“COMPUTER-BASED SIMULATION OF AUCTIONS OF OPTION CONTRACTS AND OF FUTURES CONTRACTS IN THE COLOMBIAN WHOLESALE ELECTRICITY MARKET”

Final Report – Chapter 3

Prepared for:

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1. INTRODUCTION

Although there are many models for simulating spot markets, there are no antecedents of these kind of models for simulating an options market.

We prepared a model particularly designed for simulating TERA's proposal, with some necessary simplifications given the great complexity of the problem. This complexity stems from the characterization of the risk aversion profile of the market participants. Since there is no information available on the risk profiles of market participants, we used some theoretical models to characterize consumers and producers.

This chapter is divided in three parts. In the first part we describe the assumptions that were used to characterize the behavior of market participants. In the second, we present the model. The chapter is closed with intermediate and final results obtained after running the model.

2. DEVELOPMENT OF THE MODEL

2.1. CONSIDERATIONS ON THE RISK PROFILE OF MARKET PARTICIPANTS

Risk is usually related to the possibility of financial losses or to the uncertainty of asset returns. The elimination of all sources of risk may not be feasible or unattractive under an economical viewpoint. On the other hand, a risky environment may offer greater opportunities for financial gains. In the financial area, decisions with respect to resource allocation are regarded in a risk-return framework, i.e. decisions involving a higher level of risk are only acceptable if they lead to a greater return.

There is no universally agreed way to represent the gain versus risk tradeoff . There are four approaches that are more frequently used:

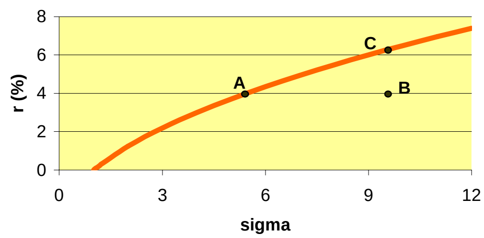
- return variance (Markowitz)
- value at risk" (VaR)
- downside risk
- utility functions

All of these approaches requires of abundant information to obtain numerical results. The information necessary is on the return of different types of financial instruments or assets, correlations among the yields of such assets, etc. As this information can only be obtained from markets that are currently in operation, it is only possible to simulate the markets outlining assumptions on such data.

To simulate the behavior of market participants, the "utility functions" approach has the advantage that only one parameter is necessary to characterize the risk profile, the "risk aversion" or the "risk tolerance".

Utility functions translate monetary revenues into "utility units" . The objective is then to maximize the expected utility. Through utility functions the investor risk return profile can be modeled with great flexibility.

Markowitz proposed that investors be assumed to be risk-averse -- more precisely, the marginal utility of wealth of each market participant is assumed to decline with wealth. In the next picture different alternatives of return (r) and variance for a given portfolio are plotted.



Mean-variance theory assumes that market participants or investors prefer either higher expected returns for a given level of standard deviation (C to B) or lower standard deviations for a given a level of expected return (A to B). Portfolios that provide the maximum expected return for a given standard deviation and the minimum standard deviation for a given expected return are termed efficient portfolios. All others are inefficient.

Central in this enterprise is the selection of an asset mix for a long-term investment policy. Such a policy asset mix plays a key role in many investment plans.

For characterizing a policy asset mix, William Sharpe establishes: "***In principle, four ingredients are needed for a complete analysis of this type. In discrete terms: (1) estimates of possible payments made by various investment products at different times and in different states of the world, (2) estimates of the probabilities associated with these times and states of the world, (3) the Investor's utility function for consumption at different times and in different states of the world, and (4) the Investor's current wealth, projected future income and required payments at various times in various states of the world. Since the first two aspects are the same for every Investor, it pays to share the cost of obtaining information about them among many Investors.*** **Economies of scale** ***thus provide the primary justification for the existence of the Analyst, to whom this material is directed***".

In mean-variance analyses, payments (item 1) and probabilities (item 2) are summarized in the mean-variance feasible region. By assuming that all market participants are risk-averse, it is possible to narrow the range of "sensible" investment opportunities to those that lie on the efficient frontier. In some cases this may suffice.

Mean-variance theory provides a neat separation between investor (or market participants) preferences and capital market opportunities. The latter are summarized in the feasible mean-variance opportunity set and its efficient frontier. The former can be shown with a set of market participants indifference curves.

In the following paragraphs we discuss how the four ingredients above mentioned were faced:

(1) Estimates of possible payments made by various investment products at different times and in different states of the world:

Using the results of the market simulations, described in chapter 2 of this Final Report, we estimated the pay-offs associated to each type of financial instrument. The methodology and results are presented in section 4 of this chapter.

(2) Estimates of the probabilities associated with these times and states of the world:

The 132 scenarios posed in market simulations (22 hydrologies x 2 demand growth rates x 3 long term marginal cost), were assumed to be all the states of the world. A probability of 1/132 was assigned to each scenario.

(3) Market participant’s utility function for consumption at different times and in different states of the world:

A linear utility functions for each market participant was adopted. This function is posed as:

$$Uki:\ Mi\ -\ \sigma_i^2 / tk \qquad (1)$$

Where:

Uki: utility function of market participant k, associated to financial instrument i

Mi: average return associated to financial instrument i,

σi : standard deviation of return of financial instrument i,

tk: risk tolerance of participant k.

This utility function assumes that market participants have an exponential utility function, and that return has a normal probability distribution. Although these assumptions can not be verified with the information available, the proposed function is simple to use, and there is no evidence for considering that a different function could produce better results.

Mi can be estimated from market simulations. Mi is the intrinsic value of an option for a strike price Si, computed as the expected loss of revenues of a seller when the spot price is above Si.

σi is the expected standard deviation of the revenues of a market participant that sold an option with strike price Si, and sells energy in the spot market when the price is below the strike price Si. It means that uncertainty of market participant i comes from its selling positions in the spot market. σi is estimated based on simulations of the spot market for each strike price.

(4) Investor's current wealth, projected future income and required payments at various times in various states of the world.

The revenues and payments of market participants are estimated based on its operation in the spot market and the financial instruments they may had sold/bought. For this assumption is important to remark that operation of the plants is independent of contracts or financial instruments they may hold.

In the following sections we describe the methodology used to compute Mi and σi, as well as the results obtained applying such methodology.

2.2. FORMULATION OF THE MODEL

The assumptions to pose the model are:

- The market participants have access to the different financial instruments oriented to risk hedging: futures, options at different strike prices or to operate in the spot market. Therefore the problem is posed as a portfolio optimization.

  As a way to unify the treatment of all the financial instruments, futures are considered as options with zero strike price, and spot market operation as an virtual option with strike price above the cost of unserved energy.

- The market participants are:
  - Generators
  - Large (unregulated) users
  - Distribution companies, in their function of last resort suppliers (LRS)
- Every market participant can participate in the following markets:
  - Futures (as zero strike price options)
  - A set of options with different strike prices (10, 40 us$/MWh were assumed for preliminary runs)
  - Spot (as an option with 400 us$/Mwh strike price).
- The Generators can bid their whole capacity available in each market, large users can bid to buy their whole demand in each market, and LRSs are obliged to buy financial instruments for theirs total demand in proportions set by the regulation.
- The market is wholly competitive, therefore no participant can influence the clearing price. No arbitrages are possible.
- The bids of market participants in each market are on the constant utility function (1). It means that for every market participant is indifferent if any of the bids is accepted at the bid price.
- Every market participant has a different risk tolerance tk. Values of tk are randomly generated in an interval t1-t2, in order to consider diversity of risk policies in each company.
- All the markets are cleared simultaneously.

Based on these assumptions, the equations of the model are found below.

The objective function is to maximize social welfare, given by:

$$\text{Max} \quad \Sigma_{ki}\ BB_{ki}\, Y_{ki} \ - \Sigma_{ki}\ BS_{ki}\, X_{ki}$$

Subject to

$\Sigma_i\ Y_{ki}\ - \Sigma_i\ X_{ki} = 0$ (offer=demand in each market k)

$\Sigma_k\ Y_{ki}\ <= Di$ (total demand of participant i bought in some(s) k market must be lower or equal than total demand)

$\Sigma_k\ X_{ki}\ <= Gi$ (total capacity of generator i sold in some(s) k market must be lower than installed capacity)

Where:

Yki: demand of consumer participant i bought in market k

Xki: capacity of generator i sold in market k

BS_{ik}: price bid by generator i in market k,

BB_{ik}: price bid by consumer participant i in market k,

Di: total demand of participant i,

Gi: total capacity of generator i.

The model assumes that Xik and Yik must be greater or equal to zero. It means that market participants are not allowed to make swaps. But it is possible to release such constraint, including allowing traders, who may have zero demand and installed capacity.

This model can be solved using linear programming. The LINDO solver was used. In the next section we describe how the coefficients of the model were estimated.

2.3. BIDS OF MARKET PARTICIPANTS

A market participant with infinite market tolerance (Uki = Mk), will be indifferent to sell (buy) in the spot market or to sell any type of options. Assuming that this participant knows the states of the world and their associated probabilities, it is possible to compute:

- Expected revenues for selling (buying) options at strike price k. For calculating the premiums of the options, we used the methodology outlined in Chapter 2, based on spot prices forecasts.
- Expected revenues for selling the energy not engaged in the option in the spot market. The revenue is the spot price SP whenever SP is below the strike price. If

the strike price is zero, no energy is sold in the spot market. If the strike price is greater or equal than the unserved energy cost, all the energy is sold in the spot market.

- Volatility of the revenues, computed as the standard deviation of revenues for sells in the spot market.

The next figures show the results of calculation of these three parameters:

Figure 1. Premium of options , for different strike prices, computed on six months periods (wet and dry). Estimations were carried out for 21 six months periods starting July 2002, until July 2011.

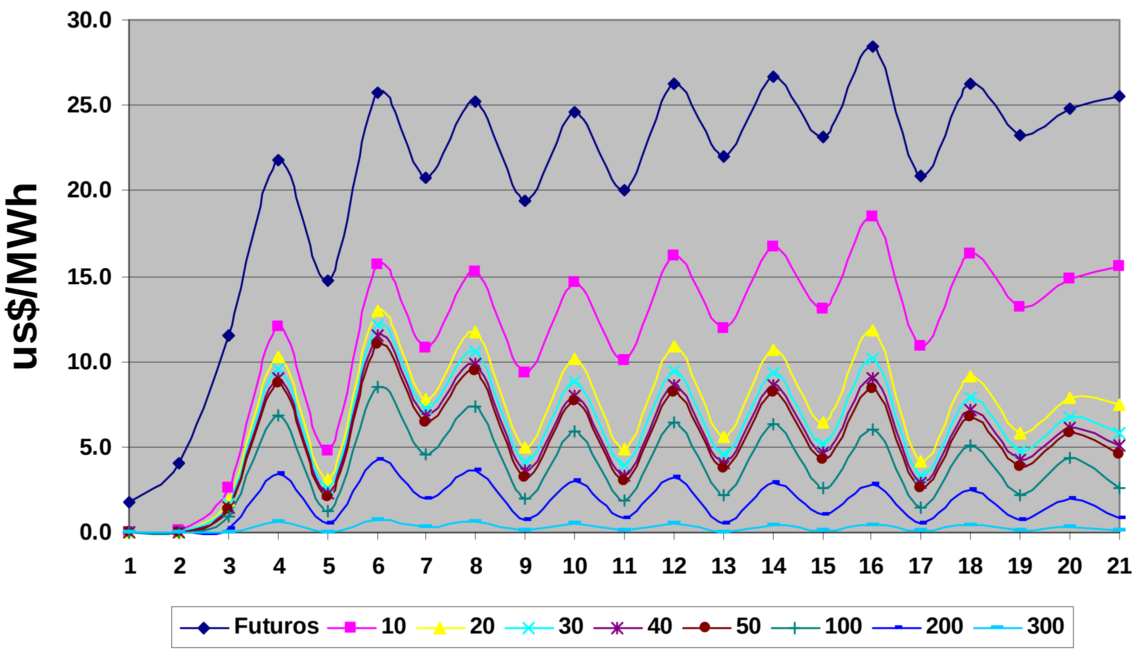


Figure 2: Average spot revenues of a base load generator – consumer who sold (bought) options at different strike prices.

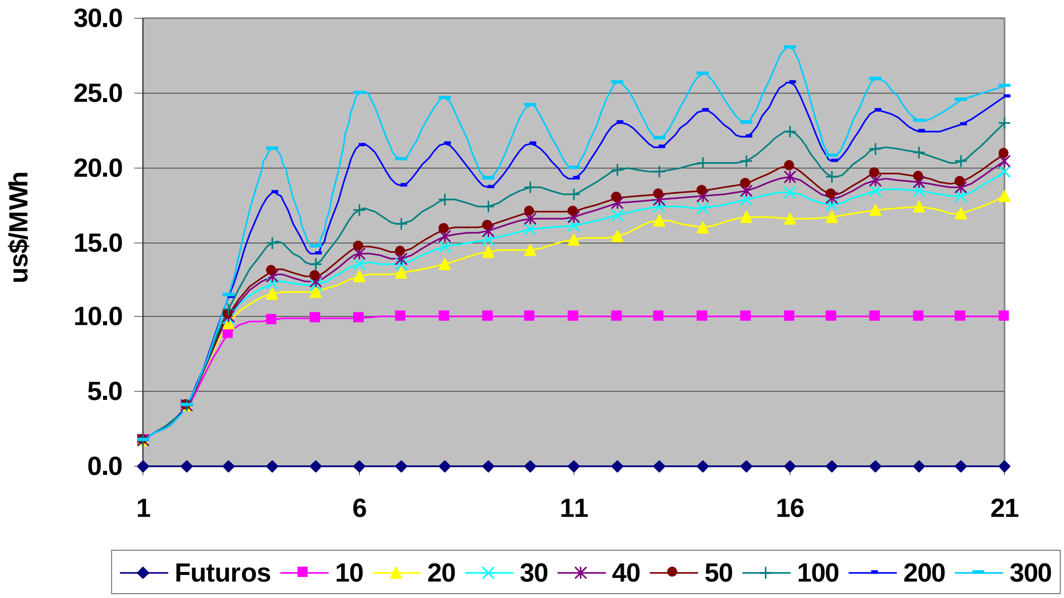
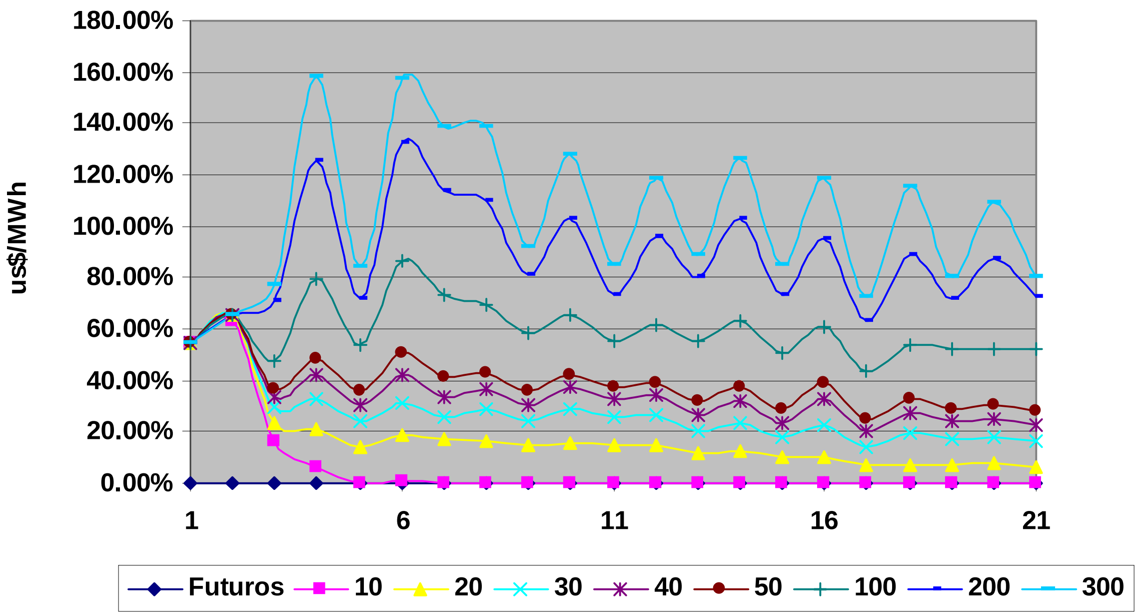


Figure 3: Volatility of spot revenues (payments) for market participants that sold (bought) options at different strike prices (computed as a % of the average spot revenue.)



From these three figures it is possible to conclude:

Seasonality is very important in options premiums, spot prices and volatility.

After an initial period were prices are un-adapted, price and volatility of options with strike price below 10 us$/MWh are equivalent to futures, since the spot price is almost all the time above such price.

Using this information, it is possible to compute the utility function for each market participant. In the next section we explain how “t “, the risk tolerance, is estimated.

The simulation of the market is performed on six months periods. For each period, the model is solved. In the next table we present the results of the estimations of options values, spot market revenues and volatilities for the first half of 2004. In the same table we also present the estimation of the utility function for different values of risk tolerance, for a base load hydro plant. The range of risk tolerances used is based on the estimations presented in section 2.4.

	Options strike price									
	0	**10**	**20**	**30**	**40**	**50**	**100**	**200**	**300**	**400**
Option value	21.8	12.0	10.3	9.6	9.1	8.7	6.9	3.5	0.6	0.0
Spot revenues	0.0	9.8	11.5	12.3	12.7	13.1	14.9	18.3	21.2	21.8
Sigma	0.0	1.3	4.5	7.2	9.1	10.6	17.4	27.4	34.5	34.5
Risk Toler.	**Utility Function**									
50	21.8	21.8	21.4	20.8	20.1	19.6	15.8	6.8	-1.9	-1.9
150	21.8	21.8	21.7	21.5	21.3	21.1	19.8	16.8	13.9	13.9
250	21.8	21.8	21.7	21.6	21.5	21.4	20.6	18.8	17.1	17.1
350	21.8	21.8	21.8	21.7	21.6	21.5	21.0	19.7	18.4	18.4
450	21.8	21.8	21.8	21.7	21.6	21.6	21.1	20.1	19.2	19.2
550	21.8	21.8	21.8	21.7	21.7	21.6	21.3	20.5	19.7	19.7
650	21.8	21.8	21.8	21.7	21.7	21.6	21.4	20.7	20.0	20.0
750	21.8	21.8	21.8	21.7	21.7	21.7	21.4	20.8	20.2	20.2
850	21.8	21.8	21.8	21.8	21.7	21.7	21.5	20.9	20.4	20.4
950	21.8	21.8	21.8	21.8	21.7	21.7	21.5	21.0	20.6	20.6
1050	21.8	21.8	21.8	21.8	21.7	21.7	21.5	21.1	20.7	20.7
1150	21.8	21.8	21.8	21.8	21.7	21.7	21.6	21.2	20.8	20.8

2.4. ESTIMATION OF RISK TOLERANCE

There are no data available to estimate the risk tolerance of market players in Colombia nor in other electricity markets worldwide.

But there are some estimations of the behavior of market participants in other types of energy commodities. The most interesting comparison for energy commodities should be the ratio between forward prices and expected spot prices at some time of delivery. With this information it should be possible to compute how much the market accepts to pay to reduce volatility from spot market (maximum) to futures (minimum).

But expectations of spot prices are not observable. Therefore, it is necessary to use indirect methods to estimate this ratio.

One alternative is to compare the prices of futures with their corresponding spot prices at the time of delivery. For market participants without risk aversion (infinite risk tolerance), and over long time frames, this ratio should converge to one.

EPRI[1] used information from seven markets of energy commodities, with seven or more years of contract prices and spot prices. In all the cases, the ratio of spot price at delivery and the forward price for the same contract six months prior to delivery consistently exceeds one, with values between 1.05 for heating oil, to 1.22 for propane. Other commodities included in the sample are: WTI crude, gasoline, gas-oil, natural gas and Brent crude.

Accepting that this ratio could be valid for electricity markets, it is possible to estimate the average risk tolerances of the market participants.

Assuming that the market clears with the same utility value for an average market participant, and using the information of section 2.4 on prices and volatilities for futures and spot prices we have:

Maximum risk tolerance:

(21.8 / 1.22) (futures price= spot price /maximum ratio) = 21.8 (spot price) – 1.58^2 (volatility of spot) * 21.8^2 / t_{min}

t_{min} = 302

Minimum risk tolerance:

(21.8 / 1.05) (futures price= spot price /minimum ratio) = 21.8 – 1.58^2 (volatility of spot) * 21.8^2 / t_{max}

t_{max} = 1142

Average risk tolerance

(21.8 / 1.13) (futures price= spot price /average ratio) = 21.8 (spot price) – 1.58^2 (volatility of spot) * 21.8^2 / t_{ave}

t_{ave} = 473

The risk tolerances of individual market participants were generated randomly: for the range obtained from this analysis it is $302 < t < 1142$.

The use of random values of “t” is useful not only for taking into consideration the uncertainty in the value of this parameter, but also for considering diversity of risk aversion in each participant.

2.5. ESTIMATION OF REVENUES IN THE SPOT MARKET

2.5.1. MARKET PARTICIPANTS

To prepare the model and to obtain preliminary results, the following market participants were considered:

[1] Fordward Price Forecasting for Power Market Evaluation, Final Report , March 1999.

Last Resort Suppliers (LRSs): they supply to regulate the demand and are obliged to buy financial instruments for their total load. We assumed that the regulated demand is 80% of total load.

Large (deregulated) Users: They were grouped in 200 MW groups, assuming that within each group the risk tolerance is the same. Thus, one bid is assumed for the whole group.

Generators: for this specific simulations the plants of each company were grouped (each company was considered as a group), with different bids for thermal and hydro plants. For the simulations in Chapter 4, we considered each plant separately (and did not group them by ownership).

The bids of large users and generators in each financial instruments market are assumed at constant utility values. This means that they will bid in each market the price that, if the offer is accepted, will maintain or increase their utility. For each one, a random risk tolerance (t_k) was obtained with a random number generator. Subsequently the bid was computed as follows:

Utility U_{sk} of participant k, assuming it only sells/buys energy in spot market (s) was estimated using the results of the market simulation. Therefore

$U_{sk} = SR_{sk} - \sigma_{sk}^2 / t_k$ (for sellers)

$U_{sk} = - SR_{sk} - \sigma_{sk}^2 / t_k$ (for buyers)

Where

Usk: utility of participant k in spot market (s)

SRsk: revenues/costs of participant k in the spot market (net of variable costs in the case of generators). In Appendix V we describe the methodology used to compute this parameter.

σ_{sk}: standard deviation of revenues/costs of market participant k associated to the operation in the spot market (see Appendix V for details on estimation of this parameter).

If market participant k sells/buys in other market i, its revenues/costs are:

Rik = POi + SRik

Rik = - POi - SRik

And utility becomes:

$Uik = PO_i + SRik - \sigma_{ik}^2 / t_k$

$Uik = - PO_i - SRik - \sigma_{ik}^2 / t_k$

Where

Uik: utility of participant k in market i

PO_i: asset price in market i

SRik: expected revenues/costs of participant k in the spot market when selling/buying the instrument in market i

If participant k bids (BID_{ik}) for asset price in market i, it will expect to obtain greater or equal revenues, but

$$U_{ik} = U_{sk}$$

Therefore

$$BID_k = - SR_{ik} + \sigma_{ik}^2 / t_k + SR_{sk} - \sigma_{sk}^2 / t_k \text{ (for sellers)}$$

$$BID_k = - SR_{ik} - \sigma_{ik}^2 / t_k + SR_{sk} + \sigma_{sk}^2 / t_k \text{ (for buyers)}$$

This formulas show that sellers accept a reduction in revenues to reduce risk ($\sigma_{sk}^2 / t_k - \sigma_{ik}^2 / t_k$), and buyers accept to pay a premium with the same objective.

2.5.2. REVENUES OF GENERATORS IN THE SPOT MARKET

From these market simulations, we obtained the expected generation of each plant, in each scenario, month and block of hours. Appendix V presents the detail of computations used to estimate the revenues of generators in the spot market, and when they sell options at different strike prices.

The expected revenues of generators in the spot market are computed as the average energy production in each block times the spot price in such block times the probability of the scenario. Then the revenues are divided by the capacity of each plant, to obtain 1 MW options for each plant.

In the case of hydro plants with regulation, the results (energy produced under each scenario) of simulations that optimize the long term operation of reservoirs were used directly. This assumption is valid, as spot market operation is independent of the financial instruments markets. Nevertheless, in some cases, a hydro generator that sold options or futures, could prefer a more conservative operation of its reservoirs, to reduce the risk associated to not being able to deliver energy in dry periods.

In the next table, a list of the market participants used in the simulation and their bids for one of the scenarios is presented. In this case, LRS bids (virtually) the unserved energy cost in the 10 us$/MWh strike price options market, in order to represent the obligation to buy options. In some scenarios this obligation was released.

Besides risk tolerance, each market participant may have a different estimation of future prices in the market. Such uncertainty in estimations may result in a second source of dispersion in the bids.

To incorporate explicitly the uncertainty in the market price forecast that market participants use for preparing their bids, we assumed that the average spot price estimated for each player is the average price estimated through market simulations plus a random component that represents dispersion in the forecasts. Therefore, the bids for futures and options are the average projected price plus/minus a normal random component.

In the table we present the bids of market participants that result from using the formulas and criterion described above. The parameters used to compute those bids were:

Parameter t randomly generated in the range $1120 >= t >= 320$, with uniform distribution

Error in spot prices forecast: 20%

Type	Market Participant		Capacity	Strike Price			
	Name	Code	MW	Futures	10	40	100
LRS	LRS's	dema	8000	24.9	13.4	12.1	9.7
LU	Large user 1	dgu1	200	24.5	12.9	11.7	9.3
LU	Large user 2	dgu2	200	26.3	14.7	13.4	11.0
LU	Large user 3	dgu3	200	21.5	9.9	8.7	6.3
LU	Large user 4	dgu4	200	25.1	13.6	12.3	9.9
LU	Large user 5	deg5	200	24.1	12.5	11.3	9.0
HY	Caribe	hcar	900	18.1	6.6	5.4	3.5
HY	San Carlos	hsca	1986	21.7	10.1	9.0	6.9
HY	Antioquía	hant	1285	22.4	10.8	9.6	7.6
HY	Oriental	hori	3073	19.7	8.1	7.0	5.0
HY	Suroccidente	hsur	1099	19.3	7.7	6.6	4.5
HY	Chec	hche	513	19.4	7.8	6.6	4.7
TE	Caribe	tcar	2296	20.5	8.9	7.7	5.6
TE	San Carlos	tsca	806	18.2	6.7	5.5	3.4
TE	Antioquía	tant	102	19.8	8.2	7.1	5.1
TE	Nordeste	tnor	437	20.6	9.0	7.9	5.9
TE	Oriental	tori	713	21.9	10.3	9.2	7.1
TE	Sudoccidente	tsuo	562	19.4	7.8	6.6	4.6
TE	Chec	tche	26	16.7	5.1	3.9	1.9

3. RESULTS

In the following pages we present the results of the market simulation for three different cases. In these simulations we analyzed the impact on market clearing prices of the following variables: 1) risk tolerance, 2) uncertainty in market prices, and 3) the obligation of LRS to contract.

Some of the model outputs are shown in the next tables. We have also included a summary of the most important results for each case analyzed. For simulation purposes, we assumed four types of financial instruments: futures, and options with strike prices 20, 40 and 100 us$/MWh.

Case 1

- Parameter t is randomly generated in the interval 320 – 1120.
- Uncertainty in market prices forecast is 20%.
- LRSs must buy options with strike price 20 us$/MWh for their total load.

The results show that the load of large users is bought in the futures market. The clearing price for futures is 20.3 us$/MWh.

The LRSs buy the energy in the options market with strike price 20 us$/MWh. The clearing price (premium) of such options market is 8.1 us$/MWh. The value of the premium for infinite risk tolerance players is 10.3 us$/MWh. This means that generators, because of their risk aversion, accept to sell the options at 2.2 us$/MWh, below intrinsic value.

CASE 1 **Capacity sold-bought**

PARTICIPANT	CAPACITY MW	futures MW	20 MW	40 MW	100 MW
dema	8000	0	8000	0	0
dgu1	200	200	0	0	0
dgu2	200	200	0	0	0
dgu3	200	200	0	0	0
dgu4	200	200	0	0	0
deg5	1000	200	0	0	0
hcar	900	0	900	0	0
hsca	1986	0	1986	0	0
hant	1285	0	0	0	0
hori	3073	899	2175	0	0
hsur	1099	0	1099	0	0
hche	513	0	513	0	0
tcar	2296	0	0	0	0
tsca	806	0	27	0	0
tant	102	102	0	0	0
tnor	437	0	0	0	0
tori	713	0	713	0	0
tsuo	562	0	562	0	0
tche	26	0	26	0	0
Clearing price		20.3	8.8	7.6	5.1
Total bought		1000	8000	0	0
Total sold		1000	8000	0	0

Case 2

- In this case, LRSs must buy their load in some of the options markets, including futures. We assumed that LRSs have a large risk tolerance, because energy prices are passed-through to regulated consumers.
- A new set of random numbers for risk tolerance and spot price uncertainty were generated.

Results show that the load of the LRSs is bought in the futures market at a clearing price of 19.6 us$/MWh, while large users move to the options market, with clearing a price of 8 us$/MWh.

CASE 2 — **Capacity sold-bought**

PARTICIPANT	CAPACITY MW	futures MW	20 MW	40 MW	100 MW
dema	8000	8000	0	0	0
dgu1	200	200	0	0	0
dgu2	200	0	200	0	0
dgu3	200	0	200	0	0
dgu4	200	0	200	0	0
deg5	1000	0	200	0	0
hcar	900	900	0	0	0
hsca	1986	1667	0	0	0
hant	1285	1285	0	0	0
hori	3073	3073	0	0	0
hsur	1099	1099	0	0	0
hche	513	176	337	0	0
tcar	2296	0	0	0	0
tsca	806	0	0	0	0
tant	102	0	0	0	0
tnor	437	0	437	0	0
tori	713	0	0	0	0
tsuo	562	0	0	0	0
tche	26	0	26	0	0
Clearing price		19.6	8.0	6.8	4.7
Total bought		8200	800	0	0
Total sold		8200	800	0	0

Case 3

- In this case we assumed that LRSs are free to participate or not in the options market.
- Their risk tolerance is randomly generated.

The Table with the results of Case 3 is presented in the next page. The results show that LRSs buy the options with 20 and 40 us$/MWh of strike price and that Large users buy futures at 20.4 us$/MWh.

The risk tolerance factor explains why each buyer chooses the market in which they participate.

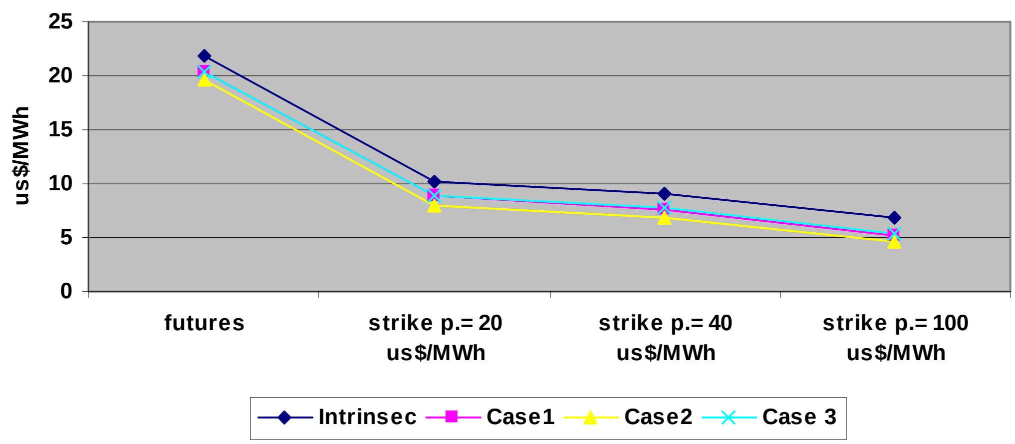
Summary of the results

The graph on the next page shows the market clearing prices obtained for each of the cases presented above compared with the intrinsic value of the options.

CASE 3 **Capacity sold-bought**

PARTICIPANT	CAPACITY MW	futures MW	20 MW	40 MW	100 MW
dema	8000	0	3256	4744	0
dgu1	200	200	0	0	0
dgu2	200	200	0	0	0
dgu3	200	200	0	0	0
dgu4	200	200	0	0	0
deg5	1000	200	0	0	0
hcar	900	0	0	900	0
hsca	1986	438	0	1548	0
hant	1285	0	0	0	0
hori	3073	0	1207	0	0
hsur	1099	0	1099	0	0
hche	513	0	513	0	0
tcar	2296	0	0	2296	0
tsca	806	0	0	0	0
tant	102	0	0	0	0
tnor	437	0	437	0	0
tori	713	0	0	0	0
tsuo	562	562	0	0	0
tche	26	0	0	0	0
Clearing price		20.4	8.9	7.7	5.3
Total bought		1000	3256	4744	0
Total sold		1000	3256	4744	0

Market clearing prices and intrinsic value of the options for the three cases:



4. CONCLUSIONS

We have developed a model to simulate the functioning of the futures and options market which is also useful to evaluate the behavior of the market participants. Some simplifications were introduced to characterize the risk profile of market participants. It would have been necessary to count with a liquid market of futures and options to be able to obtain information to characterize with econometric tools the risk profile of market participants.

The results obtained are consistent with options prices computed based on simulations, and considering participants without risk aversion.

The model is useful for estimating the prices of the financial instruments. The results of these estimations are presented in the next chapter.

APPENDIX V

5. APPENDIX V

Revenues of generators in the options market.

The revenues of generator k, in the period p (six months) when they sold an option in market i, with strike price $stpr_i$ was estimated using the next formulas:

Thermal plants

$$Rkp = \Sigma_j \Sigma_l \Sigma_m \text{ ingre } (pspot_{jlm}, cv_k, stpr_i) * T_{jm} * CAP_k$$

Where:

j= 1, … NE

l= 1,… NB

m= 1,….NM

NB; number of hourly blocks used to represent monthly load (5)

NE; numbers of scenarios

NM; number of months in period p (6)

T_{jm} : duration of block l, month m

Rkp: revenues of generator k in period p

$pspot_{jlm}$: price of energy in the spot market in scenario j, month m, block l

cv_k: variable cost of generator k

CAPk: capacity available of generator k

Function ingre ($pspot_{jlm}$, cv_k, $stpr_i$) is computed as follows:

if $pspot_{jlm} < cv_k$ and $pspot_{jlm} < stpr_i$

ingre = 0

if $pspot_{jlm} \geq cv_k$ and $pspot_{jlm} < stpr_i$

ingre = $pspot_{jlm} - cv_k$

if $pspot_{jlm} \geq cv_k$ and $pspot_{jlm} \geq stpr_i$

ingre = $stpr_i - cv_k$

if $pspot_{jlm} < cv_k$ and $pspot_{jlm} \geq stpr_i$

ingre = $stpr_i - pspot_{jlm}$

Hydroelectric plants

$$Rkp = \Sigma_j \Sigma_l \Sigma_m \text{ ingreh } (pspot_{jlm}, eneh_{jlmk}, stpr_i)$$

Where:

$eneh_{jlmk}$: energy produced buy generator k in scenario j, month m, block l, obtained from results of market simulation.

Function ingreh ($pspot_{jlm}$, $eneh_{jlmk}$, $stpr_i$) is computed as follows:

if $eneh_{jlmk} = 0$ and $pspot_{jlm} < stpr_i$

$ingreh = 0$

if $eneh_{jlmk} > 0$ and $pspot_{jlm} < stpr_i$

$ingreh = pspot_{jlm} * eneh_{jlmk}$

if $eneh_{jlmk} > 0$ and $pspot_{jlm} \geq stpr_i$

$ingreh = stpr_i * CAPk * T_{jm} - (CAPk * T_{jm} - eneh_{jlmk}) * pspot_{jlm}$

if $eneh_{jlmk} = 0$ and $pspot_{jlm} \geq stpr_i$

$ingreh = (stpr_i - pspot_{jlm}) * CAPk * T_{jm}$

Unit revenues

Unit revenues are obtained using the following formulae:

$$SRikp = \frac{Rkp}{NE * NM * 730 * CAPk}$$

Volatility

Volatility of revenues of generators was computed as follows:

$$\sigma_{ik} = \text{standard\_deviation } (\Sigma_l \Sigma_m \text{ ingre } (pspot_{jlm}, cv_k, stpr_i) * T_{jm} * CAP_k)$$

$$\sigma_{ik} = \text{standard\_deviation } (\Sigma_l \Sigma_m \text{ ingreh } (pspot_{jlm}, eneh_{jlmk}, stpr_i)$$

Demand

$$Ckp = \Sigma_j \Sigma_l \Sigma_m - \text{ingreh } (pspot_{jlm}, DEM_{jlmk}, stpr_i)$$

Where

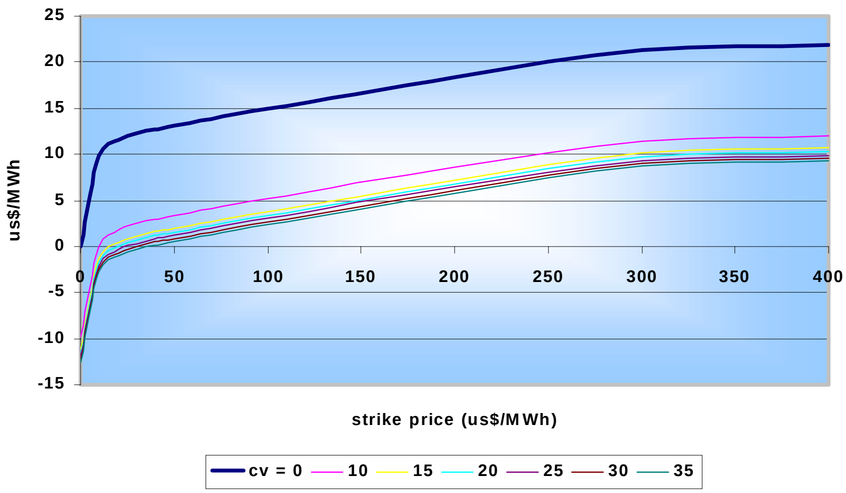
Ckp: cost of energy of market participant k, associated to buy energy, when it has and option with strike price $stpr_i$

DEM_{lmk}: demand of market participant k in scenario j, month m, block l

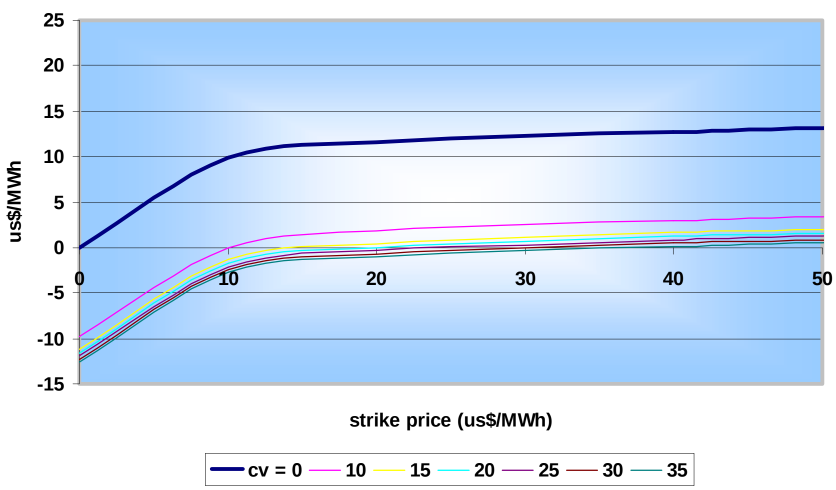
Results

In the next two pages we present graphs that show some of the results obtained from processing these calculations.

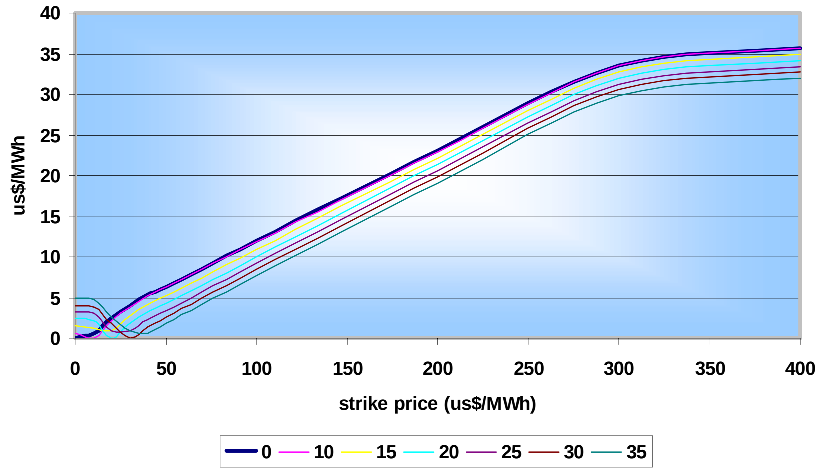
The first graph shows the Values of SR_{ik} for thermal generators with different variable costs. The curve with cv=0 also represent run of river hydro plants.



In the next graph we present the same results in a different scale. For strike prices below 10 us$/MWh, thermal generators assume the risk of negative revenues, because when spot prices are below variable costs, they have to buy energy in the spot market.



The next graph shows the volatilities estimated for revenues of generators in the different options market, and for the same set of variable costs.


40
35
30
25
20
15
10
5
0
us$/MWh
0
50
100
150
200
250
300
350
400
strike price (us$/MWh)
0
10
15
20
25
30
35