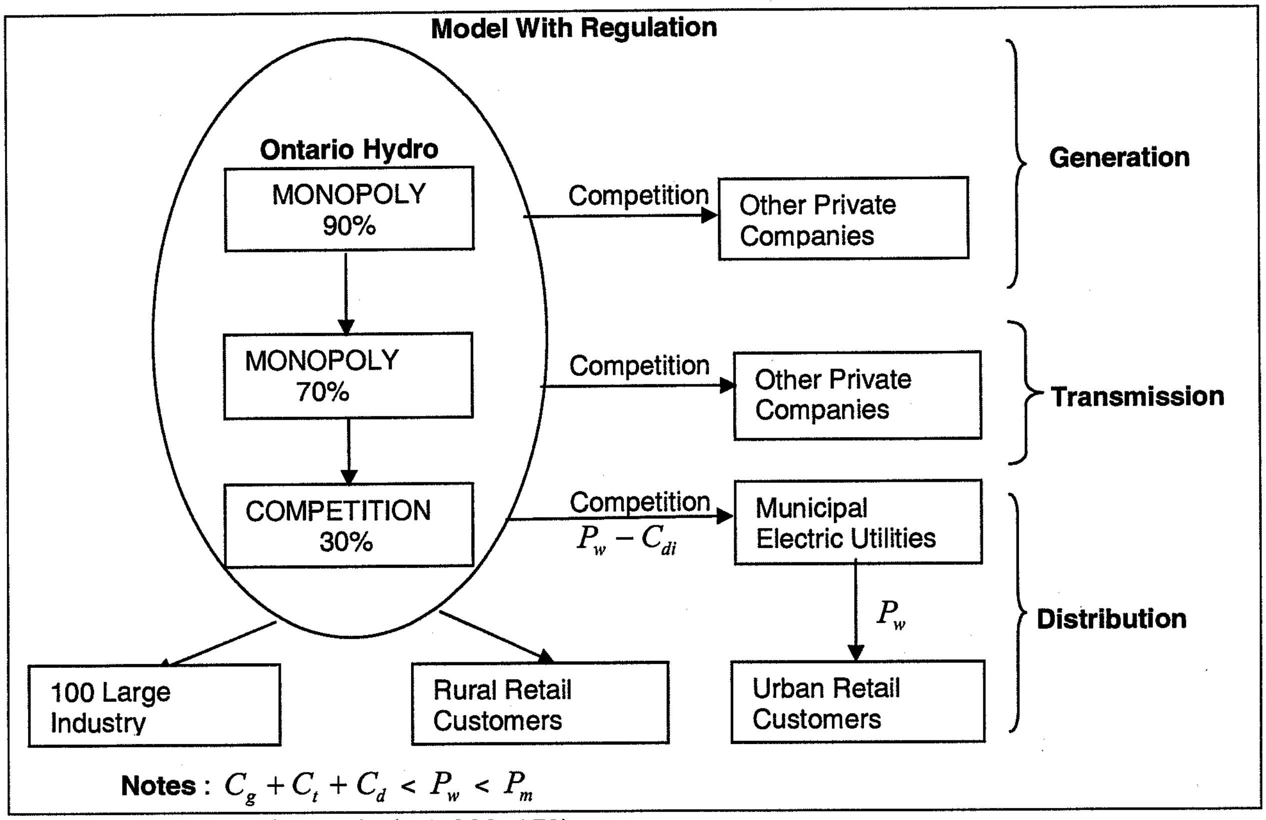
In the model with regulation, the Ontario Hydro's retail price will be controlled at the level P_w, which will be larger than the total average cost per unit of electricity $(C_g + C_t + C_{di})$, but less than the monopoly price P_w. The wholesale rate on the 300 MEUs regulated in about $(P_w - C_{di})$, here C_{di} is supposed to be the distribution cost of sub-market *i*.

As **Figure 6** shows, under regulation the price would move from P_m to P_w, social welfare would increase by an amount equal to the customer surplus under the price P_w minus the customer surplus and part of producer surplus under the price P_m. The welfare's increase is equal to the area of triangle *ABC*.

---

5 The pricing models for different electricity market structures rely on the vertical control models from Tirole (1988, 169-198).

Figure 5



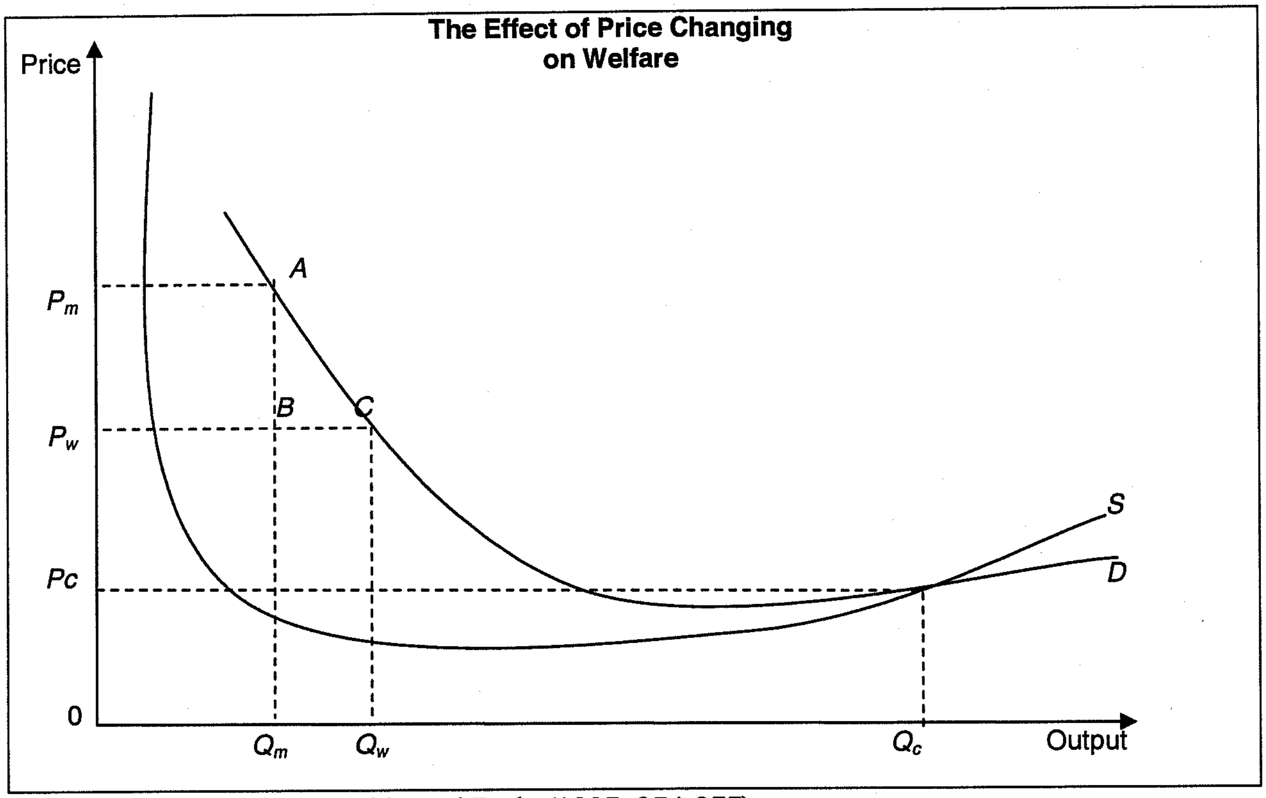
Source: The idea is from Tirole (1988, 172)

4.1 Possible Problems Arising from the Pre-restructuring Market Structure

The first two problems associated with the pre-restructuring market are correlated with vertical control. In the above discussion, we assume that the demand is certain and there exists no other services by distributors. But in practice, not only Ontario Hydro but also MEUs own sub-firms which supply distribution services such as the installing the amp-meters, checking electricity lines, and so on. These services also affect the demand for electricity.

Considering the element of electricity services, the first problem appears in the following modified model: we assume that distributor i faces the demand for electricity $Q_i = D(P_i, S_i)$, where P_i is the retail price charged by distributor i; S_i is the amount of service supplied by

Figure 6



Source: the idea is from Parkin and Bade (1997, 274-277)

distributor i; the demand for electricity is negatively related with the retail price and positively related with the amount of services. In addition, we also assume the cost of distributor i supplying S_i amount of services is $B(S_i), B(0) = 0, B'(\cdot)>0$. If, as above, the wholesale price is $(P_w - C_{di})$, the retail price is P_w and the distributor wants to supply S_i, so the distributor faces the profit

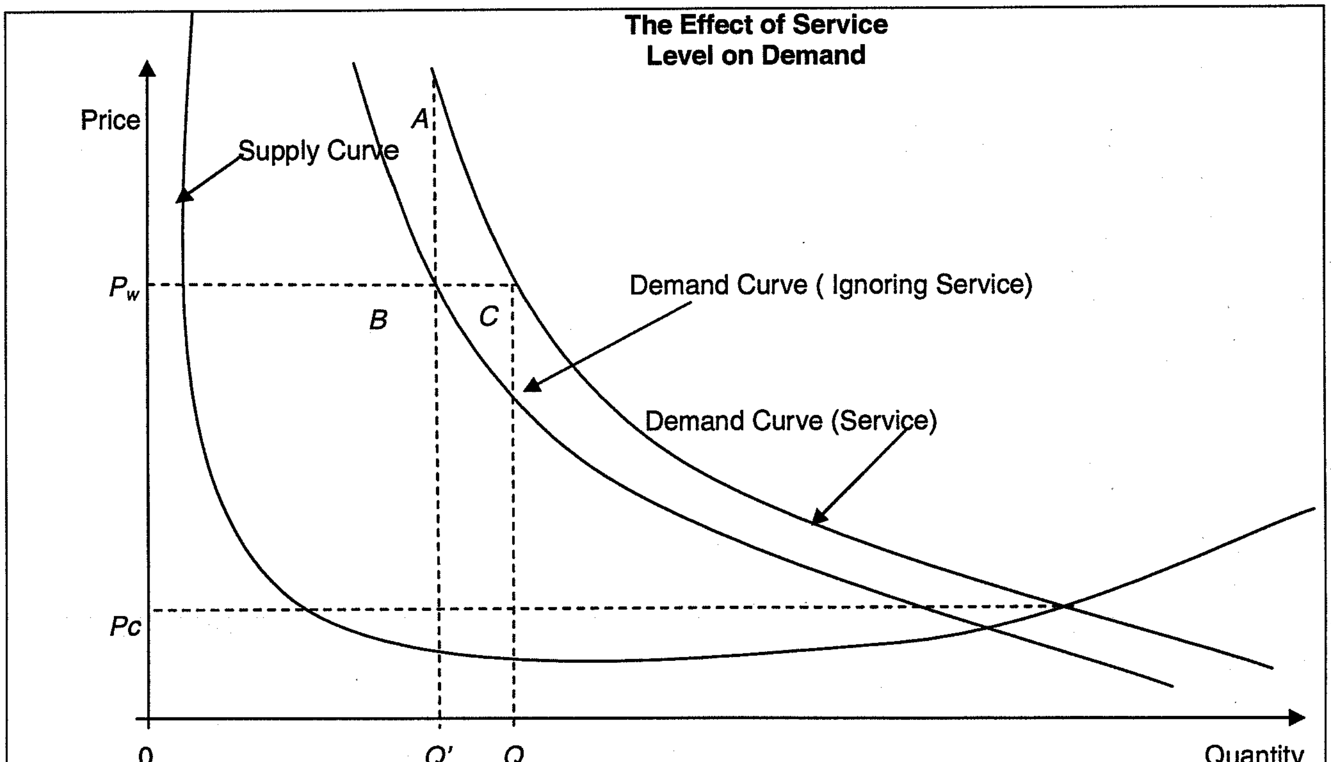
$$\prod = (P_w - (P_w - C_{di}) - C_{di} - B(S_i)) \times D(P_i, S_i) = -B(S_i) \times D(P_i, S_i)$$

If S_i>0, then we get $\prod i < 0$. In this case, the distributor i will prefer to supply no service. So, no distributor would be willing to supply services, and thus demand will turn into

$$D(P_i, 0) < Q_i = D(P_i, S_i) \;\; (S_i > 0)$$

Adding every distributor's demand together, we get the total electricity demand in the market $Q = \sum Q_i$, which will be less than the original predicted demand, taking the distribution of services into consideration. The effect of service reduction on social welfare is shown in **Figure 7**. Ontario Hydro originally predicted the optimal electricity demand in the market to be Q, but under this kind of vertical control, the distributors are not willing to supply service, so the real demand Q' is less than Q. But the price is pre-fixed at P_w, so the loss of social welfare appears as area $ABQ'QC$.

Figure 7



Note: Q is originally predicted demand; Q' is the actual demand if distributors supply zero service.

The second problem is induced by the uncertainty of electricity demand. In the long run, uncertainty of demand in Ontario is affected by the trade-off of two trends: the first is the trend towards more efficient use; the other is the development of electricity intensive industries. In the short long, demand uncertainty also depends on the weather and the work schedule: abnormally hot and cold weather will increase electricity demand for commercial and industrial usage during the day and residential electricity usage in the evening (MacRae, 1989, 247-251).

According to this reality, we should modify the model to consider demand uncertainty. We should assume the demand faced by distributor i as $Q_i = D(p_i, d_i)$ where p_i is the retail price charged by distributor i, d_i is parameter of demand uncertainty faced by distributor i. As stated above, Ontario Hydro sets the wholesale rate as $(P_w - C_{di})$, and regulates the retail rate as P_w. So the distributor i faces the profit

$$\prod i = (P_w - (P_w - C_{di}) - C_{di}) \times Q_i = 0$$

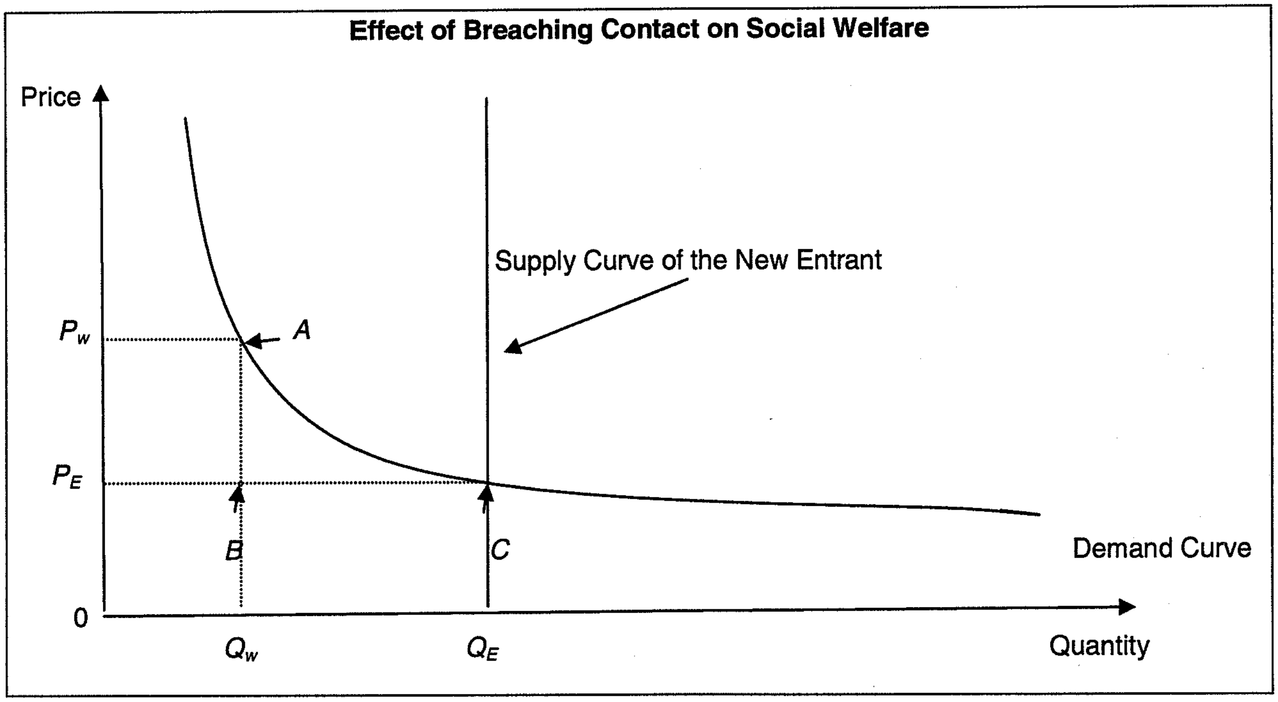
In the short run, the Ontario Hydro fixes its profit as $\sum (P_w - C_g - C_t - C_{di}) \times Q_i \quad i = 1, 2 \ldots 300$. The distributor will bear all the risk from the electricity demand's shock. If the distributor i cannot sell all of the Q_i due to the decrease in electricity demand, the distributor will take on losses. However, in the long run, as Rey and Tirole (1986, 922-926) point out, under uncertain demand, RPM gives the retailer perfect insurance because, the retailer will adjust the amount of electricity bought from the generator according to the demand change. At the same time, under RPM, the profit margin of the retailer will be always zero. Therefore, the distributor's profit is independent of demand.

The third problem also concerns the vertically integrated structure itself. As Ontario Hydro is vertically integrated in generation and transmission and some distribution, it can use monopoly power in generation or transmission to deter any potential entry into the transmission or generation areas. It can also use monopoly power in generation and transmission markets to win a competitive advantage for its own subgroup of companies in the distributors' market. Here are two examples of the third problem: "contract as barriers to entry" and "differencing the wholesale charge".

Ontario Hydro combined its production of electricity with the transmission service and set up a penalty for breaching the contract by the MEUs. We assume the wholesale rate is $(P_w - C_d)$, the penalty of breaching the contract is t ($t < (P_w - C_d)$), and the potential entrants' price is P. We then discuss the two choices faced by MEUs after signing the contract: one, if MEUs insist on their contracts, they would pay P_w; two, if MEUs breach the contract and buy the electricity from the new entrants, the resulting payment would be $(P_E + t)$. Under profit maximization, if and only if $P_E + t \leq P_w - C_d$, will the MEUs breach the contact and buy from the new entrants. But the problem occurs when $P_E < P_w$ and $P_E + t > P_w - C_d$, which means when $P_w - C_d - t < P_E < P_w$, the distributor will keep the original contact. In this case, social welfare will fall as shown in **Figure 8.** In this case, we suppose that the production capacity of new entrants is finite and cannot satisfy the whole market demand: as the retail price increases from P_E to P_w, the amount of social welfare lost equals the area ABC.

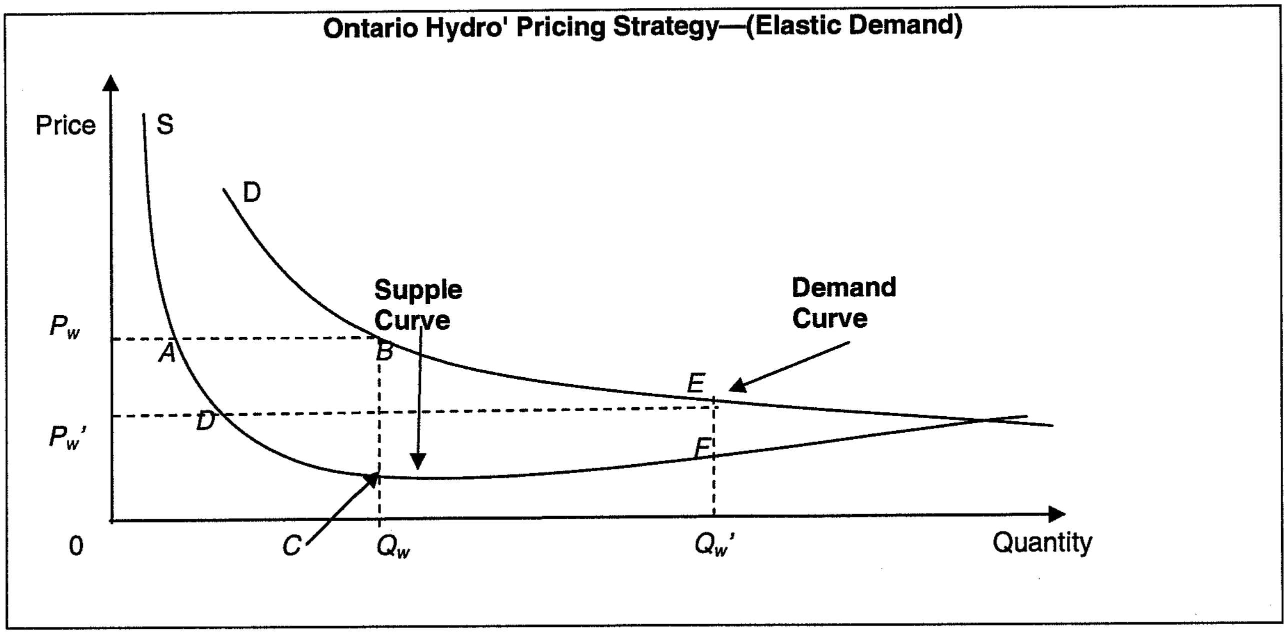
Ontario Hydro sets the wholesale price as $(P_w - C_{di})$ for distributor i, and regulates the retail rate as P_w , so other distributors like the MUEs have no incentive to reduce the retail price below P_w, because otherwise, they will receive negative profit. But, Ontario Hydro can reduce its sub-company's retail price below P_w to draw more customers. This is especially the case when it is faced with relatively elastic demand for electricity; reducing the profit per unit of electricity will increase the whole vertical integration structure's profit. The profit shown in **Figure 9** is the difference between areas *DEF* and *ABC*.

Figure 8



The fourth problem of the post-restructuring market structure is due to the reduction of the retail price from P_m to P_w. On the one hand, the price reduction modifies the profit of Ontario Hydro; on the other hand, a price reduction will increase the demand for electricity. Because of the absence of new entry, Ontario Hydro had to increase its production capacity continuously to meet more and more electricity demand. In an earlier paper, I investigated whether or not most electricity generating firms in Canada had exhausted their economies of scale (Li, 2003). In that paper, I modeled the structure of production in the industry using the neoclassical cost function approach. Then, I used two sets of cross-section data from different time periods on firms from across Canada to estimate the cost functions using regression analysis. Using the two estimated

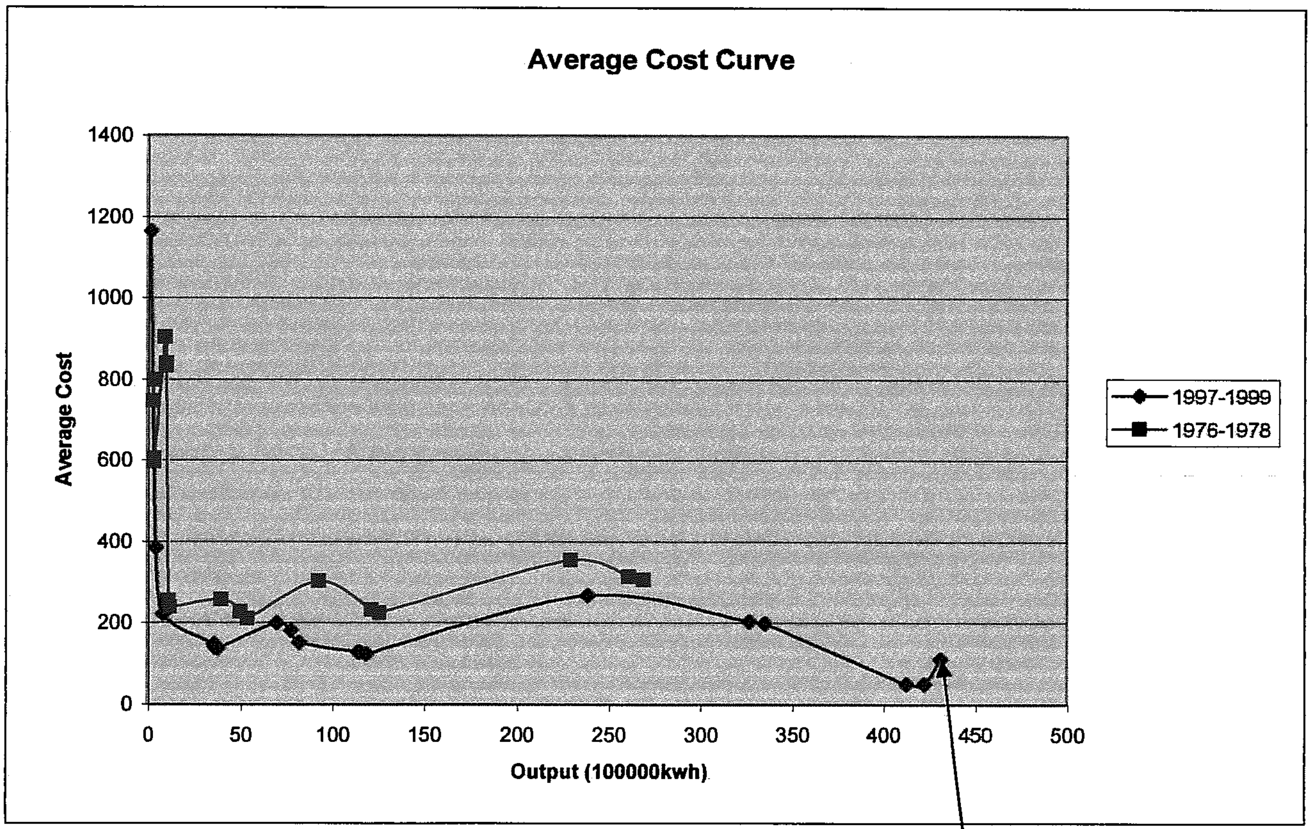
Figure 9



cost functions, I could draw two average cost curves for the 1970's and 1990's and could locate the main electricity companies on the curve. These two curves are shown in **Figure 10.** Ontario Hydro is located on the tail of the 1990's curve. From the figure, we can clearly see that most of the output in 1997-99 did not experience significant economies or diseconomies of scale. Ontario Hydro has exhausted all economies of scale, which means that its average cost will increase with increases in output.

The fifth problem which existed before restructuring is caused by the government's intervention in the investment and pricing of the electricity industry. During the 70's and 80's, the government overestimated the future demand of electricity, and was attracted by the efficiency of nuclear power generation. The Ontario government invested in nuclear plants, and borrowed a large amount of money to facilitate that investment. Unfortunately, in the beginning of the 1990's, because of the economic recession, the demand for electricity decreased dramatically.

Figure 10



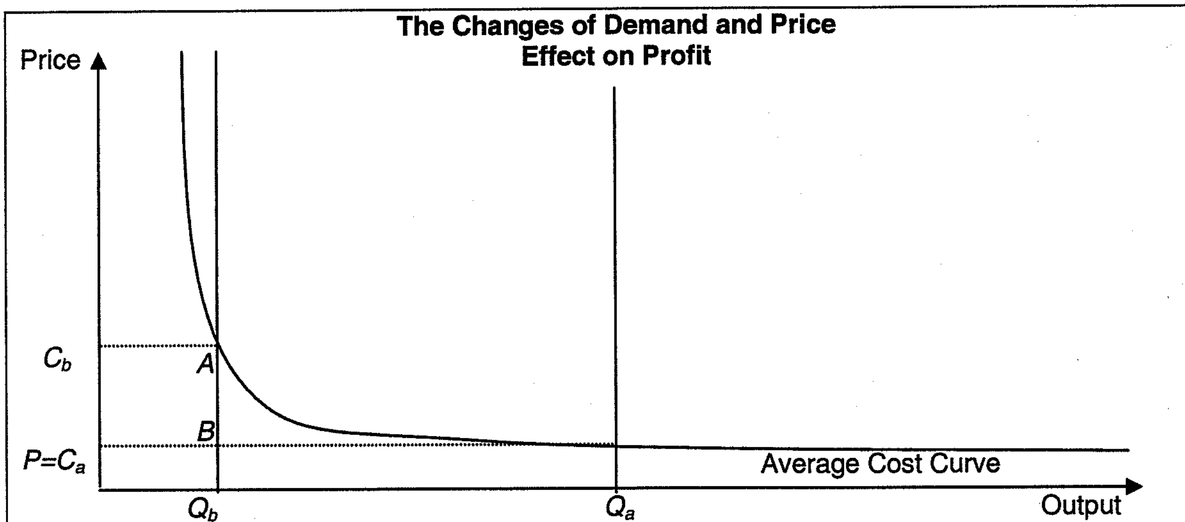
Source: Li (2003, P.14)

The average cost of electricity increased greatly with the decrease of output. To cover average costs, Ontario Hydro's customers faced retail price increases of 8.6 percent in 1991, 11.8 percent in 1992, and 7.9 percent in 1993. Under the pressure of customers, the Ontario Government froze the electricity price at its 1993 level. Since 1993, the price of electricity has not covered the production cost of nuclear plants, which are expensive to maintain. These costs include investment, interest charges, the cost of recycling nuclear wastes and lastly the cost for security within the nuclear power plants. Until the later part of the 1990's, debts incurred on behalf of Ontario Hydro amounted to more than one-half of the entire provincial debt (Hampton, 2003, 121-138; Daniels and Trebilcock, 1996, 1-8). How the reduction of demand and frozen prices enhanced the debt is shown in **Figure 11.**

5. RESTRUCTURING THE ELECTRICITY MARKET

Historically, most of electricity was produced by hydro and nuclear-fuelled plants. Both types of plants required a great amount of investment before construction, but had relatively low operation costs. The electricity industry had the appearance of a natural monopoly industry for many years, because of the very large fixed cost and large economies of scale in electricity

Figure 11



Note: Q_a is electricity output predicted before the recession
Q_b is actual electricity output in the recession
P is the freezing price which may cover the average cost C_a
C_a is the average cost when the output is Q_a
when the Output is equal to Q_b, the average cost is C_b, but as the price is fixed at P, Ontario Hydro get the lost of area $C_b\ C_a\ BA$.

generation (Tirole, 1988, 67-69). In order to control monopoly power, the natural monopoly was publicly owned; the vertically integrated structure was much easier to manage under the public sector. As discussed above, over-regulation by the government induced the problem of inefficient investment and diseconomies of scale. The vertically integrated structure caused welfare losses under demand uncertainty and the presence of distributor's service. The vertically integrated structure also discouraged competition in the generation, transmission and distribution markets. These problems provided the initial incentives for restructuring the Ontario electricity industry, but it was technological advancements that rendered the restructuring possible.

Technological developments have made other electricity-producing resources like natural gas and coal more economical than hydro and nuclear generators. A key feature of the emerging market of electricity supply is the competitiveness of these alternative electricity generating resources. Electricity can be produced by generators, such as nuclear and hydro, with very large fixed costs and low variable costs; or, it can be produced by generators, such as coal and gas-fired plants, that have relatively small costs and large marginal or variable costs (Trebilcock, 1996, 7-8).

On the same decentralizing issue, Ambec and Doucet (2003, 587-607) analyze the concentrated hydroelectric systems in Quebec, which account for some 94 percent of that province's production capacity. They use a dynamic model to point out the welfare trade-offs associated with production decentralization. Decentralization minimizes the welfare loss due to market power, but increases welfare loss due to suboptimal management of water resources. But in the case of Ontario, the situation is different. Firstly, the hydroelectric plants in Ontario are scattered all over the province, and only have 29 percent share of the province's electricity capacity. In this situation, the effect of water management on welfare is very limited. Therefore, potential benefits from competition will exceed the loss from suboptimal water management. In addition, as technology develops, new entrants will choose natural gas or coal to fuel production, which will have lower fixed cost and shorter production cycles in comparison to hydro generation.

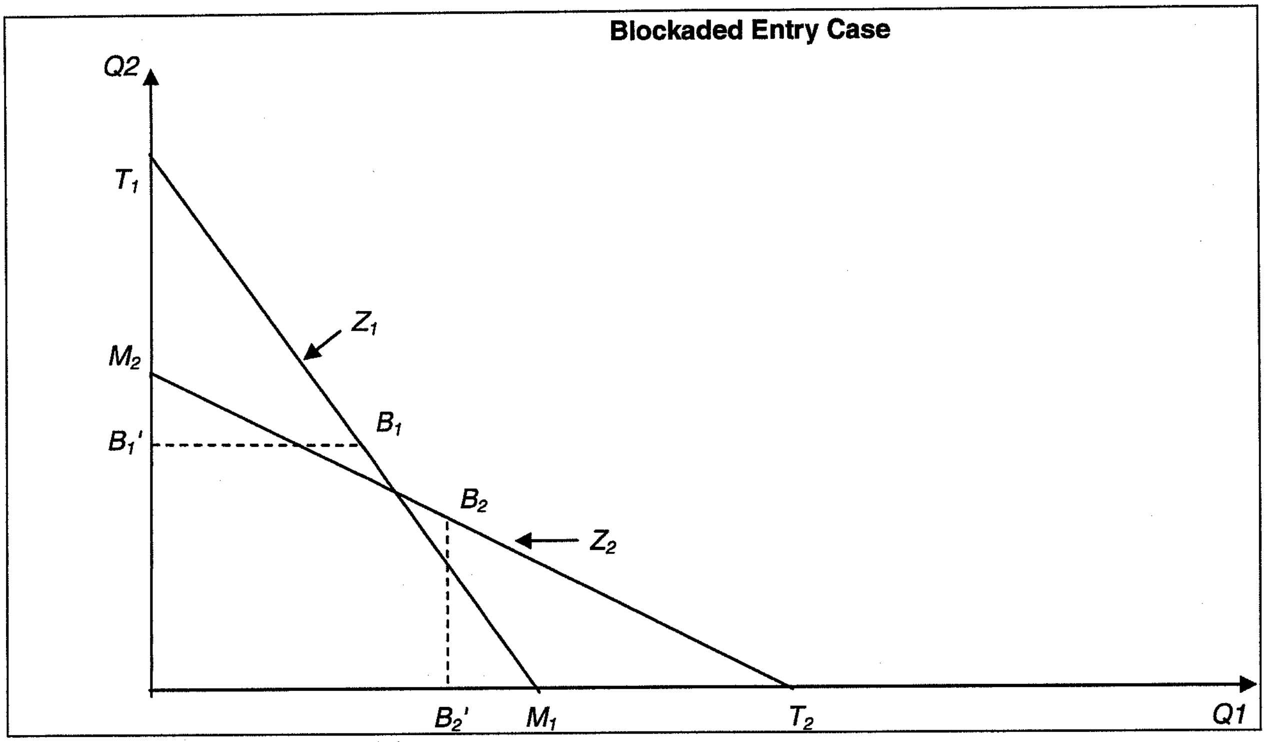
Using the Dixit's diagrammatic entry model (Waterson, 1984, 57-82), we can explain how different types of generation plants make new entry into the electricity market possible. In Dixit's model, we assume costs are made up of a constant marginal cost plus a fixed component. Relating this to a graph of the established firm's and potential entrant's reaction functions, we see that, in the presence of substantial scale economies, which are due to large fixed cost, the reaction functions will become discontinuous at a certain output level.

We consider two different conditions: Firstly, if the new entrants want to set up new hydro or nuclear plants of the same type as the established plants, we get the case of blockaded entry, which is illustrated in **Figure 12**. We plot the established firm's output Q_1 on the 'X' axis with the potential entrant's output Q_2 on the 'Y' axis. Firm 1 has a reaction function Z_1 while firm 2's reaction function is Z_2. In **Figure 12**, we can see that, in the presence of scale economies, firm1 can produce if and only if output is larger than B_1 and up to M_1 where its reaction function cuts the Q_1 axis. At M_1, firm 1 can sell the monopoly level of output. Thus, its reaction function is the line $M_1B_1B_1'T_1$. Similarly, we get the reaction function $M_2B_2B_2'T_2$ for the potential entrant. As we have drawn the figure, scale economies are so large that the potential entrant's reaction function becomes discontinuous at a point representing an output level for firm 1 below the monopoly output. Thus the established firm can produce the monopoly output without attracting entry.

Then, if the potential entrants decide to set up different types of plants which have relatively low fixed costs, **Figure 12** should be modified as shown in **Figure 13**. The reaction line of firm 1 is not changed, but because of the lower fixed costs of entrant firm 2, it decides to enter before point *B1*; the reaction function line of firm 2 becomes $M_2B_3B_3'T_2$. The established firm has two choices. One is to let the new firm in; in this case, it wishes to set an output given by the isoprofit curve tangent to firm 2's reaction function and at point F_1, it gets the profit $\prod_1$, firm 2 can enter with an output Q_2. The other option is that firm 1 produces an output slightly above the level B_2', which will bring $\prod_2$ to firm 1 and prevent firm 2's entry. Because the successively higher isoprofit function involves successively lower levels of profit, firm 1 prefers the former which is more profitable. This case is called ineffectively impeded entry. If the potential entrant uses coal and/or gas with relatively low fixed costs and higher variable costs, as the fuel source to produce electricity, it will have a good chance to enter the market and realize positive profits. Thus, because of this new technology, the structure of the electricity market changes. The government of Ontario decided to implement reforms to assist the process.

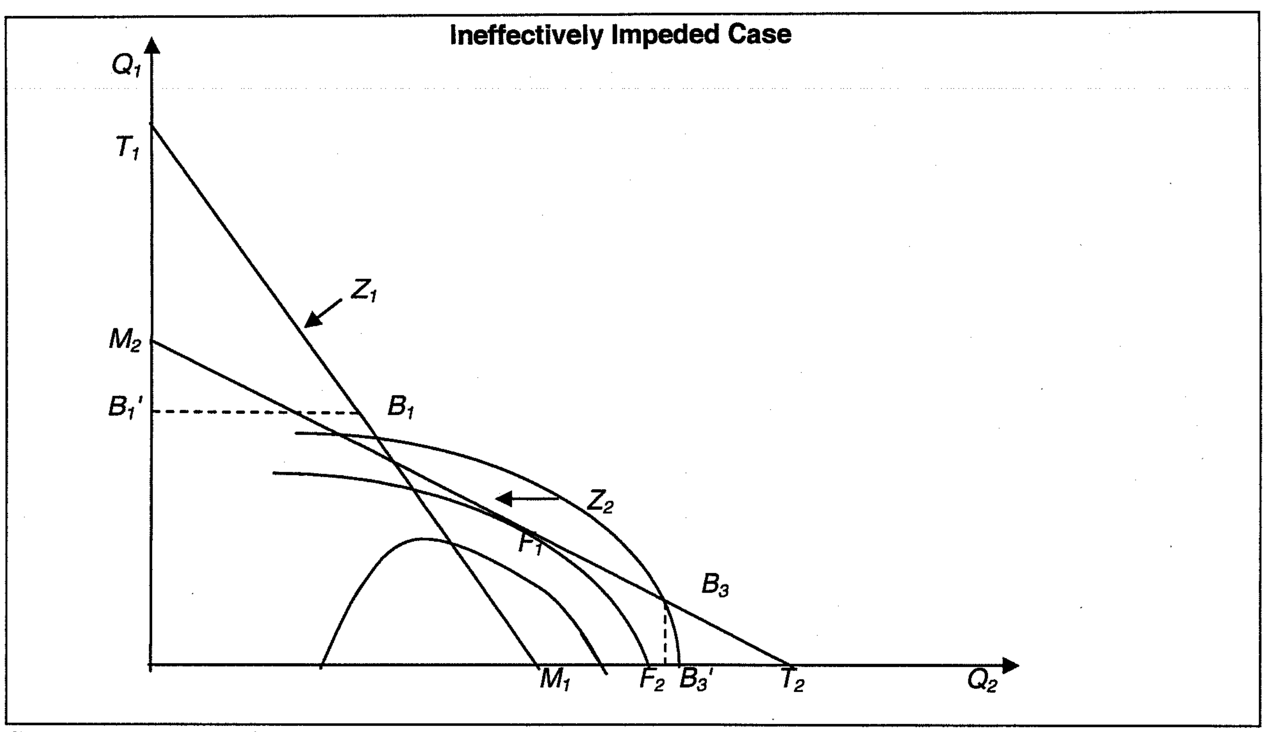
In 1997, the Government of Ontario released a white paper to uncover its plans to reform the provincial electricity market, which marked the beginning of the restructuring of the electricity industry in Ontario. In 1998, the Minister of Energy, Science and Technology introduced the Energy Competition Act to help meet the province's long-term electricity needs and ensure that Ontarians have a safe, reliable and affordable supply for power. The legislation established the framework for the competitive marketplace and enacted the other two acts: the Electricity Act

Figure 12



Source: Waterson (1984, P.63)

Figure 13



Source: Waterson (1984, P.64)

and the Ontario Energy Board Act. [6]

According to the two Acts, in April 1999 Ontario Hydro was split into five separately managed entities: two distinct commercial companies: Ontario Power Generation Inc. (OPG) and Hydro One Inc. (Hydro One); one crown corporation: the Independent Electricity Market Operator (IMO); the Ontario Electricity Financial Corporation (OEFC); and the Electrical Safety Authority. All these five operate independently from one another (National Energy Board, 2001, 35-36).

In the generation segment: general generators produce power that is delivered to wholesale customers through the high voltage transmission system. Embedded generators produce power for a single user or a group of customers within a local distribution network. General generators connected to the transmission system are part of the wholesale marketplace overseen by the IMO. Embedded generators are not required to participate in the IMO market, but can do so if they make the appropriate arrangements. [7] Ontario Power Generation Inc. (OPG) took over ownership and operation of the former Ontario Hydro generation facilities and monopolizes the generation market. Due to problems that a rose with respect to OPG's market power and the ability to manipulate generation prices, the Market Power Mitigation Agreement (MPMA) was developed to reduce OPG's share of the generation market. In the next 10 years, the share of total generation capacity in Ontario controlled by OPG will be reduced from 90 percent to no more than 35 percent by selling some generation parts of itself (National Energy Board, 2001, 36).

---

6 The information is from Regulatory Information on the Ontario Power Generation website <http://www.op g .com/info/LC_regulatory.asp>

In the transmission segment, Ontario's transmission system is a 29,000-kilometer network of high voltage power lines and transformer stations carrying power from generators to distribution companies and other heavy users. It is connected to the large North American power grid with neighboring transmission systems in Quebec, Manitoba, New York, Michigan and Minnesota. The OEB regulates the price of transmission services.[7] Hydro One owns and operates the transmission, distribution and energy retailing businesses of Ontario Hydro. Hydro One Networks, a subsidiary of Hydro One, owns and operates about 97 percent of the high-voltage transmission facilities within the province. Two smaller transmission systems, Great Lakes Power and Canadian Niagara Power, provide localised transmission service; Hydro One also owns and operates 17 interconnections with transmission systems in neighbouring provinces and the USA. The MPMA also requires Hydro One to increase its interconnection capability by 2000 Megawatts within three years of restructuring. While Hydro One still dominates the transmission market, it has separated from its upstream company (National Energy Board, 2001, 36).

In the distribution segment, almost all of Ontario's approximately four million end-use consumers receive their electricity through a low voltage network known as a distribution system. Many of the province's distribution systems are owned by the municipalities they serve. Municipal electric utilities provide distribution services to urban areas. But, all municipal electric utilities (MEUs) are required to separate the distribution business from other energy business to avoid cross-subsidisation. Due to expanding urban centres and municipal

---

[7] The information is from Regulatory Information on the Ontario Power Generation website < http://www.opg.com /info/LC_regulatory.asp>

amalgamations, many MEUs have been motivated to consolidate under the Ontario Business Corporations Act. Under restructuring, Hydro One Networks' distribution system is still the primary provider of distribution services to about 1.2 million homes and businesses across the rural areas, and to about 100 large size industries the OEB regulates the price of distribution services (National Energy Board, 2001, 37).

Regulation after restructuring is implemented through two bodies. The IMO is authorized to make and enforce the market rules which are necessary to create and administer the IMO controlled market. Each market participant is obliged to follow the market rules, in accordance with its participation agreement with the IMO and its OEB license. The IMO takes responsibility for directing the operation of an open access transmission system; establishing and operating the competitive wholesale electricity market; authorising market participants; monitoring market activities to ensure fair competition; forecasting supply requirements; and encouraging additional investment by providing information to market participants and stakeholders. In addition, the IMO identifies and reports on any inappropriate market conduct and market inefficiencies. The IMO collects facts from and provides information to market participants relating to the current and future electricity needs of Ontario and the capacity of the integrated power system to meet those needs. [8]

The Ontario Energy Board (OEB) is responsible for the licensing of the electricity market participants including the IMO, generators, transmitters, distributors, wholesalers ad retailers; determining the rates to be charged for Standard Supply Service, and the distribution and

[8] See, History of the Ontario Energy Board<http://www.oeb.gov.on.ca/html/ en / abouttheoeb / history old .htm> and Regulatory Information on the Ontario Power Generation website < http://www.opg.com/info /LC_regulatory.asp>

transmission of electricity in Ontario. It is responsible for market monitoring and also updating the Minister of Energy, Science and Technology on the competitiveness and market power, efficiency, fairness and market transparency; reviewing the IMO market rules, and considering appeals of IMO orders (National Energy Board, 2001, 37-38).

6. A MODEL OF THE POST-RESTRUCTURED ELECTRICITY MARKET

In the generation segment, although the Ontario Power Generation Inc. has been separated from Ontario Hydro, it still generates about 85 percent of the electric power sold in the province in 2002 and controls the electricity generation market.[9] As a monopoly, in the short-run, Ontario Power Generation can get the monopoly profit through charging higher prices and constraining its supply capacity.

In the transmission segment, Hydro One Inc., owned by the Ontario government, owns and manages 97 per cent of Ontario's transmission lines that criss-cross the province with assets valued at $6.6 billion.[10] Hydro One Inc. still primarily provides the distribution services in rural areas and almost 100 big industries. The municipal electric utilities, which take care of the distribution services of urban areas, have been reduced from 305 to 92 (Ontario Energy Board, 2001, 37). Most of them coincide with the expanded regional boundaries. There also exists partially vertical integration in the electricity market: the Hydro One controls most transmission and part of the distribution services.

---

[9] "Canadian Industry Link" <http://www.dfait-maeci.gc.ca/trade/ner/links-en.asp>
[10] "Quick facts about the Hydro One" <http://www.hydroone.com/en/about/quick_facts/>

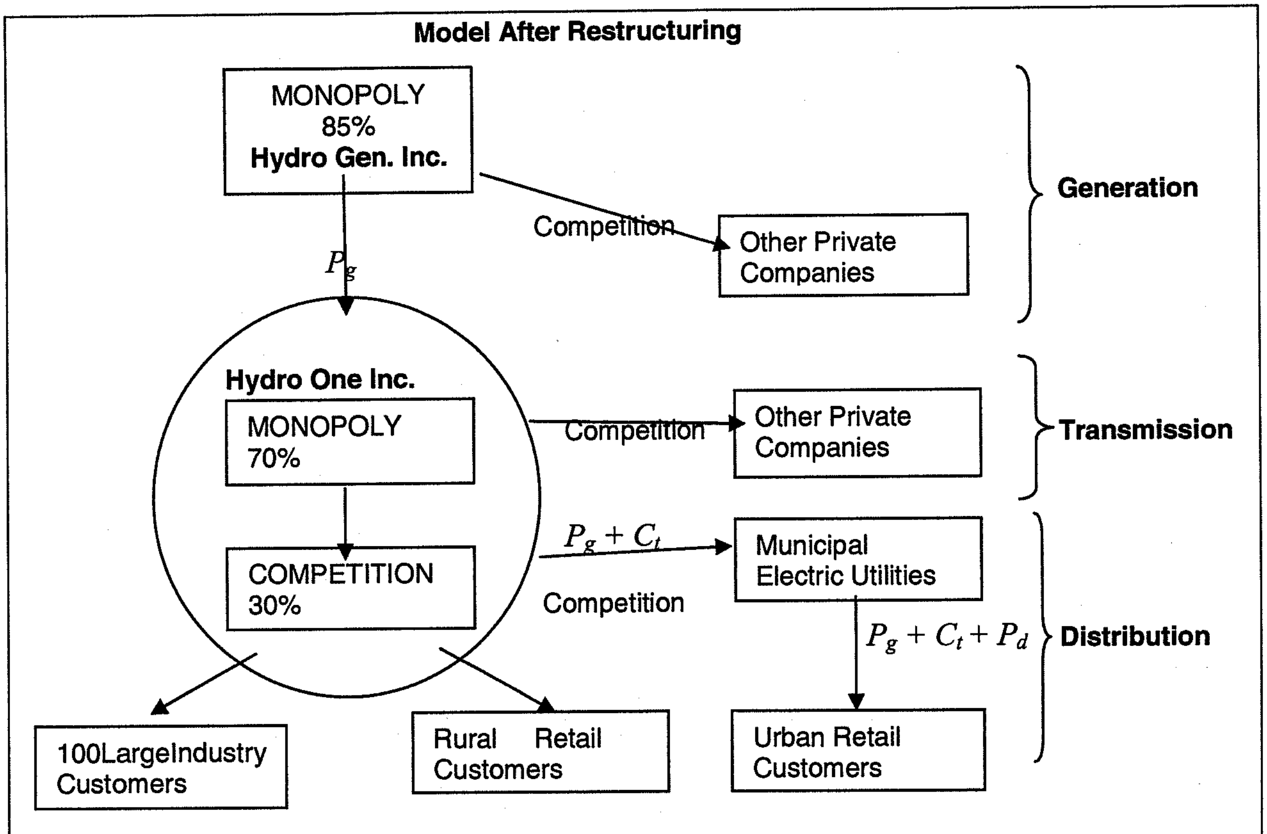
At the same time, the electricity price is not fully determined by the market: competition applies to the energy component of the electricity bill, which accounts for approximately one-half to two-thirds of the total retail price and the distribution price. The transmission price and the distribution price, which account for the other one-third to one-half of the total price, are regulated by the Ontario Energy Board (OEB) instead of being decided by the Ontario Hydro as before restructuring (National Energy Board, 2001, 35-36).

Most transmission prices are set by contract: a fixed price plus some variable component. The fixed price is an unavoidable price no matter how near the retailer is to the generator, which prevents the new generation facilities from locating beside the nearest market to avoid transmission costs (Booth and Halpern, 1996, 84-85). Some variable prices are determined by the distance between the generator and the retailer, the season and time-span of electricity usage and the amount of electricity transferred. This variable part of the price is decided by the average pricing method. A very small share of transmission prices is decided by the price pool. In addition, the variation scopes of the poll price and the contract price are regulated by the Ontario Energy Board (OEB). Thus, the transmission price of the electricity industry is virtually fixed and regulated by the government. It acts like a "veil" between the generator and retailer and has no real impact on the price strategy of generators and retailers.

The actual market structure after restructuring is illustrated in **Figure 14.**

In the generation part, as Ontario Power Generation Inc. (OPG) has market power in the generation market and does not vertically control the distribution part any more, it can charge the

Figure 14



Note: $C_g \le P_g \le P_{m1}$ $C_d \le P_d \le P_{m2}$

Source: The idea is from Tirole (1988, P.172)

monopoly price in the generation market. We assume the demand in the whole market is $Q = D(p,d)$, here P is the wholesale price charged by OPG; d is demand in the wholesale market which is uncertain. The OPG will set the price P_m to maximize its vertically integrated profit in

$$\prod_g = (P - C_g) \times D(P,d),$$

here C_g is the generation cost of electricity and $P_m > C_g$. The transmission price includes two parts: the fixed price and the average transmission cost, all of which are decided by the municipal government.

$$P_t = A + C_{ti} \times Q$$

In the distribution sub-market *i*, we assume the monopoly distributor *i* faces the demand

$$Q_i = D(P_i, d_i),$$

here P_i is the retail price in the sub-market *i*, i = 1,2…,92 (the total number of the current MEUs), d_i is the uncertain parameter of demand in the sub-market *i*. Facing this demand, distributor *i* wants to set its price to P_{mi} in order to maximize his profit

$$\prod i = (P - P_m - C_{ti} - C_{di}) \times D(P_i, d_i) - A,$$

here C_{ti} represents the average cost of transmission per unit of electricity in sub-market *i*, C_{di} is the cost of distribution in sub-market *i*. This market structure causes the "*double marginalization problem* " as the monopoly price is an increasing function of marginal cost, to the distributor the marginal cost of generation is P_{m1} instead of C_g ($P_{m1} > C_g$), so he will charge a higher retail price in this case in comparison to the vertically integrated structure. Assuming other conditions are the same, a higher retail price means less demand and a larger welfare loss.

6.1 Possible Problems of the Post-restructuring Model

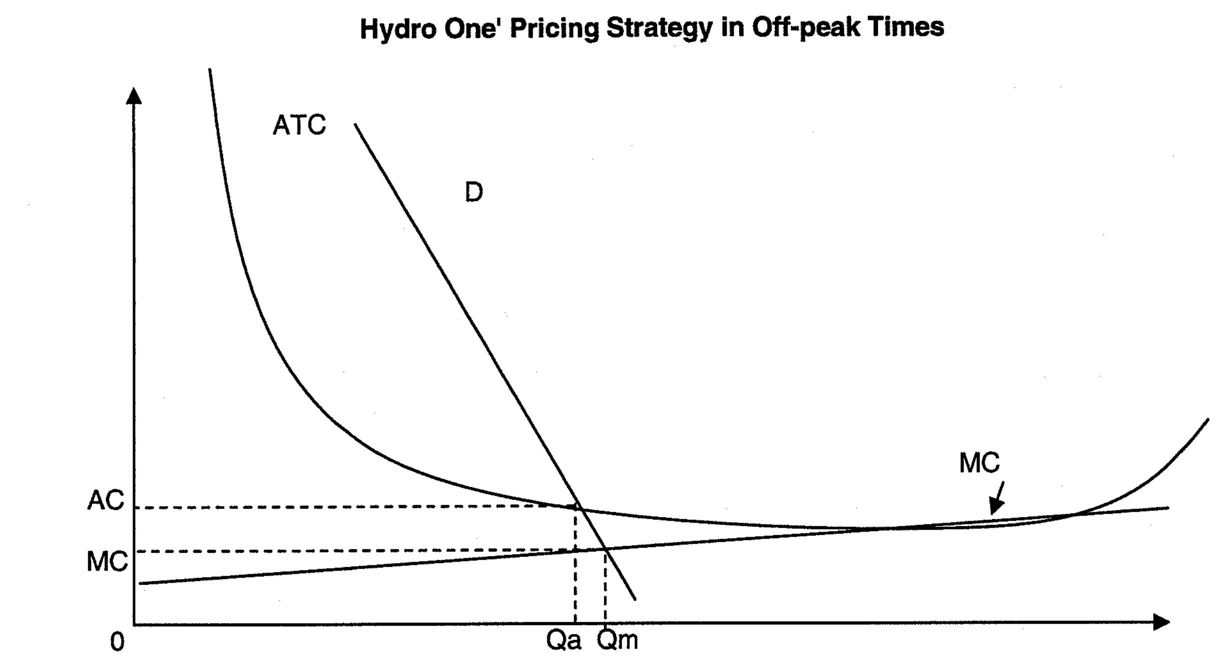
OPG monopolizes the generation market. Its inelastic production cannot adapt to the changing electricity demand. For example, in the summer of 2002, the unexpectedly hot weather led to the unexpectedly high demand for electricity (usually, the electricity demand peak appears in winter). In a short time period, the Ontario Power Generation Inc. could not increase its production of electricity enough. Therefore, at that time, the whole of Ontario was forced to face an electricity shortage problem. The lesson of electricity shortage teaches us that monopoly structure has many problems that require attention. In addition, Hydro Power Generation has to bear part of the debt induced by the nuclear plants' investment, which places a large pressure on the electricity bill and constraints the Hydro Power Generation's further development.

In the post-restructuring model, the transmission fee is decided by the government, and is equal to a fixed plus a variable component. The government uses the average pricing method to calculate the total variable cost. In off-peak times, electricity production and transmission is relatively low, the marginal cost curve is lower or equal to the average cost curve, therefore charging average cost is reasonable. However, during the peak times, the marginal cost curve is above the average cost curve. If the government still insists on average cost pricing, it will send the wrong pricing signal to retailers and customers, and encourage even more demand pressure on the transmission grids. Only marginal cost pricing can effectively reduce electricity demand in the peak hour/season. The problem with using one price over the off-peak and peak seasons is depicted in **Figures 15** and **16.**

Post restructuring, the electricity bill is divided into three parts: the generation rate, the transmission rate and the distribution rate. OPG will change the monopoly price to the MUEs, which increases their distribution costs. It leads to a higher retail price than would occur in a vertically integrated market. Thus, even under some government intervention on price, the price of electricity generation can still rise. In addition, Hydro One is still vertically integrated with most of the transmission services and part of the distribution services; the problems of unfair competition have not been totally resolved.

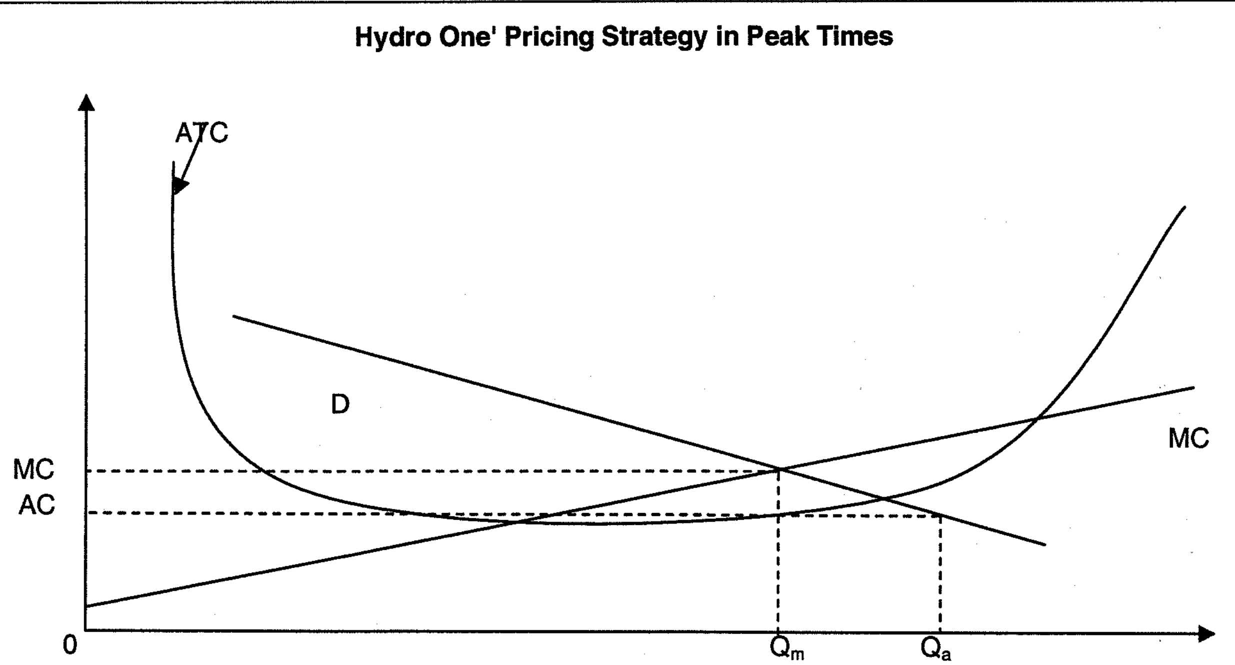
It would be interesting to know whether restructuring the electricity industry in Ontario will have the same disastrous consequences as experienced in California. To answer this question, we need to compare the situations in the post-restructuring electricity industry of Ontario with those

Figure 15



Note: when off-peak times, the demand curve is relatively inelastic, so Hydro One Inc. can charge price at AC rather than MC which can cover the total costs.

Figure 16



Note: in the peak hour/ season, the demand curve is relatively elastic, so increasing the price from AC to MC, can effectively reduce the electricity demand.

of California. The main reasons for the Californian restructuring failure are as follows (Sweeney, 2002, 277-283): first, the investment in the electricity generation capacity had not kept pace with the doubled power demand due to the economic development since the 1990's; second, a substantial amount of electricity to California was imported from states in the Pacific Northwest where heat and drought restricted the amount of electricity available from these areas; third, big generators with market power created artificial scarcity; fourth, the flawed approach to deregulation forced the local utilities to buy all their power through a power exchange at high wholesale rate, while the retail rate was restricted within a low price cap. Therefore, the local utilities bore an increasing dept load. As a result, electricity generators were reluctant to sell electricity power to these financially troubled utilities. Thus power blackouts were caused by high scarcity in the electricity industry. The restructuring situation in the Ontario jurisdiction is quite different. First of all, as described in section 2, electricity generation capacity in Ontario can satisfy peak-time electricity demand easily. Secondly, the supply of electricity in Ontario does not depend on imports. Thirdly, although the OPG has market power which may create artificial scarcity and result in higher wholesale prices, the MEU can still realize reasonable profits because there is no low price cap as in California. Thus, the electricity market conditions suggest that although the restructuring in Ontario has met with some problems, these problems are not likely to lead to the same disaster as in California.

7. AN IDEAL MODEL

In the generation segment, it would be desirable to have a few private firms compete with each other. This generation market structure is feasible in two ways. One is separating the one big utility-Hydro Power Generation Inc (OPG) into two or more generators. By selling part of its plants, OPG can use this revenue to cover part of the huge debt from nuclear plants' investment and reduce the pressure on its electricity bill and resolve the problem of diseconomies of scale. The other will be attracting new entry into the electricity market.

As the new generation companies enter into the market and with the separation of OPG plants into two or many firms, several private companies will appear in the generation market. These companies will use different resources to generate electricity; some of them are established utilities which have a fixed distribution network, some of them are new entrants. Most incumbents, having a large capacity and a fixed customer base, would produce electricity with nuclear and hydro, which means they have higher fixed costs and lower variable costs in comparison to new firms. In contrast, because of the relatively low fixed costs of coal and gas fired plants, it is predictable that most of the future entrants will place investments in these type of generating technologies. Analyzing the competitive situation of these generating companies requires some assumptions. In the short run, most entrants have lower total costs than do the incumbents, but with information asymmetry, not all distributors will change generators even when faced with lower prices. Over time the demand for electricity is likely to increase. As some incumbents have production capacity constraints (i.e., they have exhausted economies of scale), there is likely to be some residual demand left to new entrants.[11] They can charge a price higher than their costs but lower than the incumbent's cost and thus make positive profits. With competition, price falls as do profits (see **Figure 17**). In the long run, as more and more distributors choose the new entrants, the new entrants will enlarge their production capacity and incumbents will reduce their producing capacities. As coal and gas generator plants have

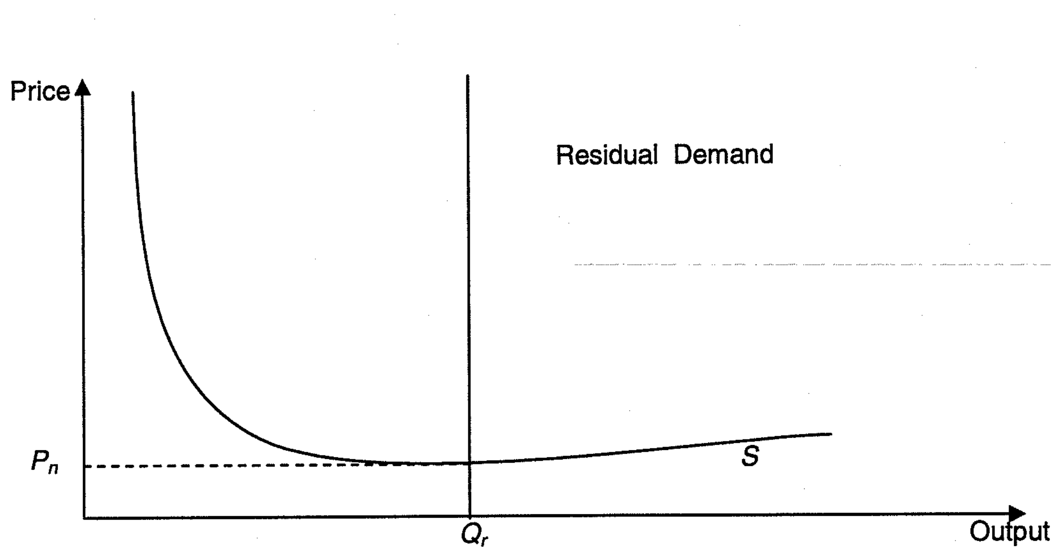
[11] As stated by Tirole (1988, 307-311) if the incumbent's equilibrium capacity is lower than market demand, an entrant could come in and than take over the market; in addition, the entrant possessing a new technology also break the preemption of the incumbent.

relatively low fixed costs but high variable costs compared to hydro and nuclear plants, their average costs will increase at a faster rate than the nuclear and hydro plants. Therefore, their relative share of production changes between insiders and new entrants, until the new entrants' average cost reaches the same level as the incumbents' (see **Figure 18**). In the polar case, if the average cost of new entrants never catches up with the insiders', then the incumbents will be driven out of the generation market. Whichever situation happens, the marginal costs of generation will be similar across firms and all generators will charge a similar price.

The transmission segment has natural monopoly characteristics; huge maintenance costs mean that it should be regulated by the government to restrain the "free rider" problem and assure the collection of these fees. Otherwise, if government deregulates the transmission part into private firms' hands, these private firms will end the requirement that utilities should reinvest a portion of their profits back into the transmission system, because of their profit maximisation incentive.

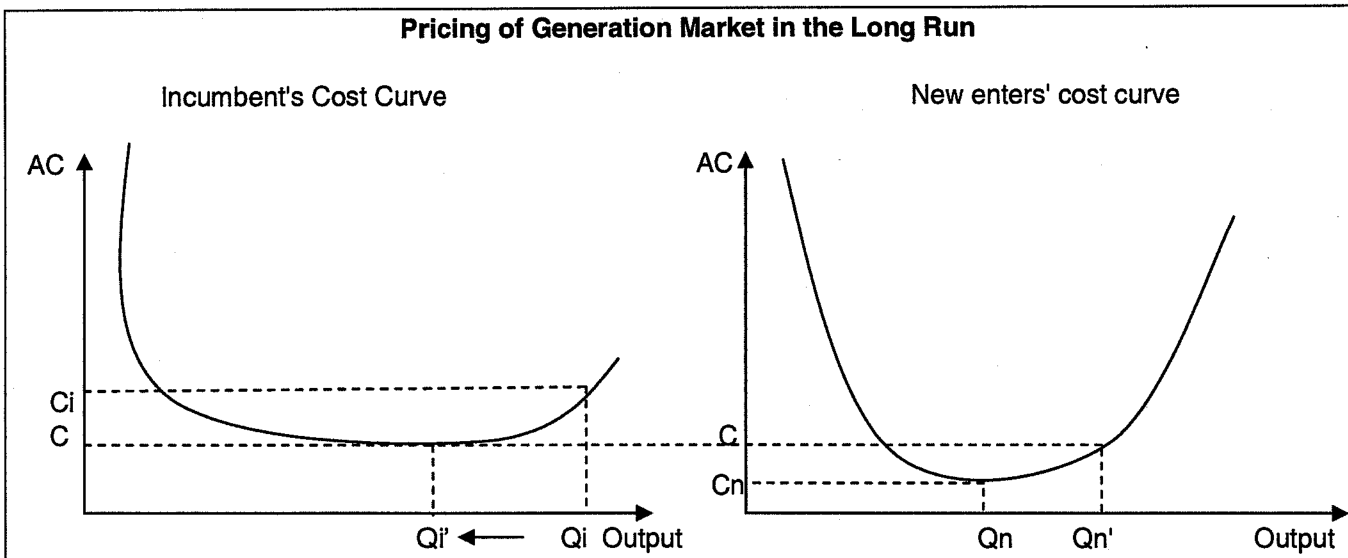
Looking at the situation in the US, for example, once deregulation was ushered in via the Energy Policy Act of 1992, the ability of states to force utilities to reinvest their profits back into the transmission system was undermined. In 1990, utilities spent $3.3 billion (in today's dollars) to update and maintain the nation's transmission system. In 2000, utilities spent $3 billion at a time when more power was moving through the grid. In addition, deregulation forced the firing of thousands of utility workers, thus hindering the ability of utilities to adequately staff the maintenance and operation of their assets. Under deregulation, energy companies simply do not have a financial incentive or responsibility to invest in transmission, because generation is the more attractive investment.

Figure 17



Note: Facing the residual demand, the new entrants have to charge the price Pn, although their costs are less than established generation companies in the market.

Figure 18



Note: In the short long, demand of incumbents' is Qi, the cost is C_i; demand of new entrants' is Q_n, the cost is C_n In the long run, demand of incumbents is reduced to Qi' , the cost reduced to C, demand of new entrants' increased to Qn', the cost equals to C too, At that time, the cost in the generation market is unique.

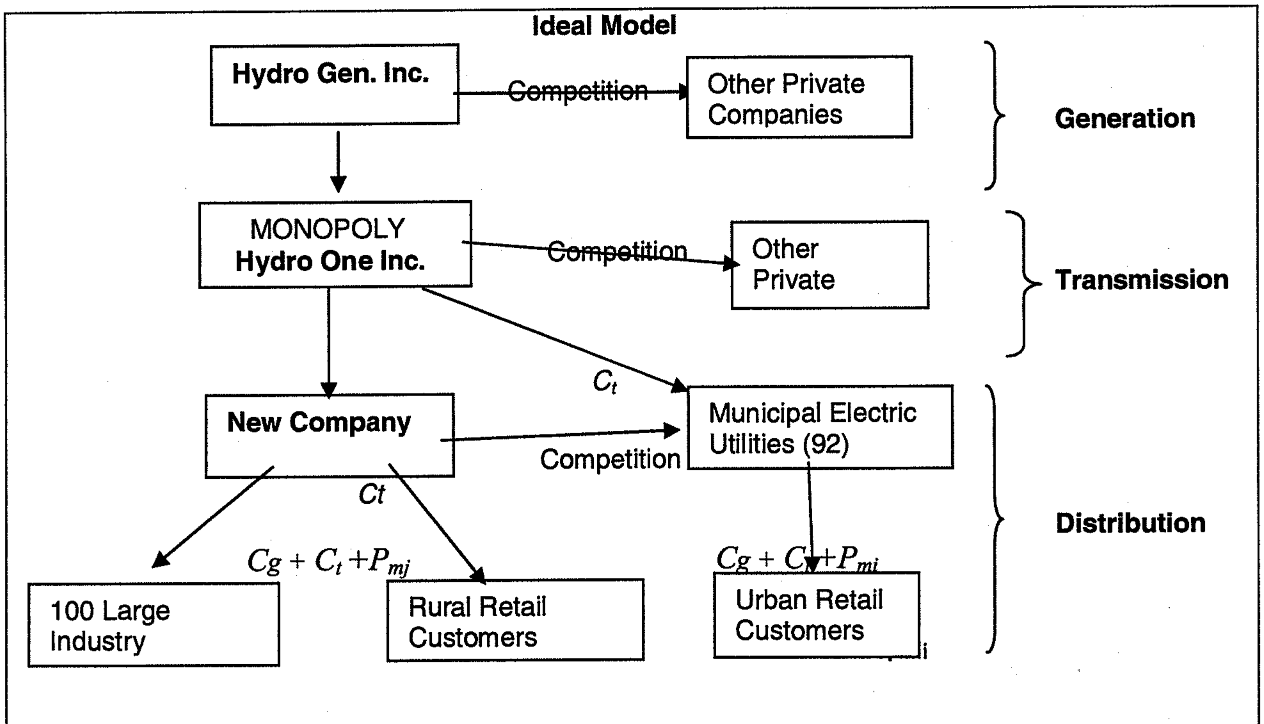
The big blackout that occurred on Aug 14, 2003, which was linked to power-line failures in Ohio, cut off power to 50 million people in eight U.S. states and Ontario. The reason for the blackout is twofold: on the one hand, the grid was antiquated and carelessly maintained; on the other hand, in the U.S. deregulation created new strains on the system, because it moves power over far greater geographic distances, placing strains on capacity. The power raised public awareness of the problem facing North America's electrical power grids and showed the failure of American's deregulation of electricity transmission.[12]

The ideal market structure model from the point of view of welfare maximization would be as follows. In the generation segment, there are a few private entities competing with each other; the share of the Ontario Power Generation Inc. in the market should be reduced therefore. The government keeps control of transmission service market in which a natural monopoly exists. In the distribution segment, the new company, separated from Hydro One Inc., competes with 92 MEUs based on benchmarks. Thus, competition should be encouraged. This ideal market structure is illustrated in **Figure 19.**

The distribution segment should reduce the current number of MEUs further and separate the distribution part from Hydro One Inc. On one hand, based on the existence of "exclusive territories" (Tirole, 1988, 1972), the distributors can charge different prices which are higher than the total cost in the local market. On the other hand, OEB should encourage "yard-stick competition" among the distributors to control their profits. The OEB would take responsibility to collect every sub-markets' economic information about the electricity. This information

[12] The U.S. blackout case is derived from Public Citizen (2003) 'The Big Blackout and Amnesia in Congress ' <http://www.citizen.org/documents/bigblackout.pdf >

Figure 19



Note: 1. $C_{dj} \le P_{dj} \le P_{mj}$, $C_{di} \le P_{di} \le P_{mi}$

2. New Company is separated from Hydro One Inc.

Source: The idea is from Tirole (1988, P.172)

would include the amount and variation of actual electricity demand, the local distribution cost, and other differences among them.

With competition in generation, the electricity generator will charge price equal to marginal costs. In the transmission part, the government monopoly controls the transmission service and regulates the different fixed and variable prices to different types of consumers. As a huge difference of electricity demand exists between peak hours/season and off-peak hours/season, the government needs to use the marginal pricing method instead of the average pricing method to reduce transmission pressure in the peak times. The transmission fee is the same to identical customers, so it has no impact on trading between the generators and distributors. In the distribution part, as distributor i can charge a price higher than costs, "yard-stick competition" (Yatchew, 1996, 333-334) controls their demand within reasonable limits.

We assume that the total generation cost of per unit electricity is C_g, the transmission cost function is

$$F(Q_i) = A + C_{ti} \times Q_i$$

here, A is fixed cost , C_{ti} is the combination of average cost and marginal cost to distributor i , Q_i is distributor i prediction of electricity demand in sub-market i, $i = 1,2\ldots,92$. We suppose the electricity demand faced by distributor i in sub-market i is

$$Q_i = D(P_i, d_i)$$

here, P_i is the retail price charged by distributor i, d_i is the parameter of uncertain demand in sub-market i. Distributor i needs to charge price P_{wi} to maximize its profit:

$$\prod i = (P - C_g - C_{ti} - C_{di}) \times D(P_i, d_i) - A$$

As the market is separated into several sub-markets and distributors themselves are connected closely to the local government, it is possible that they can predict more correctly which will reduce the retailer's risk. Because distributors are risk-averse, their utility curves are concave when facing the uncertainty of electricity demand.[13] In this case, the OEB will collect as complete as possible information to control the P_{wi} around $\prod_r$. $\prod_r$ is the profit which makes the distributor is utility equal to zero.

According to Rey and Tirole (1986, 926-927), when we assume that retailers are slightly differentiated and extremely risk averse, under demand uncertainty, the generator and social

[13] In the context of expected utility theory, risk aversion is equivalent to the concavity of u(.) (e.g., see Mas-colell, Whinston and Green (1995, 185-186)).

planner both prefer competition to exclusive territories (ET). Comparing with this case, in the post-restructuring model, the OPG get its vertically integrated profit through exclusive territories (ET). In the ideal model, the generators of electricity compete with each other. Therefore, according to their theory, the ideal model is more desirable than the post-restructuring model both from the private and social perspectives.

The ideal model resolves the problems left by the post-restructuring model. Weakening the market power of OPG makes the generation price similar to costs and the "double-marginalization problem" can be resolved. By breaking the vertical integration structure of Hydro One Inc, this will eliminate the need to cross-subsidize between the transmission part and distribution part of the market. Marginal cost pricing can help restrain part of the transmission pressure during peak times.

8. COMPARING THREE KINDS OF PRICING MODELS UNDER THREE DIFFERENT MARKET STRUCTURES

In the pre-restructuring model, the electricity price is mostly regulated. Ontario Hydro vertically controlled the wholesale and retail rates at such a level that the distributors can only cover their costs. Ontario Hydro charges the price to cover its cost and make a reasonable profit as well as to finance future investments. But, with information asymmetry, Ontario Hydro finds it hard to predict correctly electricity demand. Under vertical control, the distributor would also be discouraged from supplying additional services and may even leave the market when demand is uncertain. In the 90's, the cost of electricity increased gradually as a result of the decrease in electricity demand and the rising cost for maintenance and investments. Frozen electricity prices resulted in huge debts for Ontario Hydro.

In the post-restructuring model, as the generation part is separated from the transmission part, OPG no longer vertically controls the distributors. Using monopoly power in the generation market, OPG can charge higher prices to obtain higher profits. The transmission service, owned by the government, charges a "fair" fee both to the generation plans and to the distributors. The distributors have the right to handle their own distribution rate and get normal profits. On the positive side, the MEUs are encouraged to supply promotional services. On the negative side, double marginalization lets the price increase dramatically after restructuring.

In the ideal model, several private companies compete in the generation market, which forces them to reduce the price charged by generators and resolve the double marginalization problem. It is still the government which regulates the transmission rate, but in the peak hour/season, the government should substitute marginal cost pricing to average cost pricing to restrain demand at that time. Distributors' status as local monopolies allows them to charge higher prices than in the competitive case, to obtain some profits and reduce risks. At the same time, the "yard-stick competition" encouraged by OEB and IMO constrains distributors' prices to be around the price that lets them get the profit $\prod_r$.

9. CONCLUSION

In this paper, I applied Tirole's model (1988) to the electricity market before and after restructuring. I analyzed the model's advantages and disadvantages, and I describe what an ideal situation would look like. Here are some of my key findings.

There are many problems in the electricity industry due to the structure of the industry and the vertically-integrated public ownership. Electricity pricing under the control of the Ontario government was frozen at an unreasonably low level, causing great debts for Ontario Hydro. Electricity generation prices should not be decided wholly by the government. Ontario Hydro's restriction of the wholesale and retail rates leaves MEUs with zero profits and discourages them to supply the appropriated level of service, and even leave the market when faced with the huge risks arising in the electricity market. Ontario Hydro used its monopoly power in the generation or/and distribution parts to win some advantage for competing in other segments.

Separating the vertically–integrated part of the market and keeping the monopoly in the generation would result in double marginalization problem, and will cause the electricity bill to increase dramatically. Therefore, in order to get a reasonable electricity price as well as introduce fair competition, we must break the monopoly in generation as well as separate the vertically integrated part of the market. In addition, the transmission part needs to be monopolized by the provincial government; however the pricing method should be differentiated according to the demand. In contrast with the average pricing off-peak time, marginal pricing in the peak time can help disperse the electricity transmission pressure on the transmission grids. These lessons were drawn from the U.S.-Ontario blackout.

Considering the problems with respect to electricity ownership, market structure and pricing strategy, the optimal configuration is as follows. In the ideal model, the generation market and distribution market should be open to competition. Vertical integration of transmission and the distribution parts should be broken up. The transmission part should be owned by government (or regulated) due to its natural monopoly characteristics and the distribution part sold to private firms. Thus, competition in the first (generation), and third (distribution) process of the electric industry will restrain any private firm's profit. Monopoly in the second process (transmission) will fix transmission prices at such a level to cover operating costs and maintenance fees. The electricity price will not be as high as the price that would arise in the pre-structuring model.

Even if we know the problems that exist in the current market structure, and what the ideal structure is, there are still many practical problems concerning how to implement this structure. Faced with current pricing problems, should the government influence electricity prices? If so, what measures can be taken by the government to benefit customers without increasing the OPG's debt? What is the best way for the OPG to reduce its market share? What is a reasonable profit level for each of the distribution sub-markets under the control of OEB? All of these problems will need further investigation. This paper represents but one small step towards our understanding of this complicated and changing market.

REFERENCES

Ambec, Stefan and Doucet, A. Joseph (2003) 'Decentralizing hydro power production' *Canadian Journal of Economics*, 587-607

Booth, Laurence and Halpern, Paul (1996) 'Regulation of transmission and distribution activities of Ontario Hydro.' in Ronald J. Daniels eds, *Ontario Hydro at the Millennium,* (Montreal& Kingston, London, Buffalo: McGill-Queen's University Press)

"Canadian Industry Link" (2003) available at www.dfait-maeci.gc.ca/trade/ner/links-en.asp

Case, Peter and Akman, Matthew (2001) 'Canadian electricity deregulation', available at www.cleanair.ca/pdf/CIBC_Report.pdf

Cohen, Marjorie Griffin (2002) *From Public Good to Private Exploitation: Electricity Deregulation* (Canada:Privatization and Continental Integration Canadian Center for Policy Alternatives)

Daniels, Ronald J. and Trebilcock, Michael J. (1996) 'The future of Ontario Hydro: a review of structural and regulatory options.' in Ronald J. Daniels eds, *Ontario Hydro at the Millennium,* (Montreal& Kingston, London, Buffalo: McGill-Queen's University Press)

Environment Canada (2002) 'Fact sheet 2 - Electricity and Petroleum Industries: 1990-2000', available at www.ec.gc.ca/pdb/ ghg/1990_00_factsheet/anchor5

Freeman, B. Neil (1996) Comments of 'In search of the cat's pajamas: regulatory institutions and the restructured industry' in Ronald J. Daniels eds, *Ontario Hydro at the Millennium,* (Montreal& Kingston, London, Buffalo: McGill-Queen's University Press)

Hampton, Howard (2003) *Public Power,* (Toronto: Insomniac Press) 121-138

Hydro One (2003) 'Quick facts about the Hydro One', available at www.hydroone.com/en/ about/quick_facts/

Independent Electricity Market Operater (2000), *10 Year Outlook: An Assessment of the Generation and Transmission Facilities to Meet the Future Needs in Ontario*

MacRae, K. Morgan (1989) *Critical Issues in Electric Power Planning in the 1990s,* volume 1, 247-263

Mas-Colell, Andreu , Whinston, D. Michael and Green, R. Jerry (1995), *Microeconomic Theory*, (Oxford University Press) 185-186

National Energy Board (2001) *Canadian Electricity: Trends and Issues* (Calgary: NEB office)

National Energy Board (2002) 'Licensed market participants', available at www.oeb.gov.on.ca/html/en/licences/licensedmarketparticipants.htm

Ontario Energy Board (2003) 'History of the Ontario Energy Board' available at www.oeb.gov.on.ca/html/en/abouttheoeb/history old.htm

Ontario Power Generation (2003) 'Regulatory Information ', available at www.opg .com/info/LC_regulatory.asp

Parkin, Michael and Bade, Robin (1997) *Microeconomics: Canada in the Global Environment* (Addison-Wesley Publishers Linited) 274-277

Public Citizen (2003) 'The Big Blackout and Amnesia in Congress', available at www.citizen.org/documents/bigblackout.pdf

Rey, Patrick and Tirole, Jean (1986) 'The Logic of Vertical Restraints' in *American Economic Review*, 76(5), 921-939.

Sweeney, L. James(2002) 'Some Reflections', available at www.hoover.stanford.edu/publications /books/fulltext/electricity/277.pdf

Tirole, Jean (1988) *The Theory of Industrial Organization* (Cambridge: MIT Press) 169-199, 301-311, 338-352

Waterson, M. (1984) *Economic Theory of the Industry*, (Cambridge: Cambridge University Press), 57-82

Yatchew, Adonis (1996) 'The distribution of electricity in Ontario: restructuring issues, costs and regulation.' in Ronald J. Daniels eds, *Ontario Hydro at the Millennium,* (Montreal& Kingston, London, Buffalo: McGill-Queen's University Press)

Li, Yin (2003) 'Empirical Studies of Scale of Economics in Canadian Electric Power Generation', given in the January 2003, course paper for the class of *Empirical Industrial Organization* (Professor: M. Rafiquzzaman)