A comparative analysis of market power mitigation measures. The case of Chile's electricity industry[1].

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Abstract

In a previous paper I found that the implementation of an unregulated wholesale electricity spot market in Chile would result in prices far above competitive levels as a consequence of the unilateral exercise of market power by the largest generators. In this paper I examine whether and how much market power could be mitigated by (a) requiring the largest producer to divest some of its generating capacity to create more competitors and (b) requiring the dominant generators to enter into fixed price forward contracts for power covering a large share of their generating capacity. Splitting the largest producer in two or more smaller firms turns the market equilibrium closer to the competitive equilibrium as divested plants are more intensely used. Contracting practices proved to be an effective tool to prevent large producers from exercising market power in the spot market. In addition, a more efficient hydro scheduling resulted. Conditions for the development of a voluntary contract market are analyzed, as it is not practical to rely permanently on vesting contracts imposed for the transition period. Regulatory mechanisms to provide incentives for producers and consumers voluntary to engage in contracting practices are discussed.

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I. Introduction

Policymakers in Chile are discussing the desirability of further de-regulating Chile's wholesale electricity market. In particular, a real unregulated spot market would replace the simulated spot market that is in place today. The spot price for energy would no longer be calculated by an independent entity, according to marginal cost information provided by the generators themselves, as it is presently the case but would be freely determined by an hourly auction operated by a power exchange. Arellano (2002) analyzed and estimated the impact of this reform in the biggest Chilean electric system, called the "SIC". Its installed capacity amounts to 6660 MW. Electricity is produced by 20 different generating companies but two economic groups (Endesa and Gener) control 76% of total installed capacity and 71% of total generation. These firms differ in size, thermal/hydro portfolio and associated marginal cost functions. Endesa ("Firm 1") owns a mixed hydro/thermal portfolio; it concentrates 78% of the systems' hydro reservoir capacity. Its thermal capacity covers a wide range of fuel and efficiency levels. Gener ("Firm 2") is a purely thermal producer and concentrates the largest fraction of thermal resources in the SIC (46%).

Arellano (2002) showed that if a deregulated spot market were implemented in Chile and relied upon to allocate all power supplies, large generating companies, especially the largest producer (Endesa – Firm 1) would have the incentive and ability to exercise market power unilaterally (i.e. without collusion). Allocation of hydro and thermal resources would be inefficient. On the one hand, too little supply would be allocated to periods of high demand and too much would be allocated to periods of low demand. On the other hand, not only thermal plants would produce considerably less than the competitive level but cost of production would not be minimized as some of the plants run by the fringe are less efficient than the ones being withhold by Endesa. In my previous work I emphasized that some sort of mitigation measures were needed to prevent market power abuses in the newly deregulated spot market.

Market power has also been a major concern of governments re-structuring their power industries throughout the world. Indeed different market rules have been implemented as a shield against market power abuses. Regulators have relied on elements such as splitting the generating companies into many small firms in order to reduce the degree of concentration of the generation sector (Australia, Argentina), vesting contracts in order to reduce generating companies' incentives to charge high prices (England and Wales, Australia) and continuing regulatory surveillance and threats (England and Wales, United States), among others.

Each country / electric power system is different in terms of market structure, size, mix of generating technology and even culture. As a consequence, the experience of another market, even if successful, should not blindly be put into practice elsewhere without first carefully analyzing the individual characteristics of the particular electric power industry subject to reform. This paper attempts to do precisely that. The effect of different market power mitigation measures that have been implemented in other restructured electricity markets are thoroughly analyzed for the case of Chile's electricity industry using a simulation model framework.

In this paper I analyze and estimate the impact of two different sets of measures that could be implemented to reduce the incentive and ability of the dominant firms to exercise market power in a spot wholesale electricity market in Chile: (a) requiring the largest firm to divest some of its generating assets and (b) requiring the largest firms to enter into fixed price forward contracts covering a large share of their capacity. I will compare the new market equilibrium to the competitive equilibrium and to the base model equilibrium, in terms of aggregate levels, allocation of resources, markups and overall welfare (when possible). The model developed in my previous paper will be the basic tool to simulate the impact of the analyzed mitigation measures.

The divestiture of Firm 1's generating assets, either thermal or hydro storage plants, turns the market equilibrium closer to the competitive equilibrium not only in terms of levels (prices and output) but also in terms of the allocation of resources, as former Firm 1's plants are more intensely and efficiently used and this more than compensates for any reduction in production by the remaining producers with unilateral market power.

The application of fixed price forward contracts proved to be an effective tool to prevent large producers from exercising market power in the spot market. In addition, a more efficient hydro scheduling resulted. It is argued that it is not practical to rely permanently on vesting contracts to ensure the development of the contract market as these contracts will eventually expire and if conditions are not given for an appropriate voluntary contracting, market power abusive practices will certainly take place at that time. It is emphasized that the regulation of the industry as a whole (as opposed to the contract market) must provide the incentives for producers and consumers to contract.

This paper is organized as follows. In the next chapter I briefly describe the model used by Arellano (2002) to analyze the potential for market power in Chile's electricity industry. The (base) Cournot and the competitive equilibrium are reported. These two cases will be used as benchmark cases against which the market equilibrium with the different mitigation measures will be compared. In Chapter III I describe the model used to estimate the impact of each of these measures. Both a qualitative and a quantitative analysis are done. Chapter IV concludes and gives direction for further research.

II. Two Benchmark cases: Cournot and Competitive equilibrium

In this section I will briefly review the basic model (referred to as "the base model") that will be used to estimate the impact of the different mitigation measures. For more details see Arellano (2002).

The industry is modeled as a Cournot duopoly (Firms 1 and 2) with a competitive fringe. Firm 1 is a mixed hydro/thermal producer, concentrating 78% and 55% of the system's hydro-reservoir and total installed capacity respectively. Firm 2 is a purely thermal producer and concentrates 46% and 22% of system's thermal and total installed capacity respectively. The fringe is made up by small hydro and thermal producers.

Cournot producers face a residual demand given by:

$$D^R (P_t) = D(P_t) - S^f (P_t) - q^{MR}_t - q^{PS}_{h\,t}$$

where D(P) is market demand, D^R (P) is residual demand, S^f (P) is the Fringe's thermal supply function , q^{MR} is must-run units' generation (from thermal must run and hydro run-of-the river plants) and q^{PS}_h is the Fringe's hydro production from reservoirs distributed across periods according to a Peak shaving strategy.

Each firm's maximization problem is given by:

Firm 1's Optimization problem

$$\text{Max} \sum_t \{ P_t (q_t)*(q_{1ht} + q_{1Tht}) - CT_1 (q_{1Th\,t}) \} \quad (1)$$

s.t.

(2) $q_{1Th\ MIN} \leq q_{1Th\ t} \leq q_{1Th\ MAX}$ $\quad \forall$ t (thermal production min/max constraints)

(3) $q_{1h\ MIN} \leq q_{1h\,t} \leq q_{1h\ MAX}$ $\quad \forall$ t (hydro production min/max constraints)

(4) $\Sigma_t\, q_{1h\,t} \leq q_{1h\ tot}$ (hydro resources availability)

Firm 2's optimization problem

$$\text{Max} \sum_t \{P_t (q_t) * (q_{2Tht}) - CT_2 (q_{2Tht}) \} \quad (5)$$

s.t.

(6) $q_{2Th\ MIN} \leq q_{2\ Th\,t} \leq q_{2Th\ MAX}$ $\quad \forall$ t (thermal production min/max constraints)

where $P_t (q_t)$ = is the inverse function of the residual demand in period t; Q_t is total production by firms 1 and 2 in period t, ($Q_t = q_{1t} + q_{2t}$); $q_{it} = q_{iTh\ t} + q_{ih\ t}$ is total production by Firm "i"; $q_{iTh\ t}$ is Firm i's thermal production; $q_{1h\ t}$ is Firm 1's hydro production; $CT_i(q_{iTh\ t})$ is Firm i's total cost function; $q_{iTh\ MIN/MAX}$ is Firm i's minimum/maximum thermal production limits; $q_{1h\ MIN/MAX}$ is Firm 1's minimum/maximum hydro production limits; $q_{1h\ tot}$ is available hydro production for the whole period. The model was estimated for a 1-month time horizon subdivided in 6 sub-periods of equal length (120 hours).

FOC's can be formulated as follows:

(7) $MR_{1t} = c_1 + \lambda_{1t} - \alpha_{1t}$

(8) $MR_{1t} = \sigma_1 + \gamma_{1t} - \delta_{1t} = \Omega_{1t}$

(9) $MR_{2t} = c_2 + \lambda_{2t} - \alpha_{2t}$

where λ_{it}, α_{it}, γ_{1t}, δ_{1t} and σ_1 are the Lagrange multipliers for maximum thermal capacity, minimum thermal capacity, maximum hydro capacity, minimum hydro capacity and available hydro flows constraint respectively, MR_i is Firm i's marginal revenue and c_i is Firm i's thermal production marginal cost.

In equilibrium, production is scheduled so as to equalize marginal revenue to thermal marginal cost each period (adjusted for shadow prices). In addition, Firm 1 allocates water across time so as to equalize the marginal cost of water (Ω_{1t}) with the cost of producing an additional unit of power from the marginal thermal plant. This means that an extra unit of water will be generated until its cost is equal to the cost of the most expensive thermal plant in use. Firm 1 allocates its plants (thermal and hydro) efficiently *given* the total level of production (which is inefficient as the firm produces until marginal cost = marginal revenue < price).

Notice that this model does not take into account uncertainty as hydro flows, marginal cost and demand functions are assumed to be known by the agents. In addition, the model lacks of dynamic competition elements and does not incorporate transmission constraints or the effect of high prices on potential entry or in consumption patterns.

This model was parameterized and simulated using real cost and load data for April 2000. Marginal cost functions were estimated aggregating each plant's marginal cost. Market demand functions were assumed to be linear and parallel across periods $D(p_t) = A_t – BP_t$. Five different price elasticity assumptions, ranging from –0.1 to -1.0, and an anchor point given by the average load level per period and the associated nodal price, were used to parameterize the linear market demand function. The fringe's hydro-reservoir production was allocated across periods using a peak shaving strategy. Must run production was given by the average generation in April 2000 in the case of must run thermal plants and by the average generation in a normal hydro year in the case of hydro-ROR plants. Data used to estimate market and residual demand, assuming price elasticity = -1/3 at peak hours, are reported in Table 1.

Cournot and competitive equilibrium, for the E=-1/3 case, are reported in Tables 2 and 3[4]. As expected, total output is smaller and prices are higher than in the competitive

[4] Uniqueness of equilibrium was not investigated theoretically but empirically. In particular, the simulation was solved for 400 randomly chosen starting points. The model always converged to the same aggregated equilibrium: prices, each firm's total production, marginal cost, marginal value of water and profits. The only exception is given by the Firm 1's production strategy. Even though it is true that the equilibrium for Firm 1's *total* production is unique, this is not true for its production strategy, i.e. the decision of how much is produced from its thermal and hydro-storage plants. Multiplicity of equilibrium is explained by Firm 1 being able to allocate hydro production over time and by marginal cost being constant over relevant intervals of output. Values reported in the tables for q1h and q1th are averages calculated over 400 different estimations of the model. For more detail see Arellano (2002a).

equilibrium. Cournot equilibrium converges to the competitive equilibrium as demand level falls. Firm 1 is able to exercise market power and it does so by keeping its thermal plants outside of the market and by allocating relatively too few hydro production to high demand periods and too much to low demand periods. This hydro allocation enlarges the difference between peak and off-peak periods, as opposed to what is observed in a competitive market's hydro allocation[5]. Firm 2 is able to exercise market power only when demand is low, as it is capacity constrained the rest of the time. Its large thermal capacity was not enough to enable this producer to exercise market power. Behind this result is the fact that a large fraction of its capacity are baseload plants, which are usually not marginal and thus do not set the market price. Allocation of resources is inefficient because Firm 1 withholds thermal plants that are more efficient than some of the plants that are used by the fringe and because hydro production is not used to reduce the difference between peak and off peak periods but to enlarge it. A welfare analysis showed that even though in absolute terms, Firm 1 is the most benefited from the exercise of market power, in relative terms, the real winner is Firm 2, as its production level is very close to the competitive level but the price is considerably higher.

III. Market power mitigation measures

According to the results of my previous paper, the regulatory authority should be concerned about the market power problem and should search for some measures that could be implemented in order to mitigate this problem.

Governments reforming electricity industries have taken different approaches to deal with similar market power problems. When Australia and Argentina de-regulated their power industries, they disaggregated their generation sector into many small firms that were later privatized (or are supposed to be in the case of the remaining state owned generation companies). On the other hand, the newly formed generation firms were privatized in Chile and UK with large market shares. In the UK, however, firms were privatized with a high level of contracting (National Power with 87% and PowerGen with 88% at the moment of privatization and 72% and 70% respectively after the first set of 1 year contracts expired). Similarly generators in the New South Wales and Victoria markets (Australia) were required to sell hedge contracts to retailers of electricity in a quantity enough to cover their franchise market demand. The prices of these contracts were set by the state at fairly high levels. Finally, regulatory threats have also been used to prevent the exercise of market power: after the UK's regulatory agency threatened National Power and PowerGen to be referred to the Monopolies and Mergers Commission, the producers agreed on a price cap. They also agreed to divest a fraction of their generating capacity to independent producers.[6]

In what follows I will analyze two sets of measures that have been relatively successful in other restructured electricity systems and that are feasible to implement in Chile. Since Firm 1's large installed capacity, in particular its control of hydro-storage plants is the

[5] This effect is *smaller* the more elastic is demand.
[6] For more detail on an international comparison on restructuring and regulation of the electric power sector see Wolak (1999) and ENRE(1997).

source of its market power, it is reasonable to start analyzing the effect of requiring Firm 1 to divest some of its plants[7]. Divestiture of thermal and hydro plants will be analyzed separately. In the first case, I will analyze the impact of transferring Firm 1's thermal plants to a single firm with the potential to exercise market power as well as transferring this capacity to small producers with no market power. Secondly, I will study the effect of dispatching Firm 1's hydro storage plants competitively. In particular, I will calculate the market equilibrium under two alternative assumptions: i) the entire set of hydro storage plants is dispatched competitively and ii) only some of them are. Finally, I will analyze the impact of requiring large generating companies to contract a fraction of their production at fixed prices determined outside of the spot market.

Due to the importance of having a quantitative estimation of the real impact of these measures I estimated different versions of the original model, each of them incorporating one of these mitigation measures. All these versions of the original "base" model were estimated using GAMS/CONOPT. Even though the model results turned out to be sensitive to price elasticity of demand, I will only report results for the E=-1/3 case, as the more elastic is demand the less market power can be exercised, and the smaller the need (and the relevance) of mitigation measures.

1. Firm 1's asset divestiture

A. Full divestiture of thermal plants.

A first alternative of asset divestiture is given by Firm 1 being allowed to keep its entire hydro capacity but required to divest all of its thermal plants. Under these circumstances, hydro scheduling is the only tool Firm 1 has to exercise market power.

Thermal plants may be sold to a single producer or to many small suppliers. Both scenarios will be analyzed. If the entire thermal capacity were sold to a single producer (Firm 3), three producers, a purely "hydro" producer (Firm 1) and two purely thermal producers (Firms 2 and 3) would make up the industry. Firm 3's installed capacity would be given by former Firm 1's thermal plants. The competitive fringe would be exactly the same than in the base Cournot model. Alternatively Firm 1's thermal plants may be transferred to many small producers, in which case the industry would be made up by a purely hydro, a purely thermal producer (Firms 1 and 2 respectively) and by a considerably larger competitive fringe as it would also include Firm 1's former thermal plants. In what follows, both cases will be referred to as "Triopoly" and "Duopoly with a

[7] Similar exercises were done by Green and Newbery (1992) and Andersson and Bergman (1995). Green and Newbery (1992) estimated what the market equilibrium would look like if the industry were a quintopoly rather than a duopoly. They found that reduction in output, the price increase and the deadweight loss would be considerably smaller. Andersson and Bergman (1995) analyzed the impact of i) splitting the largest company in two firms and ii) a merge between the six smallest generators. In both cases, the market equilibrium was closer to the competitive equilibrium.

larger thermal fringe ("DLTF") respectively. Table 4 reports the new composition of installed capacity.

Marginal cost functions are plotted in Figure 1. Firm 1's original marginal cost function is above Firm 2's over almost all the range. Notice that most of the plants that would be sold are less efficient than the ones that the Fringe already had.[8].

While producers in the Triopoly case would face *exactly the same residual demand* that Firms 1 and 2 faced in the base model, the transfer of the thermal capacity to the Fringe in the DLTF case would result on Cournot producers facing *a smaller and more elastic residual demand*. In other words, in the first case, 3 producers (instead of only 2) "share" the same cake, while in the second, the original two producers "share" a smaller cake. The other elements of the model – Firm 1's hydro capacity (and constraints), Firm 2's marginal cost function, must run generation, hydro resources available and hydro generation by the fringe - remain the same.

The optimization problem to be solved must be adapted to the new circumstances: i) Firm 1 is a purely hydro producer and its only strategic decision is to schedule its hydro plants and ii) the presence of a new producer (Firm 3) in the Triopoly case or a fringe with a larger thermal installed capacity (DLTF). Each firm's maximization problem is given by:

Firm 1's Optimization problem

$$\text{Max} \sum_t \{ P_t(q_t)^* q_{1ht} \} \qquad (10)$$

s.t

$$(11)\; q_{1h\ MIN} \leq q_{1h\,t} \leq q_{1h\ MAX} \qquad \forall\, t$$

$$(12)\; \Sigma_t\, q_{1h\,t} \leq q_{1h\,tot}$$

Firms 2 and 3's optimization problem (i=2,3)

$$\text{Max} \sum_t \{P_t(q_t) * (q_{iTht}) - CT_i(q_{iTht})\} \qquad (13)$$

s.t.

$$(14)\; q_{iTh\ MIN} \leq q_{i\,t} \leq q_{iTh\,MAX} \qquad \forall\, t$$

Relevant FOCs:

$$\frac{\partial L}{\partial q_{1ht}} = Pt(q_t) + q_{1ht}^* \frac{\partial Pt(q_t)}{\partial q_t} - \gamma_{1t} + \delta_{1t} - \sigma_1 = 0 \qquad \forall\, t \qquad (15)$$

$$\frac{\partial L}{\partial q_{iTht}} = Pt(q_t) + (q_{iTht})^* \frac{\partial Pt(q_t)}{\partial q_t} - \frac{\partial CT_i(q_{iTht})}{\partial q_{1nnt}} - \lambda_{it} + \alpha^N_{it} = 0 \qquad \forall\, t\ \forall\, i=2,3 \qquad (16)$$

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[8] Given that the linear approximations used are not exactly the same, results from the different models are not completely comparable.

These conditions can be reformulated as follows:

(15') $MR_1 = \sigma_1 + \gamma_{1t} - \delta_{1t} = \Omega_{1t}$

(16') $MR_i = c_i + \lambda_{it} - \alpha_{it}$

As before, thermal generators produce until marginal revenue equals marginal cost. Firm 1 equalizes marginal revenue to the marginal value of water but this value is no longer linked to thermal marginal cost.[9] The marginal value of water indicates how much total profits would increase by having an additional unit of water available to generate. In the case of a producer with a mixed thermal/hydro portfolio, an additional unit of water would replace production from the least efficient thermal plant that is in use and profits would increase by the cost of production that has been saved. Therefore, in equilibrium the marginal value of water must be equal to the marginal cost. In the case of a purely "hydro producer" this link does no longer exist. In this case, the only way a hydro producer may increase his profits is by changing the hydro scheduling. Under these circumstances, the marginal value of water indicates how much profits would change as a consequence of having *rescheduled* hydro production if an additional unit of water became available.

A priori it is not possible to know what circumstances (triopoly or DLTF model) are more suitable for the exercise of market power. In both of them there are some elements that increase market power while some others reduce it (number of producers, size of the residual market, price elasticity of demand). In order to analyze this issue, I will focus on two results of the simulation: hydro scheduling and Firms 2 and 3 Lerner Indices.[10]

Results for both models are reported in tables 5 and 6[11]. Prices are higher and output lower in the triopoly model than in the DLTF model; both results are in between the base case and the competitive equilibrium (See figures 2 and 3). Reduction in prices and the increase in total output when compared to the base case, may lead us to, mistakenly, conclude that each Cournot producer exercises less market power.

Arellano (2002) found that Firm 1 exercised market power by reducing hydro production when demand was high and by increasing it when demand was low (relative to the competitive equilibrium). Exactly the same strategy (and in similar amounts) is carried out when Firm 1 is a purely hydro producer (See Figure 4). Firm 1's ability to exercise market power is reduced but not by much. These results also suggest that Firm 1 exercises more market power in the triopoly than in the DLTF case.

[9] Marginal revenue is equal to the marginal value of water if minimum and maximum hydro production constraints are not binding. Otherwise, min/max hydro production shadow prices must be added.
[10] In the case of Firm 1 there is no thermal marginal cost. Consequently it is not reasonable to talk of markups in the sense of Lerner Indices. This is not a problem. Since Firm 1's only tool available to exercise market power is the scheduling of its hydro-storage plants, it is this variable and not markups what should be the focus of the analysis of Firm 1's market power.
[11] Equilibrium IS unique.

In the base case, Firm 1 has so much market power, and can drive prices up by so much, especially when demand is high, that Firm 2's optimal strategy is to produce at capacity. Firm 2 is able to exercise market power only when demand is low. As Firm 1's installed capacity is reduced, Firm 2's relative position in the market is strengthened. As a result, Firm 2 constrains its production (relative to the competitive equilibrium and to the base model) in the intermediate and low demand levels, but it is still profitable to produce at capacity when demand is high (Figure 5). In addition Firm 2 is able to exercise more market power in the triopoly case, as there is another player who stands up against Firm 1.

Firm 1 exercises (a little) less market power while Firm 2 exercises relatively more. How is it then that total output is higher and prices are lower? The answer to this question is given by the owner(s) of former Firm 1's thermal plants increasing production enormously. As it can be seen in Figures 6 and 7, former Firm 1's thermal plants produce at a considerably higher rate after being divested. This increase is larger the lower is the demand level. It is also larger when the plants are sold to small producers with no market power than when they are sold to a single producer. Under these circumstances, Firm 3 would enjoy some market power and would exercise it at all demand levels except when demand is at its maximum. Even when these thermal plants are used to exercise market power and thus are dispatched at reduced levels relative to the competitive equilibrium, these levels are still considerably larger than when the plants were in Firm 1's hands. Indeed, production is large enough to more than compensate any reduction in production by the other Cournot producers (figures 3 and 7). Finally, it should be noticed that the allocation is still inefficient but less than in the base model.[12]

Table 7 reports the effect of Firm 1's thermal plants divestiture on total profits. Firms 1 and 2 are worse off after the divestiture of Firm 1's thermal plants. As expected, they are marginally better off in the triopoly than in the DLTF case. Using Firm 3's profits as a proxy of the equivalent annuity of the amount paid for Firm 1's thermal plants, one can see that Firm 1 is at its best when it controls its original mixed thermal/hydro portfolio. If required to sell its thermal portfolio, it prefers to sell them to a unique seller who enjoys some market power and thus is willing to pay for it. Notice that even though Firm 2's relative position in the market is strengthened as Firm 1 is stripped off its thermal plants, and thus it is able to exercise market power, its profits (and markups) are considerably lower. Firm 2 would still have been better off by taking advantage of Firm 1's original market power.

Summarizing: as a result of the divestiture of its thermal plants, Firm 1's market power is reduced but in no case eliminated. Indeed, Firm 1 retains its hydro capacity, which is the tool it uses to exercise market power. As a result, Firm 1's scheduling of its hydro plants is closer to the efficient allocation but it still exhibits the pattern of "less hydro production when demand is high and more hydro production when demand is low". At the same time, Firm 2 is able to constrain its production, in particular when demand is at medium and low levels. Even though both producers are able to exercise market power –

[12] In other words, Firm 2 could produce a fraction of what is currently being produced by the fringe at a lower marginal cost.

in more or less degree – the market equilibrium (and welfare) is closer to the competitive equilibrium as former Firm 1's thermal plants are more intensely used. This is true even when those plants are sold to a single producer who is able to exercise market power at certain demand levels.

B. Divestiture of hydro resources

Arellano (2002) found that the source of Firm 1's market power is the strategic management of its hydro-storage plants. Accordingly, another policy that may be implemented to mitigate the exercise of market power is to dispatch Firm 1's hydro storage plants *competitively*. Firm 1 may be entitled to keep the property of these plants but to transfer its management to an independent agent such as the CDEC, who is currently in charge of the operation of the system [13]. Under these circumstances, Firm 1 would only be able to use strategically its thermal capacity.

As a result, the industry would be made up by two large thermal producers (Firms 1 and 2) who play Cournot and by a price-taking fringe that owns a small fraction of thermal capacity but the entire hydro capacity of the system. This version of the model will be referred to as "Duopoly with a large hydro fringe" - DLHF. Installed capacity would be distributed among producers as it is reported in Table 8.

Notice that there is a change in the relative position of each firm in the market: the biggest firm in the industry is no longer Firm 1 but Firm 2. Supply and demand side of the model are basically the same than in the base model. The only difference is that in this case the entire system's hydro production from reservoirs is distributed across periods according to a peak shaving strategy (See Table 9).[14] Accordingly, Cournot producers face a smaller and *more elastic* residual demand [15].

The importance of hydro production is clearly observed in Figures 8 and 9. In the base case, the Fringe owned relatively small hydro storage plants and thus the amount of hydro production that could be allocated through a peak shaving strategy was also small. Peaks were only slightly reduced and the shape of the "shaved load curve" (i.e. total demand – hydro generation) remained mostly the same. In the DLHF model, the entire hydro production is scheduled competitively. In this case, hydro generation is large enough to flatten demand over almost all the period. This means that the shaved load curve is almost flat during a large fraction of the month, eliminating the peaks. Because of the anchors that I used (same price and same slope) this result translates into equal residual demands over the first four periods (Figure 9).

[13] Transferring these plants to many small producers is probably inefficient as the operation of the hydro system would be extremely difficult. In addition, transferring all the hydro plants to a unique producer would not work either as it was analyzed in the Triopoly version of the model.
[14] In this case, a peak shaving strategy consists in allocating more hydro production to the periods of higher demand. Hydro-ROR plants are still assumed to be must run plants.
[15] The residual demand faced by Cournot producers in this case is relatively more elastic than in the base case the higher is the demand level.

Since Firm 1 does not have hydro resources to allocate across periods, the optimization problem is completely static. There are no interactions between one period and another; each producer treats each period as a different and independent market. Each firm's (i=1,2) maximization problem is given by

$$\text{Max} \sum_t \{P_t(q_t) * (q_{iTht}) - CT_i(q_{iTht})\} \quad (17)$$

s.t.

$$q_{iTh\ MIN} \leq q_{it} \leq q_{iTh\ MAX} \qquad \forall t \quad (18)$$

The solution to this problem is given by six different and independent FOCs for each firm (equations 19 and 19'). In equilibrium each firm adjusts its production rate until marginal revenue equals marginal cost (corrected by shadow prices if appropriate)

$$\frac{\partial L}{\partial q_{iTht}} = Pt(q_t) + (q_{iTht})^* \frac{\partial Pt(q_t)}{\partial q_t} - \frac{\partial CT_i(q_{iTht})}{\partial q_{iTht}} - \lambda_{it} + \alpha^N_{it} = 0 \qquad \forall t \quad (19)$$

$$(19')\ MR_i = c_i + \lambda_{it} - \alpha_{it} \qquad \forall t$$

Results are reported in Table 10[16]. Thermal quantities and prices are the same in the first four periods, a result expected given that after allocating hydro production through a peak shaving strategy, residual demands were the same in those periods (Figure 9).

Producers charge a price that is in between the one that would be charged in a competitive market and in the base model. Prices and total output are considerably closer to the competitive equilibrium. This effect is more significant when demand is at high and medium levels, which are precisely the periods when Firm 1 was able to exercise more market power. The increase in total output is not the result of all producers increasing uniformly its production. On the contrary, observe what happens to the use of thermal capacity, the only resource that can be used strategically in this model. While Firm 1 *increases* the use of its plants, Firm 2 *reduces* it. In a completely "thermal" game, it is Firm 2 and not Firm 1 who really enjoys market power.

Since hydro plants are dispatched competitively, hydro production is larger (with respect to the base case) when demand is high and is smaller when demand is low. Total output increases when demand is at high and medium levels because the increase in hydro production and Firm 1's thermal production more than compensate Firm 2's and the fringe's reduced thermal production (Figures 10-15).

According to Table 11, requiring Firm 1 to dispose of its hydro plants effectively reduces its market power. In fact, the industry reduces its average markup from 61.5% to 40.1%. Reduction in average markup is, however, not a generalized result. Indeed Firm 2 increases its average markup (from 44% to 48%) while Firm 1 reduces it (from 72% to 26%).

[16] Equilibrium is unique.

Even though Firm 2 is, this time, able to exercise market power, it would have been better off by taking advantage of the greater market power that Firm 1 could exercise when it had all of its capacity. On the other hand, although Firm 1's thermal plants are more intensely used and that profits earned directly from these plants increased by almost 4 times, this is not enough to make up for the (direct) reduction in profits that results from the loss of its ability to schedule its hydro plants unrestricted, as thermal plants represented only 7% of Firm 1's total profits in the base case. Indeed, Firm 1's total profits are only 17% of what it earned in the base case. On the aggregate, however, Firm 1 is not considerably worse off. In fact, when the revenue from the sale of its hydro plants is considered, Firm 1's "adjusted- profits" are only 3% lower than when it had all of its capacity[17]. (Table 12). How is it that prices can go down so much and there be a small effect on Firm 1's profits? The explanation is twofold. On the one hand, prices are lower than in the base case but still higher than what would be observed under perfect competition, as Firm 2 is able to exercise market power. On the other hand, former Firm 1's hydro plants are more intensely used in the periods of high demand, when the price is higher, and less intensely used in the periods of low demand, when the price is lower, as opposed to the hydro scheduling strategy used by Firm 1 when it enjoyed market power. As a result, profits earned from former Firm 1's hydro plants are lower than in the base case, but only by 15%, and they are still 20% higher than under perfect competition. This effect along with the increased profits Firm 1 earns from its thermal plants explains the result.

As a final exercise of Firm 1's assets divestiture, I analyzed the impact of requiring Firm 1 to divest only its largest hydro system, "Laja". Under these circumstances, Firm 1 would only be able to strategically schedule 42% of the system's total hydro production as opposed to 87% in the base model[18]. This model will be referred to as "Duopoly with a medium hydro fringe – DMHF". See Table 8 for the resulting distribution of installed capacity.

The most interesting result (Table 13) is how each firm's relative position in the market changes with the demand level. In the base model, we found that Firm 1 was the one that really enjoyed market power, while in the purely thermal game (DLHF), it was Firm 2. In this "in-between" model, both firms seem to enjoy market power, although who can really exercise it varies with the demand level. When demand is at its peak, Firm 1 is the one who constrains its production; Firm 2's optimal strategy is to produce at capacity. Unlike that, in the middle hours, it is Firm 2 the one that enjoys market power; Firm 1's production closely resembles its production in the DLHF model (when its market power was reduced)[19]. (Figures 10-15).

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[17] As in the previous exercise I am using the profits earned by the owner of former Firm 1's hydro plants as a proxy of the equivalent annuity of the amount paid for those plants.

[18] As a consequence of a larger share of hydro production being allocated competitively, the shaved load curve exhibits smaller peaks than in the base model. In fact, during the middle hours, shaved demand is almost constant.

[19] Estimated equilibrium is unique except for Firm 1's production strategy.

Summarizing: while the disposal of Firm 1's hydro-storage plants considerably weakens its relative position in the market, Firm 2's is strengthened. Indeed, Firm 2's relative position in the market is the strongest when the entire set of Firm 1's plants is dispatched competitively. Even though Firm 2 is able to effectively exercise market power, the market equilibrium is closer to the competitive equilibrium as total output is considerably larger.

Firm 1's asset divestiture: Comparison and welfare analysis

Different alternatives of Firm 1's asset divestiture have been analyzed. I found that the incentives to exercise market power, even though smaller, are not reduced significantly since Firm 2 is now in a position to withhold output to keep prices up from the competitive level. As a consequence of its installed capacity being reduced, Firm 1's relative position in the market is weakened while Firm 2's is strengthened. This result is particularly important when Firm 1 is prevented from strategically dispatching its hydro storage capacity, as it is the main tool it has to exercise market power. It is in this case that Firm 2's position is the strongest and exercises the most market power, while Firm 1 exercises the least.

In order to evaluate these policies, a welfare index was calculated as the sum of the producer and consumer surplus (See Table 14). Observe that the four alternatives of asset divestiture are very similar in terms of welfare, the producer surplus and consumer surplus change. If any of these measures were implemented, welfare would be between 2.7 – 3.3% higher than when Firm 1 has its entire capacity and is able to exercise market power (base case) and between 1.0 – 1.5% less than if the market were perfectly competitive[20]. This result is explained by a reduction in the producer surplus (between 9 and 15%) and an increase in the consumer surplus (between 14 and 21%) when compared to the base case[21,22].

Aggregate results across the mitigation measures analyzed being similar does not mean that the different forms of Firm 1's asset divestiture are equivalent. On the contrary, this similarity hides important distributive differences. Firm 1's direct profits are considerably more affected when it is not allowed to schedule its hydro plants strategically; a reasonable result given that its hydro capacity is the source of its market power. However, once revenues from the sales of its assets are taken into account, Firm 1 is almost indifferent between the four different alternatives that have been analyzed.

[20] The measure of welfare loss used does not take into account inefficiencies that may result from producers allocating resources to maintain their market power, such as lobbying or, more generally, any deterring competition practice. In addition, dynamic elements, such as entry, were not included either. If the high prices that result from the exercise of market power attract excessive entry as in Green and Newbery (1992) then the welfare loss would be larger.

[21] Given that none of these measures completely eliminates the exercise of market power, the producer surplus is still higher (between 18 and 27%) and the consumer surplus is still lower (between 12 and 17%) than what would be observed if the market were perfectly competitive.

[22] When compared to the base case, welfare only improves slightly as most of the reduction in the producer surplus is compensated by an increase in the consumer surplus. This result is not a surprise given that I assumed that market demand was relatively inelastic (E=-1/3 at the peak anchor point).

However, Firm 2 and the "initial" fringe are not[23]. Indeed, the reduction in the producer surplus that would be observed if Firm 1's ability to exercise market power were constrained by any of the analyzed measures, would be almost completely explained by the smaller profits earned by Firm 2 and the Fringe. They are certainly not indifferent among the different forms of Firm 1's assets divestiture. They strongly prefer the status quo, and if that is not possible, they prefer the alternative that keeps more market power in the hands of Firm 1 (Triopoly over DLTF and DMHF over DLHF). On the consumer side, exactly the opposite happens. Consumers are better off the less market power can be exercised by Firm 1. Regulatory authorities will have to keep in mind the distributional effects that may take place as a result of each form of Firm 1's asset divestiture. [24]

Requiring the largest producer to divest some of its generating capacity to create more competitors does not eliminate the incentives or the ability to exercise market power, as under those circumstances, both firms are able to constrain their production in different amounts. The main difference in this regard is that Firm 2 holds a stronger position in the market. At the same time, however, market equilibrium is considerably *closer* to the competitive equilibrium not only in terms of levels (prices and output) but also in terms of the allocation of resources. This result is explained by former Firm 1's plants (either thermal or hydro storage) being more intensely and efficiently used, an outcome that should not come as a surprise since a large fraction of the capacity that was kept out of the market by Firm 1 were low-marginal cost plants. The resulting higher (and more efficient) production level more than compensates any reduction in production carried out by Cournot producers.

2. Contracting practices

As a final exercise I will analyze the impact of contracting practices. I will assume that - for reasons that will be later discussed - generators and buyers meet in a contract market and sign contracts for a certain amount of energy and price. After these contracts are signed, both parties (and possibly some others) meet again in the spot market. The contract price may be determined in different ways (by regulators, as a function of the expected spot price, and so on) but once it is set, it is not changed and thus has no direct effect on the spot price.

The economic literature, both theoretical and empirical, has showed that the more contracted producers are, the less market power is exercised and the closer the outcome to a perfectly competitive (PC) market, in terms of prices and efficiency of output decisions. These results are explained by the change in producers' incentives that is observed as a consequence of contracting practices being introduced. In particular, the more contracted a producer is, the more his profits are determined by the contract price as opposed to the spot market price. As a consequence, the firm has less incentive (or no

[23] By the "initial" fringe I refer to the small producers that were present in the industry before any Firm 1's asset divestiture took place. In other words, it does not include the new owners of former Firm 1's plants.
[24] In order to analyze the convenience of deregulating the system and implementing any of the policies that have been proposed, one should also do a welfare analysis of the current regulation.

incentive at all in the margin) to manipulate the spot price, as this would have little effect on its revenues. Indeed, for sufficiently high contract levels (when the firm is "over-contracted"[25]) profits are maximized at a price below its marginal cost.[26] Producers' incentive to raise the price is decreasing in the contracted quantity (See Newbery 1995). Wolak (2000) and Scott (1998) pointed out that what is really important for the final outcome is the overall level of contracting as opposed to the individual level. [27]

In order for contracting practices to mitigate market power, there must be some price responsiveness in demand. In other words, the more inelastic is demand, the less important is the contracting level in producers' incentives to manipulate the price.

While the literature has extensively analyzed the impact that contracting practices have on the "market equilibrium", the same has not happen with respect to their effect on hydro scheduling decisions. Scott (1998) shows that the higher the level of total contracting, the higher is total and hydro generation.[28] He also found a positive relationship between the total level of contracting and the marginal value of water. The effect of contracts on the hydro *scheduling* issue is not explicitly analyzed in his paper. In particular, it is shown that the higher the level of overall contracting, the higher is hydro generation, but it is impossible to know how a particular firm allocates water across periods.[29] For instance, what does the firm do when it is over contracted in one period and under-contracted in the other one? My model will give an answer to this question.

Generating companies will be entitled to sell to consumers a pre-arranged quantity at a pre-arranged price ("strike price"). In particular, I will assume that these contracts take the form of "two-way options", i.e. both parties deal with the spot market and the consumer (producer) is compensated for the difference between the spot price (P) and the strike price (W) if P>W (P<W). Contracts are private and are arranged before the spot market meets. In order to quantitatively analyze the effect of contracting practices, each firm's objective function must be modified as follows:

$$\text{Max} \sum_t \{ P_t(q_t)*(q_{it} - k_{it}) - CT_i(q_{iTh\,t}) + k_{it}W_{it}\} \qquad i = 1,2 \qquad (20)$$

where k_{it} is the contracted quantity and W_{it} is the contracted price. The last term indicates the fixed revenue the firm gets from its contracts. This term has no effect in the solution of the model, as the contracted quantity and price were determined outside the spot market (and before this market meets).

[25] A firm is over-contracted when the contracted quantity is more than what the firm can economically produce.
[26] Wolak (2000) uses a very simple framework to illustrate these effects.
[27] For more details on the impact of contracting practices see Wolak (2000), Allaz and Vila (1993), Newbery (1995), Green (1999), Powell (1993) and Scott (1998).
[28] Over a certain level of contracting hydro generation is greater than in PC.
[29] It is impossible to know the answer to this question because of the way results are reported (hydro generation against total contracting level).

FOCs are[30]:

$$\frac{\partial L}{\partial q_{it}} = Pt(q_t) + (q_{it})^* \frac{\partial Pt(q_t)}{\partial q_t} - \frac{\partial CT_i(q_{it})}{\partial q_t} = 0 \quad \forall t \qquad (21)$$

$$MR_{it} = c_{it} \quad \forall t \qquad (21')$$

The producer equalizes marginal revenue to marginal cost, but marginal revenue is not a function of the firm's total production, as before, but only of the level of production that is actually sold in the spot market. Notice that the smaller is this term, the closer is the marginal revenue to the price level, and the closer the "market power" equilibrium to the competitive equilibrium. Equation 21' can be used to analyze the impact of being over (k>q) or under (k<q) contracted. When the producer is under-contracted, the market outcome will lie somewhere between the perfect competition and the no-contract equilibrium. When the producer is over-contracted (k>q), it does not behave as a net seller in the market but as a *net buyer*. In that case, the producer is no longer interested in driving prices up, but instead, it wants to drive prices *down* (and *below* marginal cost).

The competitive equilibrium will be the benchmark used to calculate the level of contracting at a certain time. In particular, when I say that the contracting level is x% I will mean that the contracted quantity (k) is given by x% of the load that the firm would be expected to generate under perfect competition. This approach allows me to incorporate the fact that the contracted quantity is not constant across the month.[31]

Results for different contracting levels (0%, 50% and 100%) are reported in Tables 15 to 17. As before, results will be reported for the case in which price elasticity of demand is –1/3[32]. Notice that when k=0 we go back to the original base model and that when the firms are "fully contracted" (contracting level = 100%) results are very close to the competitive equilibrium[33].

As expected, the more contracted the firms are, the lower are the prices and markups and the higher is output. In particular, when the firms are "fully contracted" the equilibrium is very close to the competitive equilibrium. In addition, prices tend to be closer to marginal cost as the contracting level increases; indeed when Firm 1 is over-contracted (t=5 for a contracting level of 100%) price is lower than marginal cost as predicted by the theory.

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[30] For simplicity I am maximizing over q_{1t} rather than over q_{1ht} and q_{1Tht}. Qualitative results regarding hydro scheduling and thermal/hydro split of production remain the same. I also assumed that minimum and maximum capacity constraints are not binding.

[31] Unfortunately I do not have good information regarding contracting practices in Chile. I only have data on the annual level of contracting but there is no additional information regarding how it is distributed across the year, if there is any particular relationship with capacity, etc.

[32] Conclusions are the same for the remaining cases.

[33] Notice that a contracting level of 100% does not mean that contracted quantity = production (k=q). How much the firm will produce at every period is an endogenous variable and thus difficult to predict with certainty at the time contracts are signed.

Total production increases with the contracting level, as has also been found in the literature. There are two additional results are worth noting. First of all, notice that as the contracting level increases, Firm 2 loses all the market power that it had before. Arellano (2002) found that Firm 2 could only exercise market power when demand was low, because in the remaining periods it was capacity constrained. However, when producers sell contracts and the contracted quantity is sufficiently large, Firm 2 cannot exercise market power even in those low demand periods. Secondly, observe what happens to Firm 1's production level. In addition to the fact that it produces more the more contracted it is (Figure 20) there is an important change in the way hydro production is scheduled (Figure 18). There may be two effects in place at the same time. By one side, I expect that the more contracted is the firm, the more efficient is its hydro scheduling. I also expect that the firm would allocate more production to those periods when it is over-contracted so as to drive the price down. What we observe is that as the contracting level increases, hydro scheduling is closer to the efficient (competitive) allocation. As a consequence, contracting practices result in gains in both productive and allocative efficiency. In addition, Firm 1 uses (relatively) more water when it is under-contracted (high demand periods) and less when it is over-contracted (when compared to the PC equilibrium). This implies that the contracting practices' "distortion reducing effect" dominates the second effect. Indeed, Firm 1 increases total production when it is over-contracted by relying as heavily as it can on its thermal plants; notice how closely is thermal production to the competitive equilibrium (Figure 20).

Note as well that my results differ from what was found by Scott (1998) regarding the impact of contracting practices on hydro production. He found a positive relationship between hydro production and the contracting level. According to my results, the higher is the contracting level, the closer is hydro scheduling to the optimal allocation, meaning that *more* is produced from hydro sources when demand is high and *less* is produced in low demand periods.

The more contracted the firm is, the higher is the marginal value of water, a result that is consistent with Scott (1998)'s findings for the electricity market in New Zealand (Table 18**)**. The intuition behind this result is the following: the more contracted the firm is, the more it produces and given that the marginal cost function is increasing, the more costly it is to produce. In equilibrium the marginal value of water has to be equal to thermal marginal cost, and thus the more the firm wants to produce, the more valuable is water.

Do contracting practices help to mitigate market power? According to Table 19, the answer is yes. Firm 1's Lerner Indices are notably lower the more contracted the firm is.[34] This is in line with the role contracts have had in the UK, where according to Newbery (1997) "[they] have turned out to be absolutely critical for introducing competition". By selling contracts, Firms 1 and 2 give up to some or most of their market

[34] Notice that the markup is *negative* for t=5, contracting = 100% indicating that the price is less than the marginal cost. This result is consistent with what we expected for periods when the firm is over-contracted.

power. As a result, the production level is closer to the competitive equilibrium and productive and allocative efficiency greatly improve.[35]

Even though it is true that given a large forward contract position, the generator would have less incentive to exercise market power, an important issue is whether the contract market will develop or not. In particular the relevant question is why would the producers voluntarily give up to their market power position and sign these contracts. As Harvey and Hogan (2000) claim "it is clear that generators will understand the incentives and will not be likely to volunteer for forward contracts at low prices that reduce their total profits"[36]. Important elements in the development of this market will be the price at which the contracts will be signed. This is an important issue for further research.

Wolak (2000) uses a simple model of the spot market to show that producers will be more willing to participate in the contract market the more elastic is demand for electricity, as the lower spot price is more than compensated by increased sales. However, demand for electricity is usually less than one. He also argues that risk averse agents or regulation may also explain the development of a contract market. Wolak does not explicitly model the contract market and nothing is said regarding how the contracted quantity and prices are set. Allaz and Vila (1993) model the contract and the spot market in a two period setting (contracts are signed in the first period and spot market transactions take place in the second). They showed that producers are willing to sell contracts in an attempt to improve their situations on the spot market. Under these circumstances the contract market develops even in the absence of uncertainty. However, this result strongly depends on the Cournot assumption, as Green (1999) showed. In addition, they showed that if both producers sell contracts simultaneously, a prisoner's dilemma problem emerges. When repeated interaction is added to the model, a reasonable assumption in the case of the power industry, producers should learn after a while and will probably collude and not sell contracts at all.

Green (1999) uses the supply function equilibrium (SFE) approach to model the spot market (assuming linear supply functions) and different conjectures (among them Bertrand and Cournot) to model the contract market. In his model, producers know that by selling contracts, the spot price is reduced while the equilibrium output is increased. They also know that the equilibrium in the spot market could be the same if they had adopted a more aggressive strategy in that market. Green argues that in order to be willing to participate in the contract market they need an additional incentive. He points out to two: a change in rival's strategy or a hedging premium. In the particular case of his linear model with risk neutral agents (contract price is equal to expected spot price) each producer's strategy is independent of his rivals' contract sales. As a consequence, generators with Cournot conjectures sell no contracts in equilibrium, as this does not affect his rival's strategy. Under these circumstances, the contract market would not develop. Green (1999) points out that Allaz and Vila (1993) got a different result because

[35] Unfortunately it is not possible to carry out a welfare analysis as it was done in the previous section because that would require too many arbitrary assumptions (risk attitude of the agents, an estimation of the risk premium, estimation of the contract price and expected spot price, etc.)

[36] pp.9-10

in their model the producers' strategy is given by the quantity offered in the market and this quantity is a negative function of the rival's contract sales. Finally, Green shows that when the buyers are risk averse and thus willing to buy contracts for more than the expected spot price the contract market develops even if producers have Cournot conjectures. The hedging premium is the additional reason the firm needed to enter the contract market.[37]

Powell (1993) also analyzed the impact of risk aversion in the development of the contract market. In particular, he added risk aversion on the part of the buyers to the Allaz and Vila (1993) model. He found that buyers were interested in purchasing hedging contracts, even at a hedging premium, because they wanted to be risk protected but *also* because of the contracts' "controlling monopoly power" effect. Indeed, Powell showed that the contract market would develop even if the buyers were risk neutral and contracting were costly (contract price > expected spot price); buyers realized that the more contracted generators were, the less market power could be exercised in the spot market, and this was reason enough to contract even at a premium rate. An important element of his model is the contract price and how it is determined. He found that when generators do not cooperate in any market (contract / spot market) the competitive outcome may emerge and full hedging results. However when generators cooperate in one or both markets a price premium and only partial hedging results, being the size of the contract market smaller when generators cooperate only in that market as they use it to pre- commit to a certain output level. Partial hedging is reinforced by the fact that the "controlling monopoly power" effect turns contracts into public goods and each buyer wishes to free ride, reducing demand for contracts.

The contract market may also develop as a result of regulation. When the England and Wales market was deregulated the government put in place a set of contracts between the privatized companies and the RECs. Approximately 87% of National Power and 88% of PowerGen's capacity was covered in the initial portfolio (Green 1994). Green (1999) reported that generators remained heavily contracted after the first set of contracts expired. In particular, greater sales of contracts used to back sales in the competitive market made up for much (but not all) of the fall in the coal contracts.[38] He argues that contract prices have generally been above the pool prices and seem also to have been above the pool prices expected at the time the contracts were signed. This suggests the existence of a hedging premium which producers had been explicitly allowed to charge as part of an agreement to keep wholesale prices below specified levels. Similarly, Wolak (2000) pointed out that generators in the NSW and Victoria markets (Australia) were required to sell hedge contracts to retail suppliers of electricity in a quantity enough to cover their captive consumers' demand. The prices of these contracts were set by the state government at generous levels relative to prices in the wholesale market. The vast majority of these vesting contracts have expired and it seems that many retailers have voluntarily purchased contracts to hedge the spot price risk associate with selling at a

[37] Green (1999) also argues that producers may use contract sales as a commitment device. In particular they would sell contracts to commit to keep output high and spot price low in response to the threat of entry or of regulatory intervention.
[38] See Supplemental Materials for Green (1999) in www.stern.nyu.edu/~jindec/supps/green/green.pdf

fixed price to end consumers. However, voluntary hedging has not been enough to compensate for the expired vesting contracts.

Four different lines of reasoning for the development of the contract market have been analyzed. Wolak (2000) and Allaz and Vila (1993) argued that producers sell contracts in order to improve their situation in the spot market. This argument is probably weak as demand for electricity is relatively inelastic and the result is sensitive to the Cournot assumption. In second place, Green (1999) and Powell (1993) argued that producers might sell contracts, even if this results in their position in the spot market being weakened, if there are risk averse buyers willing to pay a premium in order to be risk protected. Powell (1993) showed that buyers might exhibit strategic behavior and buy contracts, even at a premium price, as a way to prevent producers from exercising market power in the spot market. This result holds even if the buyers are risk neutral. Finally, Wolak (2000), Powell (1993) and Green (1999) showed the role that regulation had in the birth of the contract market in Australia and England and Wales.

A priori it is difficult to know whether the conditions will be given for the development of a voluntary contract market in the post deregulation electricity industry in Chile. At this time, all that can be done is to conjecture. It is clear that in the transition period from the system that is in place today to a deregulated system, regulation that requires retailers to purchase hedge contracts in a quantity enough to cover their monopoly franchise demand may be needed[39]. However, at a certain time, these mandatory contracts will necessarily expire, and if the authority wants to rely on the contract market to prevent producers from exercising market power, it must ensure that conditions will be given for this market to develop.

Green (1999) and Powell (1993) have emphasized the role that risk averse buyers might have in this regard. In order to analyze whether buyers in Chile are risk averse or not, one needs to examine who these buyers are and what do they purchase electricity for. In the case of large consumers who use electricity as an input of production, it is reasonable to expect them to be risk averse, as they usually sell on very thin margins. Accordingly, they would probably be willing to pay a hedging premium for their purchased contracts. Unfortunately the number of large consumers that are entitled to contract with generators is small and certainly not enough to guarantee the development of a deep contract market.[40]

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[39] The contracted price will probably not be important for the development of the market but it will certainly have significant distributional effects. There are different approaches that may be used to set the strike price in the vesting contracts. An alternative is to continue calculating the regulated price, using a similar but improved methodology than the one that is used today (currently the regulated price is supposed to be an average of forecasted spot prices in a competitive market). This calculated price could be used as an anchor for the contracts' strike price. For instance it could be used as a price cap or as the middle point in a +/- x% band where the strike price could be allowed to fluctuate. The latter us is less restrictive than directly imposing a price and allows the contracting parties to some degree of negotiation. In addition, if the regulated price were truly a good forecast of the competitive price, as it is supposed to be, the contract price would also be a good proxy.

[40] Large consumers in Chile are those whose maximum demand is greater than 2 MW. They amount to a negligible fraction of consumers and 50% of total consumption (more than 30% of it is located inside the distribution companies' franchise market and thus are not really free to choose who to contract with).

A second set of potential buyers of contracts are the distribution companies. How interested these firms are in voluntarily contracting strongly depends on the regulation of the price charged to end-consumers. If they are allowed to completely pass through the "generation" price, it is very likely that they will have no incentive at all to contract. On the other side, if the final price is fixed (and constant) they would face the risk of any spot price change and thus would be more inclined to contract. Forcing distribution companies to contract, for instance by not giving them access to the spot market or by mandating them to contract a certain quantity, may be a dangerous policy. Even though it may result in a deepening (or a development) of the credit market, it may also result in anticompetitive practices at the same time. Think for instance on a distribution company required to be fully contracted and allowed to completely pass through the contracted price to end consumers. If at the same time, and for any reason, generation companies have incentives to contract, distribution companies may feel free to ask for certain "rewards" in order to be willing to buy the contracts. These rewards will most likely come in the form of privileges that go against the development or the functioning of a competitive spot market. [41]

Producers and buyers engaging in contracting practices is an insurance against market power abuses in the spot market, as the more contracted generators are, the closer is the outcome to the competitive equilibrium. Unfortunately, the development of the contract market is not always guaranteed as it has been showed in the literature. If the Chilean authority wishes to rely on the contract market to mitigate market power, it must have to be extremely careful in the incentives the regulation provides for the parties to voluntarily contract. Focusing only in the regulation of the contract market is not only insufficient but also myopic. Vesting contracts will expire sooner or later and at that time, it would be the regulation of the whole industry the one that will be key in providing the incentives to contract. A final warning regarding the importance of appropriate regulation and how much it is convenient to rely on the contract market is given by Powell (1993)'s results: the more opportunities producers have to cooperate, the more partial (as opposed to full) hedging results.

IV. Conclusions

If an unregulated spot wholesale electricity market system were implemented in Chile large generating companies, especially the largest producer, would have the incentive and the ability to exercise market power. Two sets of mitigating measures have been analyzed: i) requiring the largest producer to divest some of its generating capacity to create more competitors and ii) requiring the dominant generators to enter into fixed price forward contracts for power covering a large share of their generating capacity.

The different forms of divestiture of Firm 1's assets that have been analyzed showed us that this firm's market power relies on its hydro capacity; a change from a mixed thermal/hydro portfolio to a pure hydro portfolio would not have a big impact on Firm 1's incentives to exercise market power. As a result, Firm 1's scheduling of its hydro

[41] This is exactly what currently happens in Chile.

plants is closer to the efficient allocation but it would still exhibit the pattern of "less hydro production when demand is high and more hydro production when demand is low". As a consequence of its installed capacity being reduced, Firm 1's relative position in the market would be weakened while Firm 2's would be strengthened. This change in the "balance of power" resulted in all the exercises of divestiture that were carried out. Firm 2's relative position in the market is the strongest when the entire set of Firm 1's plants is dispatched competitively. Even though both firms would be able to exercise a certain degree of market power, the divestiture of Firm 1's assets, either thermal or hydro storage plants, would turn the market equilibrium closer to the competitive equilibrium not only in terms of levels (prices and output) but also in terms of the allocation of resources as former Firm 1's plants (either thermal or hydro storage) would be more intensely used and this would more than compensate any reduction in production by the Cournot producers. As a result, these forms of asset divestiture would entail big gains in terms of consumer surplus. At the same time, the producer surplus is reduced, a result that is almost completely explained by the smaller profits earned by Firm 2 and the Fringe (if revenues from the sale of Firm 1's plants are taken into account, Firm 1's total profits are only slightly smaller). Even though their impact in terms of aggregated welfare is very similar, there are big differences in terms of the change at the firm and consumer level. In particular, the more market power Firm 1 is able to exercise, the better off are Firm 2 and the Fringe and the worse off are the consumers. Regulatory authorities must be aware of the distributional effects that may take place as a result of each form of Firm 1's asset divestiture.

The market power mitigation role of contracting practices was also analyzed. I found that the more contracted the firms are, the closer is the market outcome to the competitive equilibrium. In addition, there was an interesting effect in terms of hydro scheduling: unlike what had been found in a previous paper (Scott 1998), the more contracted is the firm, hydro scheduling is more efficient, meaning that more water is allocated to periods of high demand and less water to periods of low demand.

Firm 1's asset divestiture and contracting practices bring the market equilibrium closer to the competitive equilibrium. However, requiring firms to contract entails less intervention in the industry structure and in the firms' behavior. After vesting contracts expire (if this is the case) firms would be able to decide whom to contract with and at what price. Contracting practices could even be useful to fulfill other objectives of the Chilean reform like transactions between generating companies and distribution companies being more transparent and a reduction of barriers to entry for new and small producers. Depending on the specific features of contracts (frequency, contracted quantity relative to total demand, etc.) they may increase or reduce barriers to entry to the industry. Newbery (1997) argued that contracts in the UK have been the mechanism for entering the industry with no risk. This has turned out to be an effective disciplinary tool as customers may choose to sign long term contracts with an entrant if the incumbent producers charge high prices. In the case of Chile it has been proposed to require distribution companies to openly bid their contracts and to purchase contracts for a quantity enough to satisfy their captive consumers' demand. The open bidding process should take place 2 years ahead of consumption. In this way, new IPPs would be able to participate in the bid and would have enough time to build a new plant. In order to further reduce barriers of entry, it may be convenient to spread bids (in terms of volume traded) over a period of time; in this way small producers would also be able to enter the industry[42]. Finally, unlike the divestiture of Firm 1 assets, that mainly affected Firm 1, requiring producers to sell contracts in the transition period is probably more "fair" in terms of the impact that it has over the two firms, and thus will be probably easier to implement.

Unfortunately, it is not clear whether or not the contract market will develop. Risk averse consumers willing to pay a premium over the expected spot price, strategic behavior by consumers and the role of regulation in the development of the contract market were conceptually analyzed. Regulation of the contract market, such as the imposition of vesting contracts may be helpful in the transition period. However it is not convenient to rely exclusively on it as vesting contracts will necessarily expire at a certain time. When that happens producers and consumers must face the right incentives in order to voluntarily contract. In addition, since the contract and spot markets are interdependent, their regulations also are. One must be very careful of the effects of any regulation intended to develop or deepen the contract market as this normative may, at the same time, introduce distortions or incentives to manipulate the price in the spot market. It should be kept in mind that the final goal is not the development of the contract market but a competitive spot market and so more importance must be given to the regulation of the whole industry and the incentives producers and consumers have to voluntarily contract: how are final prices determined, is there a price pass through, how many agents are entitled to engage in voluntary contracting practices, is there a mandate to supply power and so on. Clearly more quantitative research is needed on this subject.

Additional measures, that have not been analyzed here, may also be implemented to mitigate market power. Wolfram (1999) emphasized the importance of the regulatory threat. The basic idea is that a regulatory authority with real power to punish companies who exercise market power (or too much market power) provides enough incentive for the firms to behave competitively (or closer to it). The regulatory threat may also be helpful to prevent producers from cooperating in the contract or in the spot market, a desirable result as cooperation results in only partial (as opposed to full) hedging. Wolfram's argument is similar to Green (1999)'s regarding the role of contracting practices as a commitment device. The interconnection of the SIC system with the SING system has been proposed as a way to reduce the dependence the SIC has on its hydro-storage resources. [43] In addition, by increasing the number of firms and the number of large consumers, competition may also be enhanced. Finally, giving large consumers access to the spot market would introduce demand side bidding. As a result, demand would be more price sensitive and the exercise of market power would be more difficult. Arellano (2002) showed that the more elastic is demand the closer is a welfare index to the competitive level. This calls for bigger efforts to increase the number of customers whose consumption decisions are affected by the spot market price.

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[42] The convenience of spreading the bids over the year should be subject to a cost-benefit analysis as transaction cost will probably be higher.

[43] The SING system is the interconnected system located in the North of Chile.

Before the regulatory authorities decide to deregulate the price and include some sort of control mechanism to prevent market power abuses, there are two issues that I think should be addressed. First of all, any market power mitigation measure that is introduced attempts to control or influence the spot market's price.[44] As more controls are introduced, the spot market looks less like a real market and more like a centralized market subject to a different form of regulation. The point is then why bother in reforming the price system and move towards a system where prices are market-set if at the end the authority wants to introduce additional controls that prevent the price from being really market based? The authority should introduce these control mechanisms not as a way to continue regulating the price but to get the "market-based" price as close to the competitive one as possible. This leads to a second point: if the current pricing system already sets the price at a level that is close to the competitive level, is it really convenient moving forward to a system where prices are completely market based, even though that entails the risk of market power abuses? In order to answer this question, some previous questions should be addressed: is the current regulatory system pricing at levels that are really close to the competitive equilibrium? If yes, what additional benefits would have de-regulating prices? Some people mention that the system would gain in transparency[45]. Until now critics have come on qualitative grounds but there are no quantitative estimations on how far or close current nodal price is from the competitive price. In order to analyze the convenience of deregulating the system (and implementing any of these measures, if needed), a careful welfare analysis of the current regulation must be done. It is clear is that more quantitative work is needed before implementing a power exchange system.

[44] As Wolak (2000) pointed out: "if one is concerned about the exercise of market power in a restructured electricity market, then effective price regulation can be imposed by forcing a large enough quantity of hedge contracts on the newly privatized generator". Page 45

[45] Newbery (1997) argued that "regulation is an alternative way [to competition] to induce firms to cut costs but it is very difficult to detach the price that they are to face from the costs that they tell you…if the companies know that when they cut their costs the government will lower the price, that reduces the incentive to cut costs" P. 12.

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Tables

Table 1: Data used to estimate market and residual demand(E=-1/3)

t	Average load (MW)	Price (US$/MW)	A (Market demand intercept)	B (market demand slope)	q^{MR} (MW)	q^{PS} (MW)
1	4749.7	31.10	6332.9	50.9	274.6	394.5
2	4329.6	31.10	5912.8	50.9	183.8	394.5
3	4091.1	31.10	5674.3	50.9	183.8	394.5
4	3643.3	31.10	5226.5	50.9	183.8	394.5
5	3270.8	31.10	4854.0	50.9	183.8	394.5
6	2988.5	31.10	4571.7	50.9	183.8	394.5

Table 2: Base Model, Competitive results (E= -1/3)

t	qth1	qth2	QRth	qh1	qh2	QRh	QR	Qthfringe	Qtot	Price
1	673.1	944.4	1617.5	2133.1	0.0	2133.1	3750.6	420.5	4839.0	29.4
2	673.1	944.4	1617.5	1802.6	0.0	1802.6	3420.1	420.5	4418.9	29.4
3	673.1	944.4	1617.5	1564.1	0.0	1564.1	3181.6	420.5	4180.4	29.4
4	673.1	944.4	1617.5	1116.3	0.0	1116.3	2733.8	420.5	3732.6	29.4
5	673.1	944.4	1617.5	764.7	0.0	764.7	2382.2	420.1	3380.5	28.9
6	566.2	944.4	1510.6	743.7	0.0	743.7	2254.4	416.6	3249.3	26.0

Table 3: Base Model, Cournot Equilibrium (E=-1/3)

t	qth1 #	qth2	QRth	qh1 #	qh2	QRh	QR	Qthfringe	Qtot	Price
1	133.7	944.4	1078.1	1743.0	0.0	1743.0	2821.3	441.2	3931.3	47.2
2	140.1	944.4	1084.5	1572.0	0.0	1572.0	2656.5	437.5	3672.3	44.0
3	120.3	944.4	1064.7	1472.6	0.0	1472.6	2537.3	434.9	3550.4	41.7
4	122.0	944.4	1066.4	1247.0	0.0	1247.0	2313.4	429.9	3321.5	37.4
5	127.0	867.7	994.7	1094.1	0.0	1094.1	2088.7	426.6	3093.6	34.6
6	131.9	773.6	905.4	995.1	0.0	995.1	1900.6	424.5	2903.3	32.8

# denotes Multiple equilibrium. Values reported are averages over 400 different simulations

Table 4:
Installed capacity in the SIC after full divestiture of Firm 1's thermal plants (MW)

Economic Group	Thermal	Hydro-reservoir	Total
Triopoly			
Endesa (Firm 1)	0	2454	2454
Gener (Firm 2)	1212	0	1212
Firm 3	939	0	939
Fringe	472	697	1169
DLTF			
Endesa (Firm 1)	0	2454	2454
Gener (Firm 2)	1212	0	1212
Fringe	1411	697	2108
Total	2622	3151	5773

Hydro-ROR not included in the table.

Table 5: Divestiture of Firm 1's thermal plants - Triopoly (E=-1/3)

t	qth1	qth2	qth3	QRth	qh1	qh2	QRh	QR	QTh Fringe	Qtot	Price	Ex-Firm 1's thermal
1	0.0	944.4	673.1	1617.5	1620.8	0.0	1620.8	3238.3	431.9	4339.3	39.2	673.1
2	0.0	944.4	572.2	1516.6	1506.6	0.0	1506.6	3023.2	429.4	4030.8	37.0	572.2
3	0.0	920.5	500.7	1421.2	1435.1	0.0	1435.1	2856.3	427.8	3862.3	35.6	500.7
4	0.0	786.6	454.6	1241.2	1301.2	0.0	1301.2	2542.4	424.8	3545.4	33.0	454.6
5	0.0	662.4	454.6	1117.0	1177.0	0.0	1177.0	2294.0	422.0	3294.3	30.6	454.6
6	0.0	568.3	454.6	1022.9	1083.0	0.0	1083.0	2105.8	419.9	3104.0	28.8	454.6

Table 6: Divestiture of Firm 1's thermal plants - DLTF (E=-1/3)

t	qth1	qth2	qth3	QRth	qh1	qh2	QRh	QR	QTh Fringe	Qtot	Price	Ex-Firm 1's thermal
1	0.0	944.4	na	944.4	1712.0	0.0	1712.0	2656.4	1026.3	4351.7	38.9	673.1
2	0.0	944.4	na	944.4	1547.3	0.0	1547.3	2491.7	998.5	4068.5	36.2	673.1
3	0.0	944.4	na	944.4	1428.1	0.0	1428.1	2372.5	978.4	3929.1	34.3	673.1
4	0.0	833.5	na	833.5	1259.6	0.0	1259.6	2093.1	950.0	3621.4	31.5	673.1
5	0.0	709.3	na	709.3	1135.5	0.0	1135.5	1844.8	929.1	3352.1	29.5	673.1
6	0.0	615.2	na	615.2	1041.4	0.0	1041.4	1656.6	913.3	3148.1	28.0	673.1

Table 7

Effect of Firm 1's thermal plants divestiture on total profits (E=-1/3)

Index (Base Model = 100)

Model	Firm 1	Firm 2	Firm 1+ Firm 3/Fringe
Base	100.0	100.0	100.0
Triopoly	79.7	70.8	97.8
DLTF	77.8	68.9	96.6
Perfect Competition	80.7	55.9	80.7

Table 8

Installed capacity in the SIC after divestiture of Firm 1's hydro plants (MW)

Economic Group	Thermal	Hydro-reservoir	Total
DLHF Model			
Firm 1	939	0	939
Firm 2	1212	0	1212
Fringe	472	3151	3623
DMHF Model			
Firm 1	939	1754	2693
Firm 2	1212	0	1212
Fringe	472	1397	1869
Total	2622	3151	5774

Hydro-ROR not included in the table.

Table 9: Hydro production according to Peak shaving (MW)

Demand level	Base Model	DLHF	DMHF
1	274.6	2406.5	1296.8
2	183.8	1986.4	1296.8
3	183.8	1747.9	1215.8
4	183.8	1300.1	785.9
5	183.8	948.5	419.6
6	183.8	927.5	379.2

Table 10: Full divestiture of hydro – storage plants, DLHF model. (E=-1/3)

t	qth1	qth2	QRth	qh1	qh2	QRh	QR	Qth fringe	Qtot	Price
1	457.7	877.5	1335.2	0.0	0.0	0.0	1335.2	426.8	4562.9	34.8
2	457.7	877.5	1335.2	0.0	0.0	0.0	1335.2	426.8	4142.8	34.8
3	457.7	877.5	1335.2	0.0	0.0	0.0	1335.2	426.8	3904.3	34.8
4	457.7	877.5	1335.2	0.0	0.0	0.0	1335.2	426.8	3456.5	34.8
5	454.6	868.6	1323.2	0.0	0.0	0.0	1323.2	426.6	3092.7	34.6
6	454.6	737.9	1192.5	0.0	0.0	0.0	1192.5	423.7	2938.2	32.1

Table 11: Lerner Indices

	Base model		DMHF Model		DLHF model	
t	**Firm 1**	**Firm 2**	**Firm 1**	**Firm 2**	**Firm 1**	**Firm 2**
1	76.4%	38.4%	60.2%	45.7%	25.3%	48.5%
2	74.7%	41.2%	55.9%	49.9%	25.3%	48.5%
3	73.3%	43.5%	54.6%	48.5%	25.3%	48.5%
4	70.3%	48.5%	54.5%	48.3%	25.3%	48.5%
5	67.8%	48.2%	54.4%	48.3%	25.2%	48.2%
6	66.0%	45.3%	52.3%	45.8%	27.2%	44.2%

Table 12

Effect of Firm 1's hydro plants divestiture on total profits (E=-1/3)

Index (Base Model = 100)

Model	Firm 1	Firm 2	Fringe	Firm 1 adjusted *
Base	100.0	100.0	100.0	100.0
DLHF	17.1	73.3	215.1	96.7
DMHF	54.9	80.1	158.6	98.0
Perfect Competition	80.7	55.9	68.6	80.7

* Firm 1's profits + Profits the fringe gets from former Firm 1's hydro plants.

Table 13: Partial Divestiture of hydro plants: DMHF model (E=-1/3)

t	qth1 #	qth2	QRth	qh1 #	qh2	QRh	QR	Qthfringe	Qtot	Price
1	385.7	944.4	1330.1	859.0	0	859.0	2189.1	432.5	4312.8	39.7
2	380.2	930.3	1310.5	661.5	0	661.5	1972.0	428.0	4091.2	35.8
3	369.5	877.8	1247.3	619.7	0	619.7	1867.0	426.8	3904.0	34.8
4	371.1	871.8	1242.9	612.1	0	612.1	1855.0	426.7	3462.1	34.7
5	367.7	869.7	1237.5	613.5	0	613.5	1850.9	426.7	3091.6	34.6
6	343.8	789.1	1132.9	556.7	0	556.7	1689.6	424.9	2888.1	33.1

# denotes Multiple equilibrium. Values reported are averages over 400 different simulations

Table 14: Welfare analysis
(Index, Base Case = 100)

Model	Firm 1*	Firm 2	Fringe **	Producer Surplus	Consumer Surplus	Welfare
Base	100.0	100.0	100.0	100.0	100.0	100.0
Triopoly	79.7 (97.8)	70.8	113.8 (84.0)	88.5	117.7	103.0
DLTF	77.8 (96.6)	68.9	108.1 (77.4)	85.5	120.7	103.0
DLHF	17.1 (96.7)	73.3	215.1 (84.5)	88.5	118.1	103.3
DMHF	54.9 (98.0)	80.1	158.6 (87.9)	91.5	114.0	102.7
Perf. Competition	100.0	55.9	68.6	72.3	136.5	104.3

*In parenthesis Firm 1's profits + profits from former Firm 1's plants. ** In parenthesis profits earned by the former fringe (i.e. *without* including former Firm 1's plants)

Table 15: Cournot Equilibrium, Contracting level = 0% (E=-1/3)

t	K1	K2	qth1#	qth2	QRth	qh1 #	qh2	QRh	QR	Qthfringe	Qtot	Price
1	0	0	133.7	944.4	1078.1	1743.0	0.0	1743.0	2821.3	441.2	3931.3	47.2
2	0	0	140.1	944.4	1084.5	1572.0	0.0	1572.0	2656.5	437.5	3672.3	44.0
3	0	0	120.3	944.4	1064.7	1472.6	0.0	1472.6	2537.3	434.9	3550.4	41.7
4	0	0	122.0	944.4	1066.4	1247.0	0.0	1247.0	2313.4	429.9	3321.5	37.4
5	0	0	127.0	867.7	994.7	1094.1	0.0	1094.1	2088.7	426.6	3093.6	34.6
6	0	0	131.9	773.6	905.4	995.1	0.0	995.1	1900.6	424.5	2903.3	32.8

# denotes Multiple equilibrium. Values reported are averages over 400 different simulations

Table 16: Cournot Equilibrium, Contracting level =50% (E=-1/3)

t	K1	K2	qth1	qth2	QRth	qh1	qh2	QRh	QR	Qthfringe	Qtot	Price
1	1403.1	472.2	454.6	944.4	1399.0	1967.6	0.0	1967.6	3366.5	429.1	4464.4	36.7
2	1237.8	472.2	454.6	944.4	1399.0	1720.1	0.0	1720.1	3119.1	427.2	4124.6	35.1
3	1118.6	472.2	454.6	944.4	1399.0	1541.3	0.0	1541.3	2940.2	425.9	3944.4	34.0
4	894.7	472.2	454.6	944.4	1399.0	1205.4	0.0	1205.4	2604.4	423.4	3606.1	31.8
5	718.9	472.2	454.6	944.4	1399.0	931.3	0.0	931.3	2330.2	421.2	3329.7	29.9
6	655.0	472.2	454.6	944.4	1399.0	758.2	0.0	758.2	2157.1	418.8	3154.2	27.8

Table 17: Cournot Equilibrium, Contracting level =100% (E=-1/3)

t	K1	K2	qth1	qth2	QRth	qh1	qh2	QRh	QR	Qthfringe	Qtot	Price
1	2806.2	944.4	673.1	944.4	1617.5	2134.7	0.0	2134.7	3752.2	420.5	4841.4	29.3
2	2475.7	944.4	673.1	944.4	1617.5	1804.6	0.0	1804.6	3422.1	420.5	4420.9	29.3
3	2237.2	944.4	673.1	944.4	1617.5	1566.2	0.0	1566.2	3183.6	420.5	4182.4	29.3
4	1789.4	944.4	673.1	944.4	1617.5	1118.4	0.0	1118.4	2735.8	420.5	3734.6	29.3
5	1437.8	944.4	673.1	944.4	1617.5	756.3	0.0	756.3	2373.8	420.3	3372.3	29.1
6	1310.0	944.4	566.4	944.4	1510.8	743.6	0.0	743.6	2254.4	416.6	3249.2	26.0

Table 18: Marginal Value of water (Ω_1)

	Contracting Level		
T	0%	50%	100%
1	11.13	17.13	29.27
2	11.13	17.13	29.27
3	11.13	17.13	29.27
4	11.13	17.13	29.27
5	11.13	17.13	29.27
6	11.13	17.13	25.98

Table 19: Lerner Indices

t	Contracting = 0%		Contracting = 50%		Contracting = 100%	
	Firm 1	Firm 2	Firm 1	Firm 2	Firm 1	Firm 2
1	76.4%	38.4%	53.3%	24.7%	0%	0%
2	74.7%	41.2%	51.2%	25.8%	0%	0%
3	73.3%	43.5%	49.6%	26.7%	0%	0%
4	70.3%	48.5%	46.2%	28.5%	0%	0%
5	67.8%	48.2%	42.8%	30.3%	-1%	0%
6	66.0%	45.3%	38.5%	32.6%	0%	0%

Figures

Figure 1

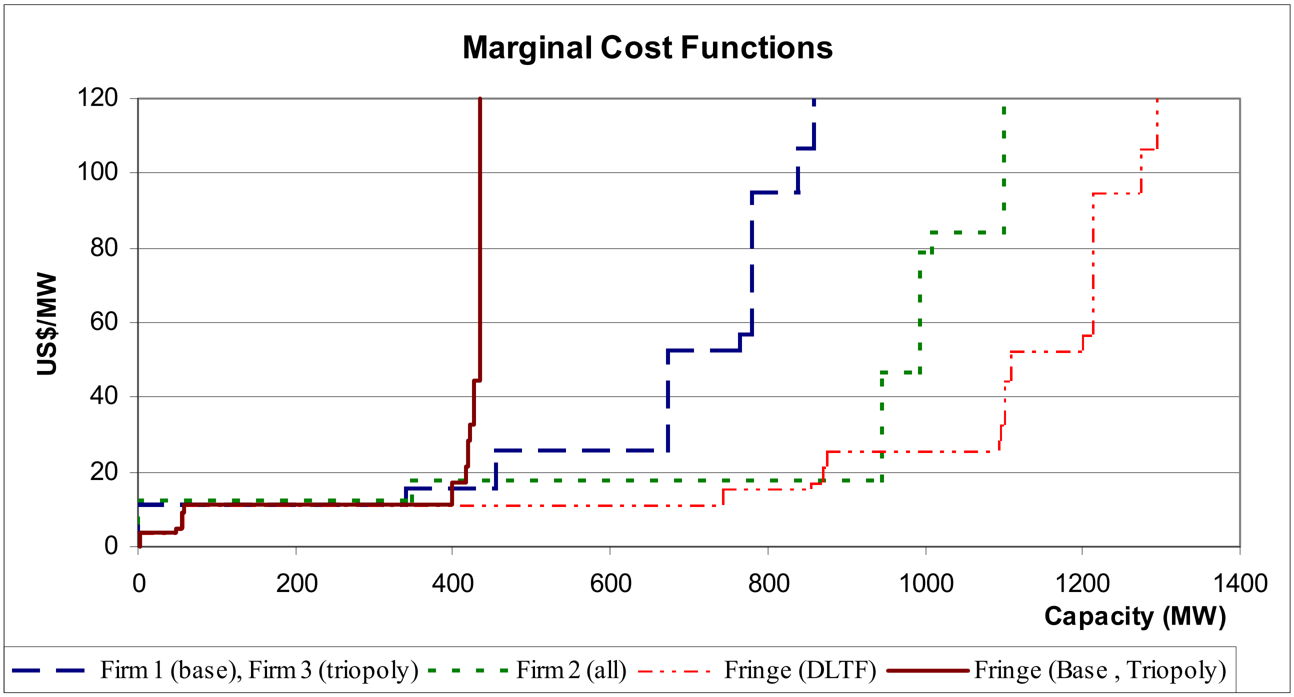
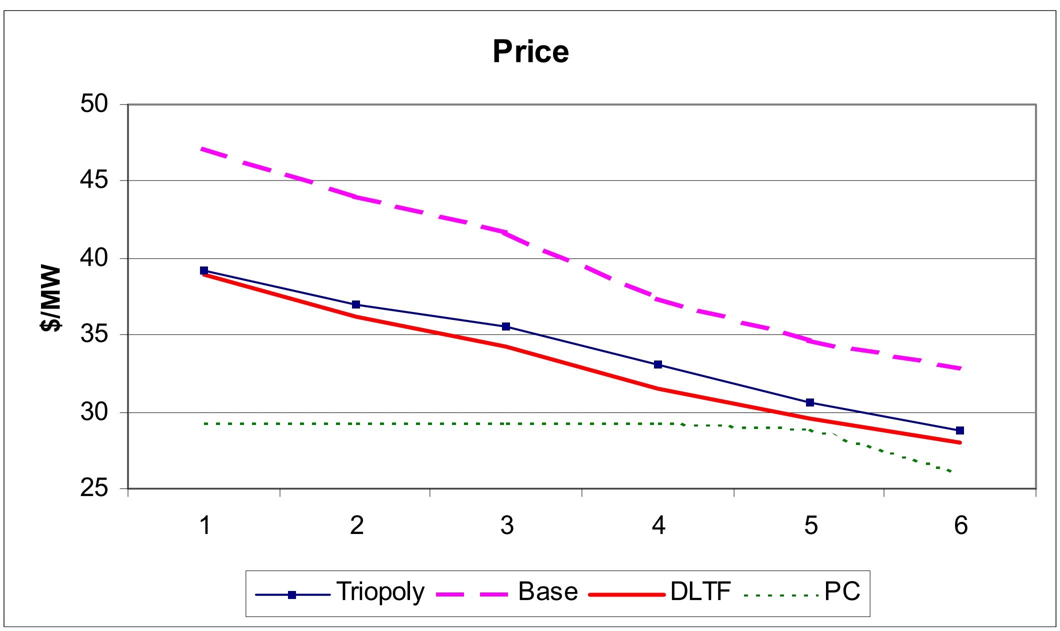


Figure 2



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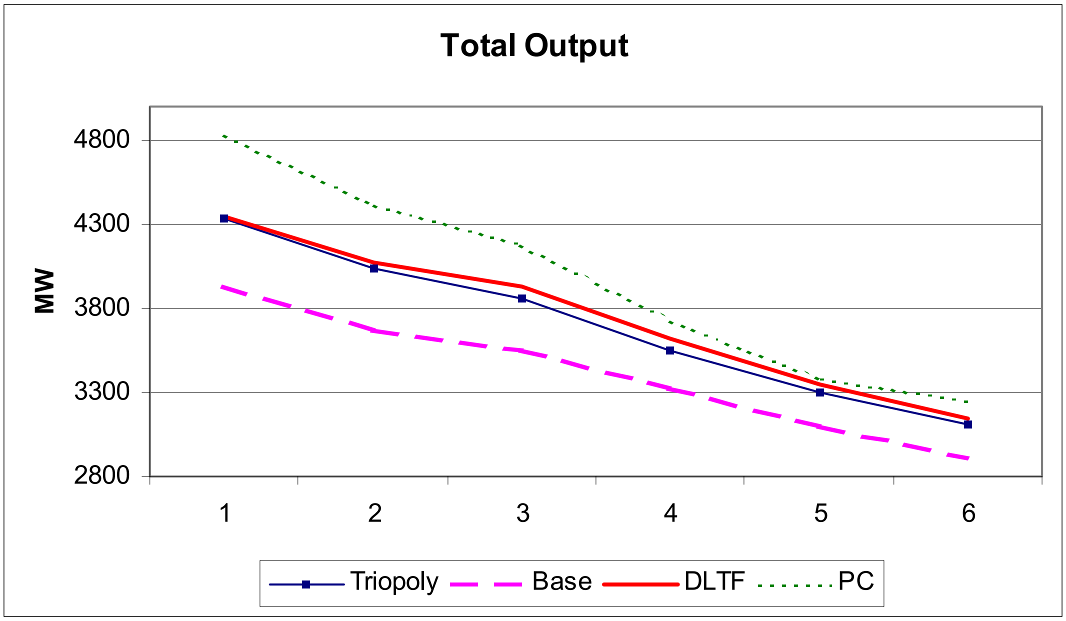

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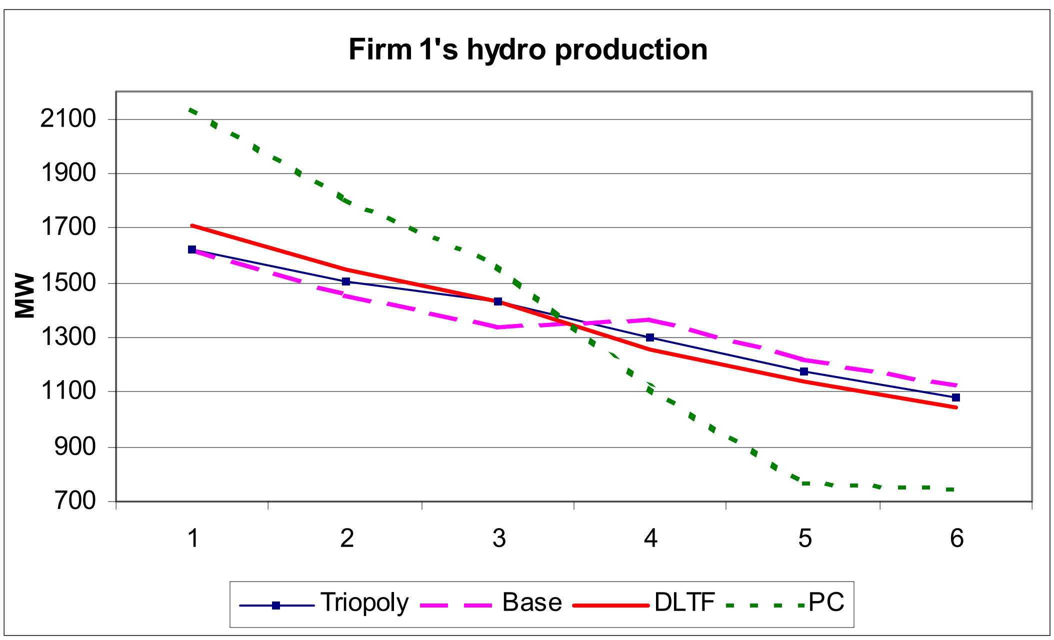

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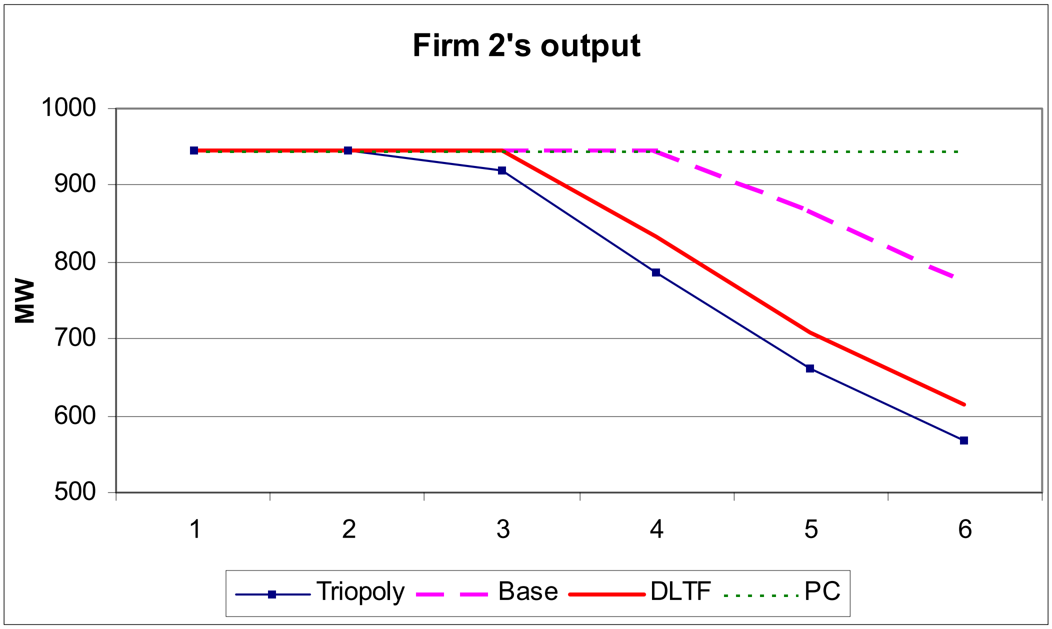

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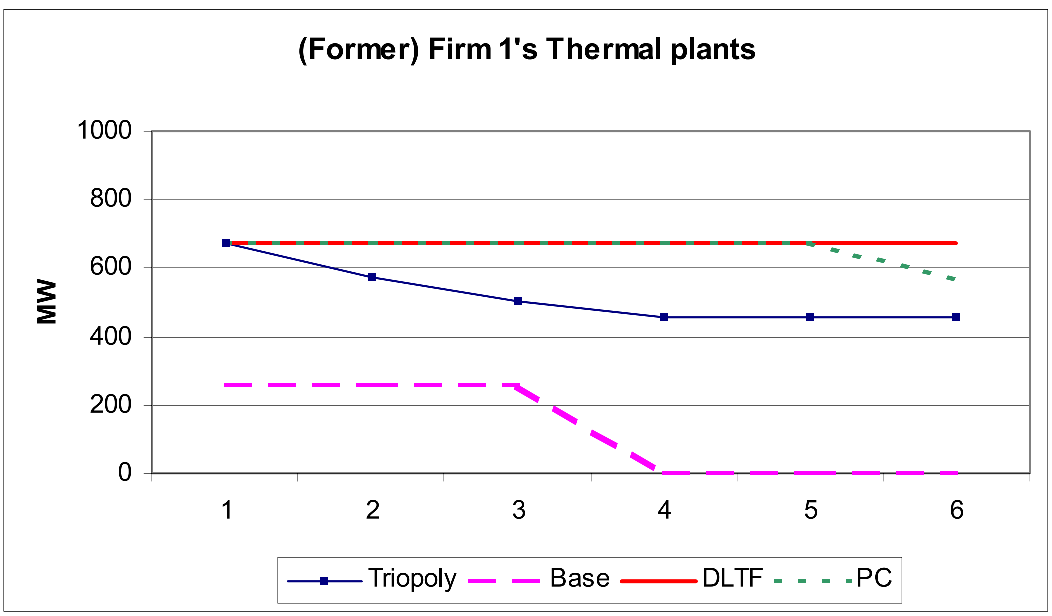

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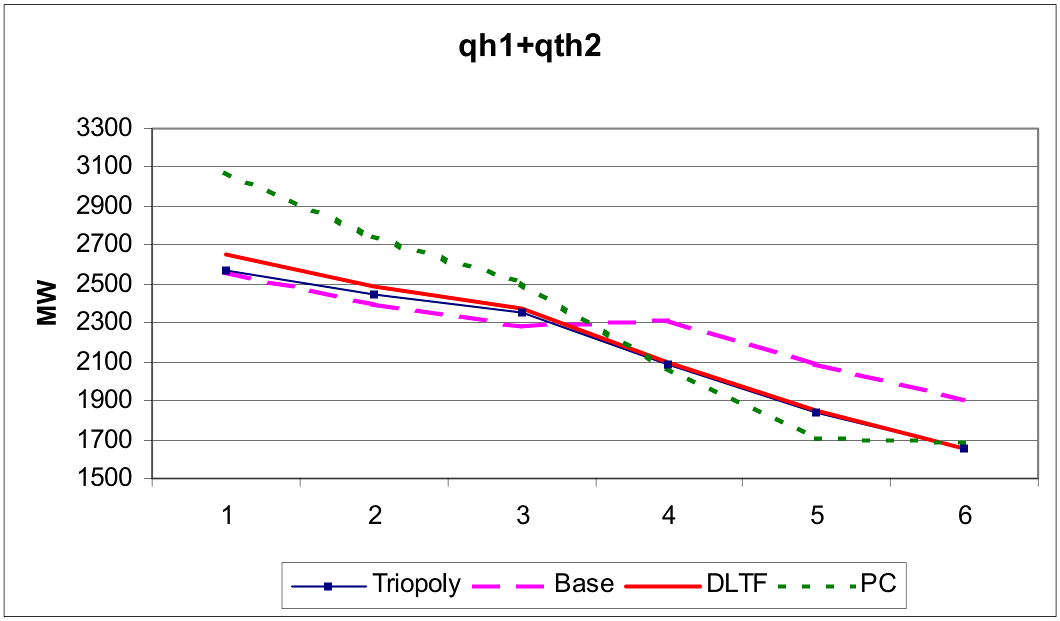

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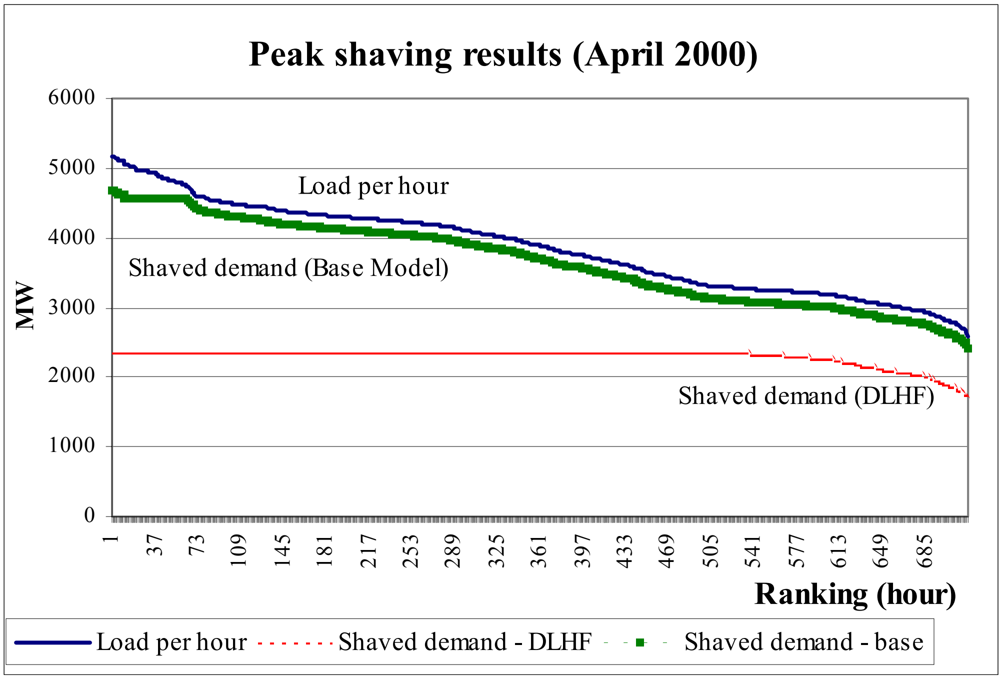

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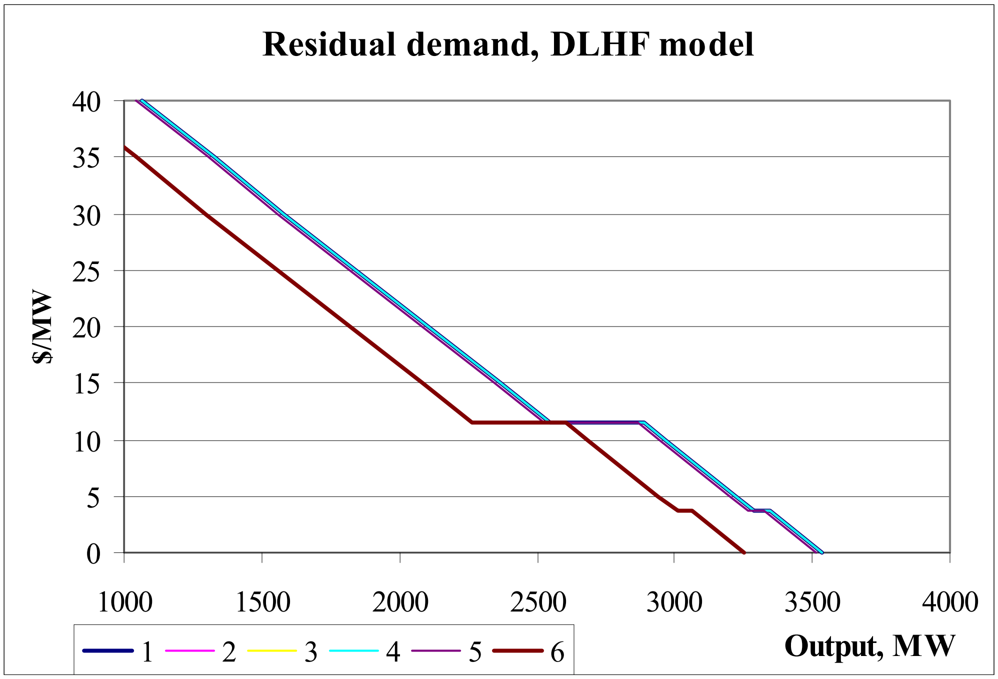

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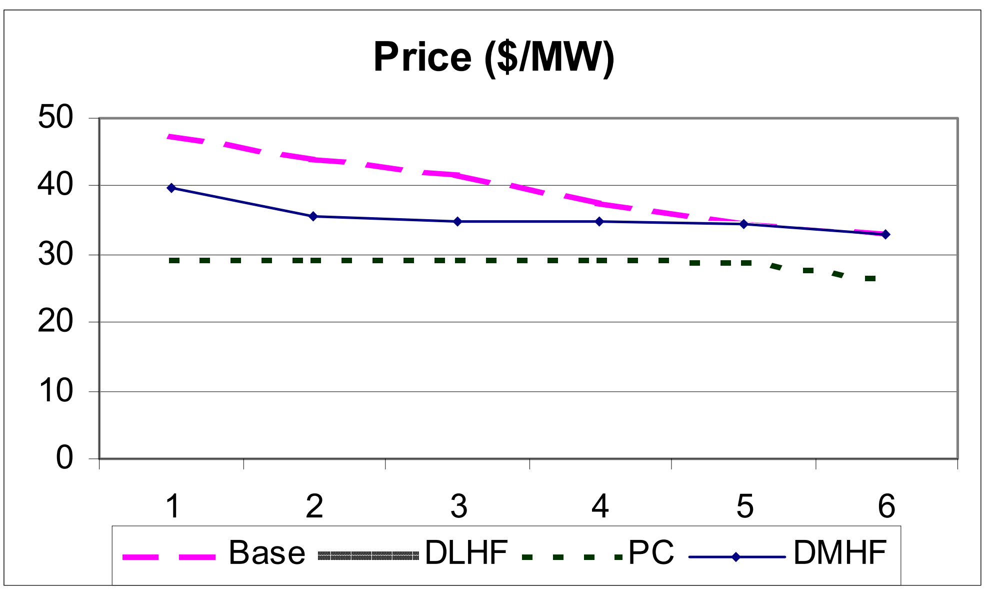

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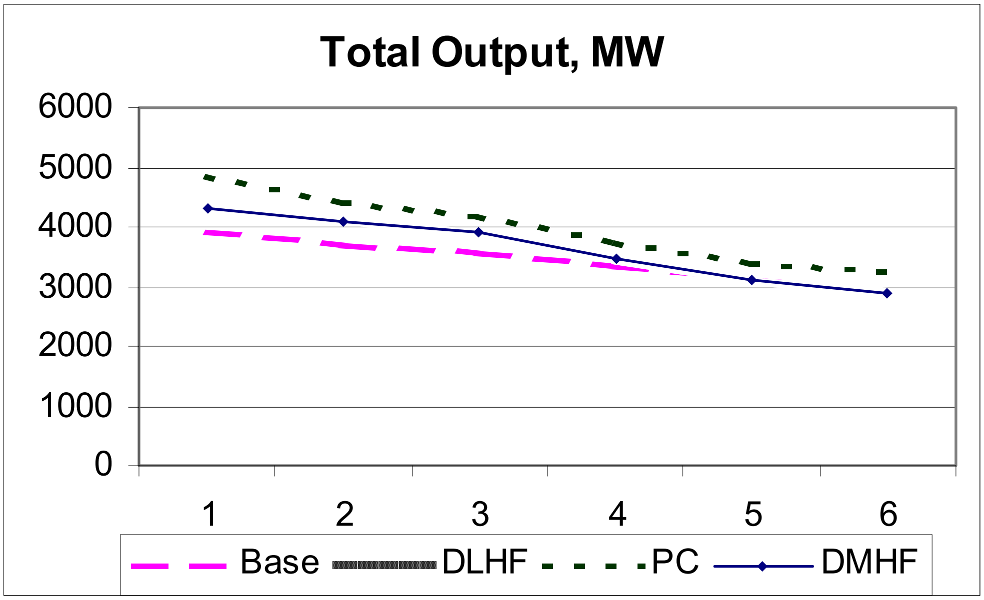


Figure 12

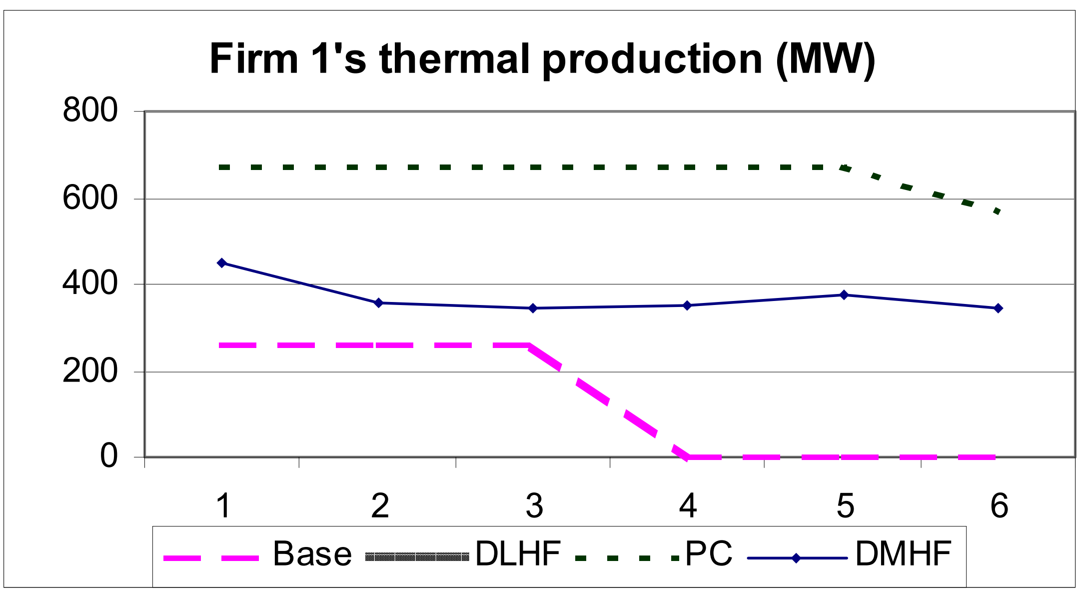


Figure 13

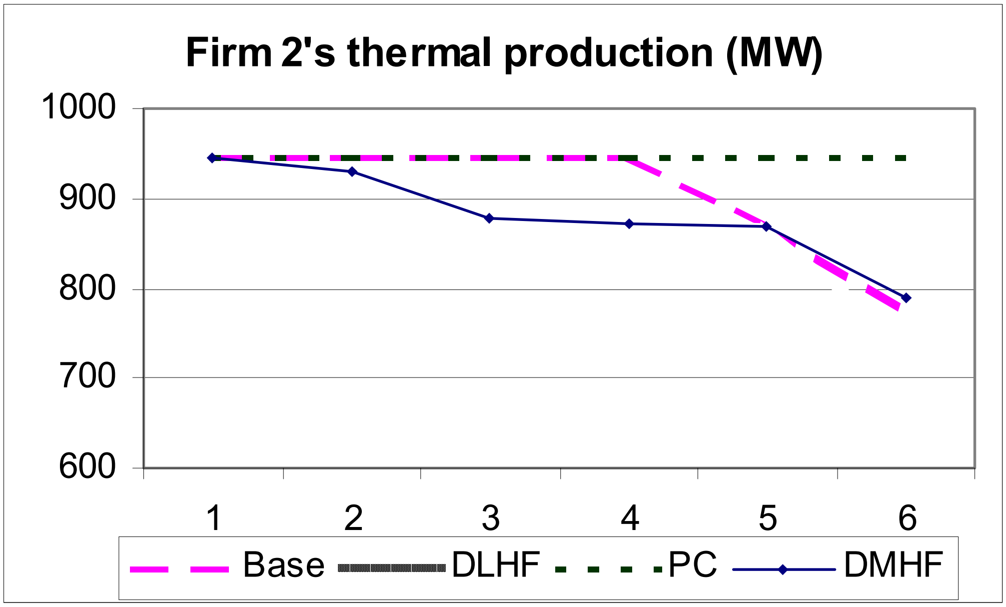


Figure 14

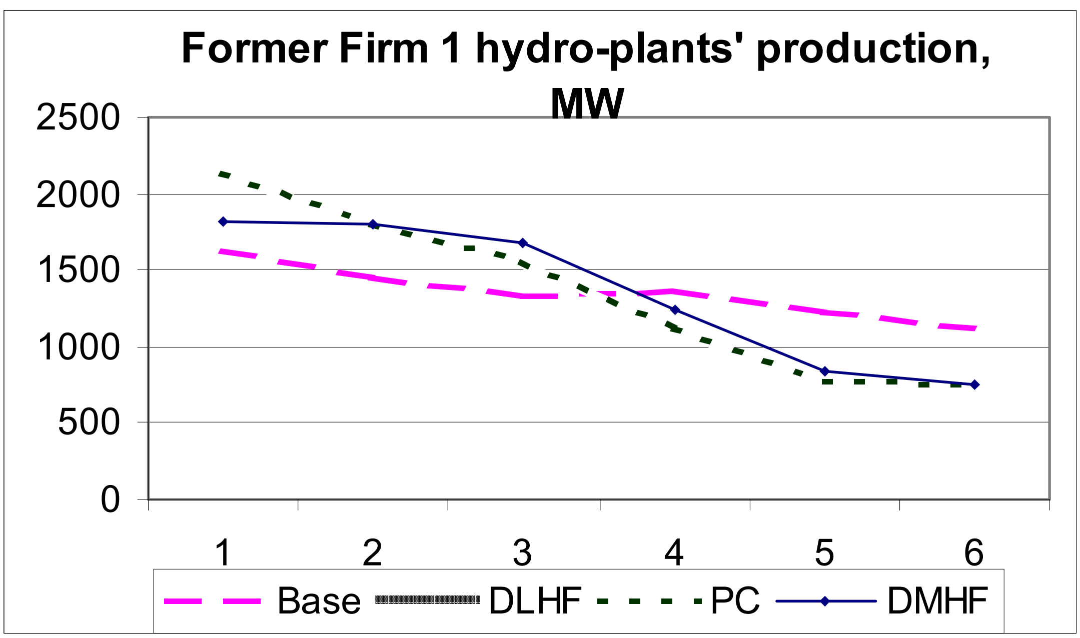


Figure 15

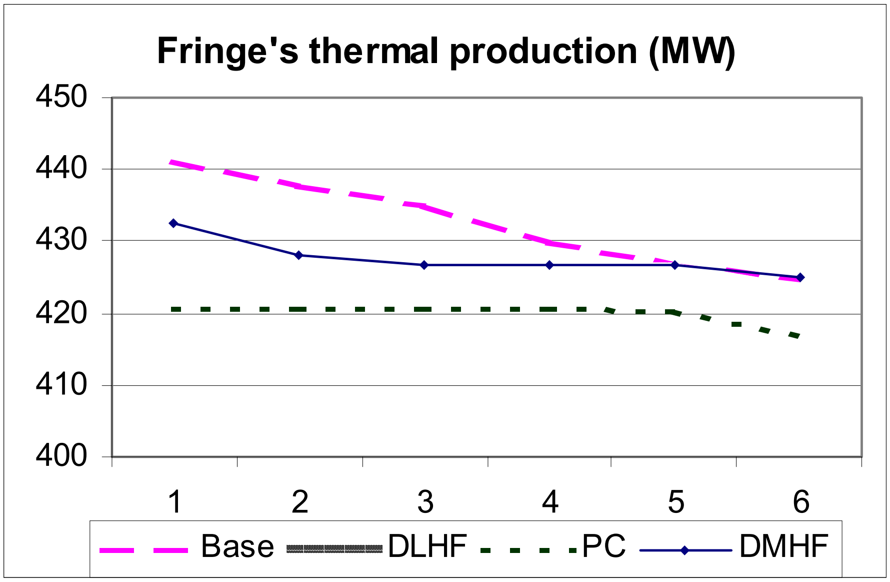


Figure 16

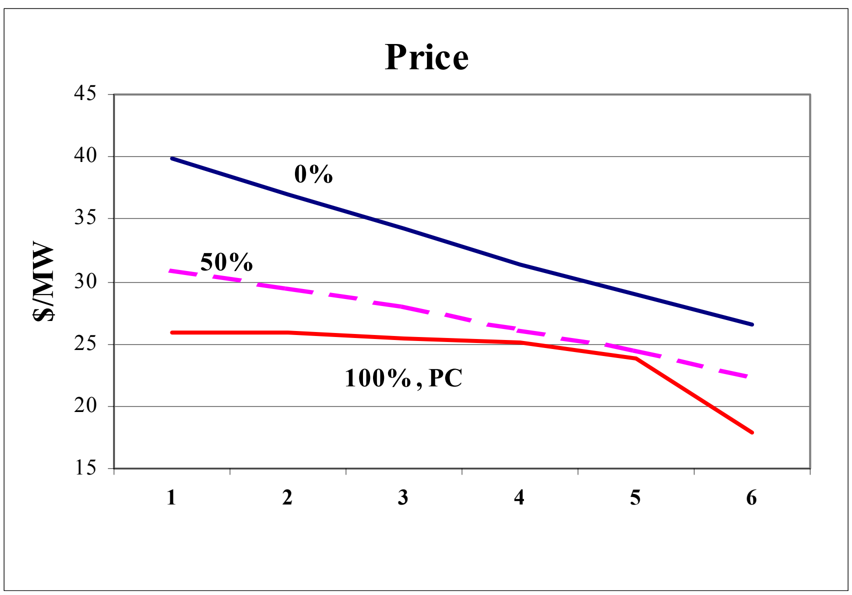
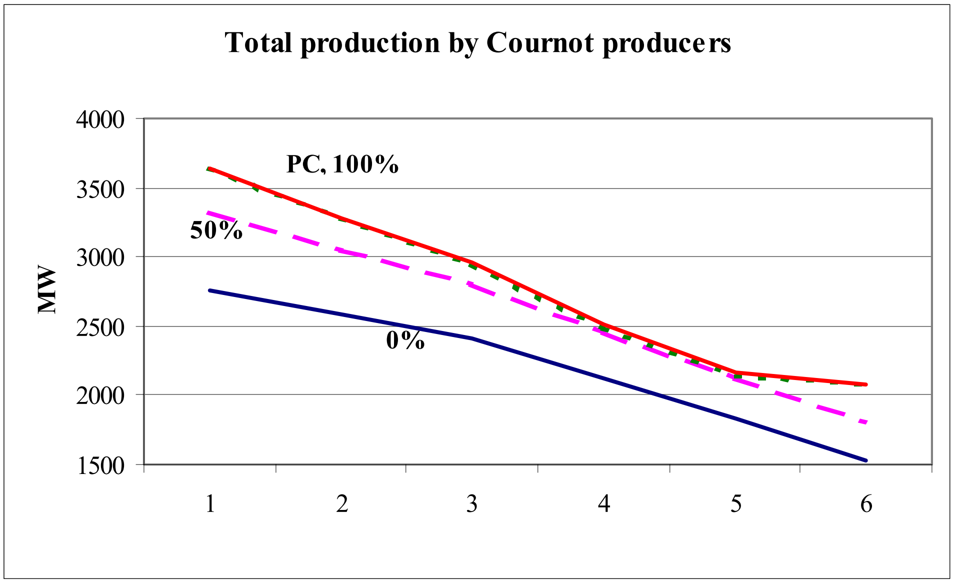


Figure 17



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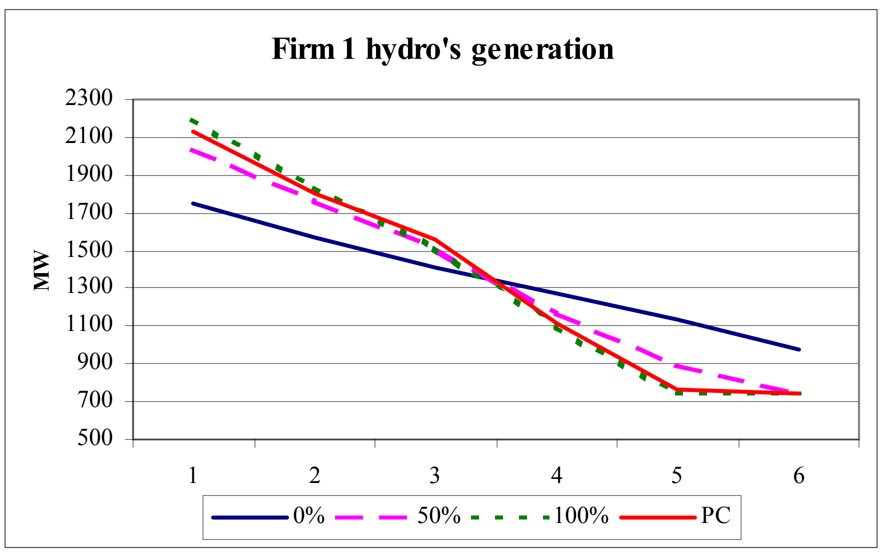

Figure 19

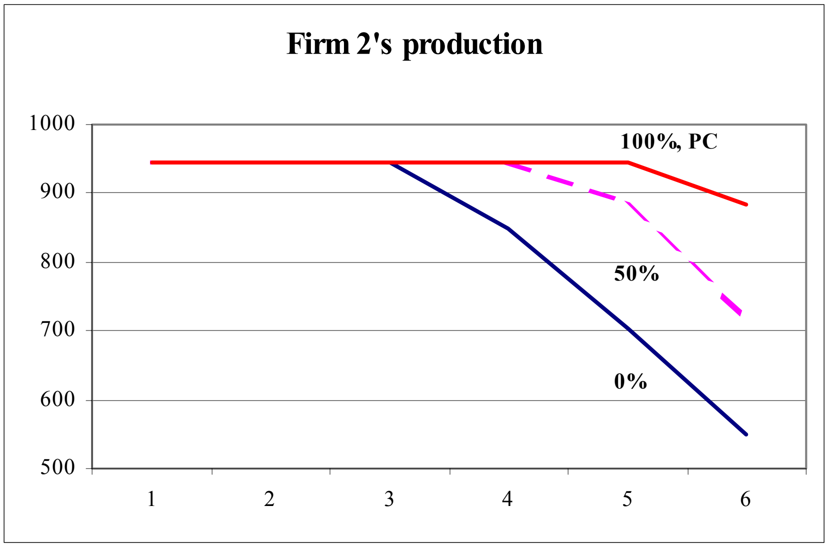

Figure 20