Competition in Southeast European Electricity Markets without optimal use of Transmission Infrastructure

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1. Introduction

The main idea behind the liberalisation process and major goal of the EU directive was to provide lower electricity prices for the whole economy by introducing competition and to improve market efficiency and social welfare.

In a deregulated electricity market, different generation mixes and production costs for electricity are resulting in regional differences for electricity prices. The price differences and possibility to trade electricity in an open market caused a considerable increase in electricity exchange between countries over cross-border transmission lines. The transmission infrastructure was not projected for electricity trading in such an extent and therefore facing new challenges to cope with the rising amount of power flows between countries. Because of unexpected power flows and loop flows, the transmission grid is reaching its limit on some locations (congestion).

The insufficient transmission infrastructure is resulting in market separation and creation of sub-markets which is against the main goal of the European Commission- to introduce a common European electricity market. The incompatibility of market designs among European countries, imperfect design of cross-border trade and the lack of coordination between transmission system operators (TSOs) implicates that potentially available transmission infrastructure is not used in an optimal way. This “unused” capacity causes inefficiency because more expensive means of production are used and competition between market participants is reduced. The optimal use of infrastructure is very important not only for the case of Continental Europe where this kind of problems is present (*Boucher, Smeers, 2002*), but also even more in the enlarged European Union (*Keseric et al. 2005*) [3].

Although considerable research has been devoted to model electricity markets, there is still a lack of knowledge how and to what extent suboptimal allocation and use of transmission infrastructure combined with strategic behaviour will influence the price development in the future regional market in Southeast Europe (SEE).

The core objective of this paper is to study the influence of transmission capacities on the market price and which producers will have influence on the regional SEE electricity market depending on grid topology and generation costs.

The paper is organized as follows:

Section 2 provides the introductory data and facts considering the electricity market, the generation and transmission capacity and major national players in SEE electricity market. In Section 3 we look briefly how cross-border trade in SEE is organized and explain why not all available capacity is allocated and traded on the market. Section 4 describes the basic principles of agent-based modeling used to simulate electricity markets. Furthermore, we show the general construction and parameters of the learning algorithm considered in this work. Section 5 presents our test system including a detailed description of the auction mechanism and the learning algorithm used by market participants to determine their offers. In Section 6, we explain the model settings, results and analysis of performed simulations. The concluding Section 7 summarizes our key findings and discusses the future work.

2. Electricity markets in SEE

SEE countries are facing with forthcoming challenges that bring deregulation. After the Athens Memorandum all electric utilities are preparing for transition from centralized, vertical integrated monopoly structure to liberalized undertakings based on free electricity market. Market privatization, potential business possibilities and opportunities for investments in new production capacities and extension of transmission lines are major challenges for SEE countries within this process. In this context, the better use of transmission infrastructure and upgrades are technically aimed not only for covering a sharp increase in demand in this region but also for improving competition between power producers. Actual primary goal is creation of liberalized regional Electricity Market in SEE. SEE countries could later join to European Union's Internal Electricity Market as associated region so they will be more attractive and productive than any of countries alone. Regional Electricity Market will improve competition, bring lower costs and prices, better service to end customers so all countries will benefit from it.

Nevertheless looking inside each country, the level of horizontal concentration in generation assets is in general very high. Most of the countries show a common market structure: a big company ("the national champion") and a small competitive fringe. Considering the geographical position we analyse influence of the market producers from following countries: Albania[1], Bulgaria, Bosnia and

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[1] The Albanian power sector with installed generation capacity of 1,5 GW are suffering from electricity deficit and limitations in transmission capacity to the neighboring countries. Because of its marginal importance, the Albanian power system is not modeled in this study.

Herzegovina, Croatia, Macedonia, Romania, Serbia, Montenegro and Slovenia. To study the impact of the future regional SEE market on central European and CENTREL countries, two power systems of the neighboring countries Austria and Hungary are modeled.

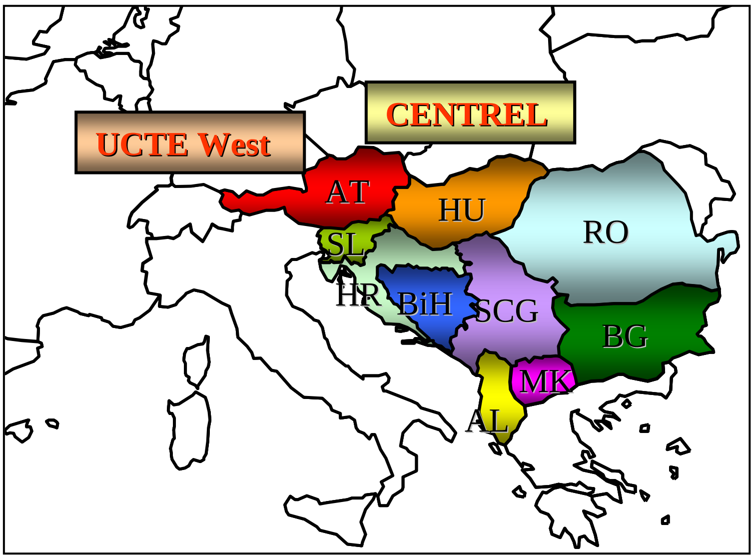


Fig. 1. Regional electricity market in SEE

<u>Bulgaria (BG):</u> The installed capacity in Bulgaria is about 13 GW, with thermal capacity making up 50% (6.5 GW), hydro power plants making up approximately 20% (2.8 GW), and Kozloduy nuclear power plant about 30% (3.76 GW) of total capacity. The National Electricity Company (NEK) owns the transmission systems and acts as a system operator of the national grid. Since 1999, the Bulgarian power system derives about 42 % of its total national electricity production from his only nuclear power plant Kozloduy. The first two nuclear reactors were shut down in 2003 and as part of the country's accession talks with the EU the next two reactors are scheduled to be shut down in 2006 - well short of their normal designed life time. Nevertheless, Bulgaria plans to build 2 GW of new nuclear capacity between 2010 and 2018. Part of this plan will be a second nuclear power plant in Belene with a 1GW unit to help maintain Bulgarian position as the leading net exporter of electricity in the region. The new unit at Belene is projected to deliver electricity at a price in the range of 30 to 40 €/MWh.

<u>Bosnia and Herzegovina (BiH):</u> The total installed generation capacity of the power system of BiH was at the end of 2004 about 4 GW. Currently there are three separate, vertically organized companies, dealing with generation, transmission and distribution in BiH:

- Elektroprivreda BiH, with its headquarters in Sarajevo (1867 MW),
- Elektroprivreda HZHB, with its headquarters in Mostar (762 MW),
- Elektroprivreda of Republika Srpska, with its headquarters in Trebinje (1340 MW),

Each electricity supplier is responsible for the scheduling and dispatch of its own power plants within its territory. However, a Joint Power Coordination Centre (ZEKC), which is jointly owned and operated by the three utilities, will be transformed into the Independent System Operator (ISO).

Croatia (HR): The installed generation capacity of the Croatian power system in 2004 was 4 GW. Thermal power stations generated 51%, hydro plants 37% and only nuclear power station Krsko which belongs to 50% to HEP produced 12% of electrical energy in 2004.

The only relevant electricity supplier of size is presently Hrvatska Elektropriveda (HEP) which is modelled as a strategic agent in the national market. This state-owned company which is responsible for generation, transmission and distribution generates about 95% of Croatia's electricity. The rest is generated in small hydro facilities and from privately-owned industrial cogeneration power plants. The Croatian electricity company HEP owns three major oil-fired plants (Zagreb, Sisak, and Rijeka) plus several small plants fired with coal and natural gas and the national transmission system is also owned and operated by this company. Congestions in the transmission grid occur on the border between Hungary and Croatia, mainly because of the loop flows from Northern Europe to the biggest electricity importer Italy.

Hungary (HU): The total installed capacity of the Hungarian power generating system is about 8 GW against peak load of 6 GW. Hungarian power utility MVM and its subsidiaries are among the most important players in the national electricity sector. The Hungary's only nuclear power plant Paks operating with a total nominal power of 1.86 GW is a subsidiary of MVM. Hungary is very dependent on Paks which four reactors generated approximately 40% of total demand. Conventional thermal production has a total capacity of more then 60% of installed capacity which is almost equally shared between power plants burning locally mined lignite and brown coal.

The transmission system is operated by Mavir, which is legally unbundled from former incumbent MVM. Hungary is a net importer of electricity and an important transit country for power flows moving from Ukraine and Slovakia southwards to Croatia, Serbia and Italy. The competition in the national market is induced by trading with imported power, but there is also a lack of transmission capacity. Although the Hungarian power system is well interconnected, with links to Austria, the Slovak Republic, Croatia, Slovenia, Romania, Bulgaria and Ukraine's Burshtyn Island, free capacity for trade is limited. About 80% of capacity is still reserved for long term contracts. The rest is auctioned on a monthly and yearly basis, but these conditions with scarce capacities are resulting in relatively high prices. Until a higher amount of import capacity is made available by MVM, traders continue to focus on the annual cross-border capacity auctions and remain hopeful that better trading opportunities lie ahead. Besides national incumbent MVM, also several large foreign utilities are active in the Hungarian electricity sector, including the some of biggest European players: EdF, German’s RWE and Eon, Belgium's Electrabel and Switzerland's Atel, but their relative small size does not allow them to exercise market power.

Romania (RO): The installed capacity in Romanian power sector at the end of 2004 was about 16 GW of which 60% are thermal conventional, 36% hydro and 4% nuclear. The Romanian Power Grid Company-*Transelectrica* (TEL) has been created as a joint stock state-owned company by splitting off the former vertically integrated National Electricity Company into four separate legal entities. *Termoelectrica* owns most of the conventional thermal power plants, of which about half is coal-fired. Combined heat and power (CHP) plants represent 80% of total coal-fired capacity and 45% of total thermal capacity. About 30% of Romania's annual consumption is supplied by *Hidroelectrica* which runs 347 hydro power plants and pumping stations with an installed capacity of 6 GW. Romania is a regional exporter of electricity with balance of physical exchanges of 1.1TWh in 2004. Romania has good cooperation with Bulgaria, Serbia & Montenegro and other SEE countries for creation of one regional market.

Serbia and Montenegro (SCG): The market concentration in electricity market of SCG is high. The largest and most important power producer is Electric Power Industry of Serbia (EPS) which owns power generating facilities with the total capacity of 8.35 GW. Net output capacity of lignite-fired thermal power plants amounts to 5.17 GW, whereas the capacity of hydro power plants amounts to 2.83 GW. On the second place is Electric Power Industry of Montenegro (EPCG) with relative small market share and installed capacity of 868 MW.

Slovenia (SL): The total installed capacity of Slovenian's power sector in 2004 was 2.7 GW of which 37% in thermal power plants, 35% in the nuclear power station Krsko and 28% in hydro power plants. The largest production share is held by the HSE group (Holding Slovenske elektrarne). The public company Elektro-Slovenija (Eles) carries out the tasks of the transmission system operator. The transmission system is very well connected to the electric power systems of the neighbouring countries. After a reconnection of the 2nd synchronous zone of Balkan to 1st UCTE synchronous zone, the loading of the transmission network is somewhat higher due to an increased scope of dealing, which is due to the export and import of electricity.

As a conclusion of this section we can reassert that the most efficient way to introduce competition in the generation sector and reduce potential market power of the national "champions" is to create an integrated regional electricity market with a wider level playing field for all market participants.

3. Market integration in SEE

According to the Athens Memorandum, the electricity sectors in SEE countries, slowly but with sure steps, goes into direction of their regionalization. A perfect integration between markets supposes that all opportunities to arbitrage price differences are used, even if at the end of this arbitrage a price difference remains between regions because of congestion. This supposes that all possible "technical" transmission capacity between regions is available to market participants to arbitrage price differences. The possibility of arbitrage between regions depends mainly on national electricity market designs and cross-border congestion management procedures. Congestion arises from the saturation of transmission infrastructure. Because one cannot build the infrastructures with infinite capacities, congestion is unavoidable but should not be excessive.

Different electricity market designs deal with transmission constraints in different manners [5]. Not all models have equal efficiency results. Congestions in transmission grids are one of the principal sources of externalities on electricity markets. The strength of a market design depends on how the design internalizes externalities. It can be seen that too simplified market designs (when they do not represent accurately the physics of the grid) could prevent the use of all physical transmission capacities [11]. This problem is even bigger when different market designs and TSOs (Transmission System Operator) cohabite on a meshed network where there is the same "physics" for grid. In this case, given that the grid operation is made in a decentralized way some "border effects" could arise and undermine the optimal use of existing infrastructure. The available transmission capacity is even more reduced because of non-compatibility of markets designs and the lack of full coordination between TSOs.

Joint allocation methods and congestion management procedures are one of the important prerequisites for construction of regional electricity market in SEE countries. Considering the congestion management methods in SEE, the non market-based bilateral methods, mostly not coordinated between neighboring TSO's are currently in use [7]. Such methods result in the fact that not all transmission capacity is efficiently allocated and available for electricity trade. Almost half of congestion on interconnections is managed by a non-market based mechanism like pro-rata, priority list or not at all. The other half is managed with the capacity auctions but these auctions are not coordinated, except between Austria and Hungary (see Fig. 2). Whatever the method used to deal with congestions, the "interconnection capacities" available and sold by the TSOs are calculated using forecasts of situation in real time (scenarios). Market designs that do not represent exactly the real grid and the lack of full coordination between TSOs worsen an accurate forecast of the real system situation. These two factors yield to a too conservative evaluation of available transmission capacities.

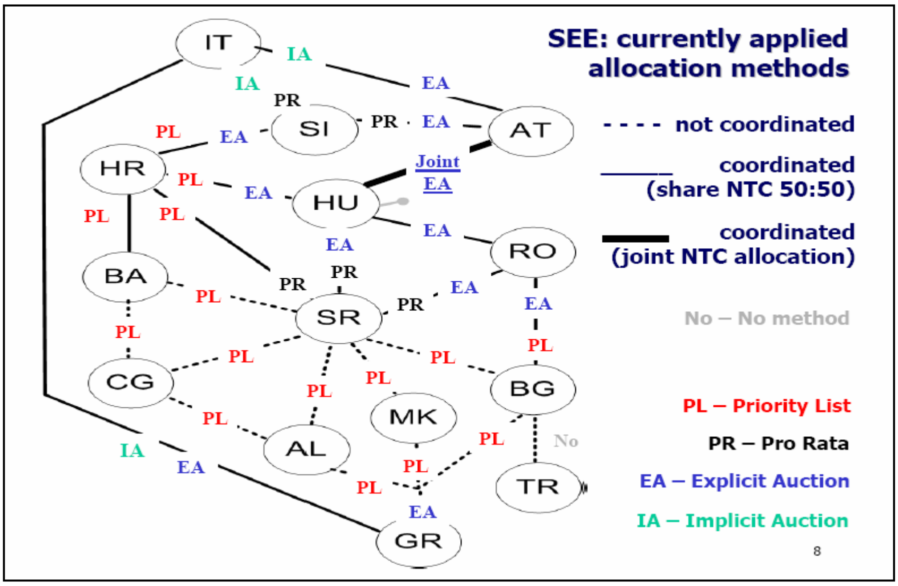


Fig. 2. Currently applied allocation and congestion management methods for transmission capacity in SEE; Source: [6]

In conclusion the weaker the market design is the higher is the portion of transmission infrastructure that is not available to the market participants. In an environment of perfect competition this unused capacity leads to inefficiencies in electricity markets because more expensive means of production are used. But in an imperfect competitive world, the transmission capacity plays also a role of competition improvement.

4. Agent-based modelling

The very complex interactions and interdependencies among electricity market participants are much like those studied in game theory. However, the strategies used by many market participants are often too complex to be conveniently modelled by standard game theoretic techniques. In particular, the ability of market participants to study new market rules and then rapidly adapt their strategies to gain higher profits adds additional complexity. Game-theoretical description of competition in markets (all agents agreeing in an equilibrium) is usually based on the assumption that all agents have perfect information and perfect rationality. In an electricity market, the different agents in principle know neither the set of actions the other agents have at their disposal nor the different reward functions. In this context, it is difficult to assume that the players are indeed going to adhere to Nash equilibrium since they do not have all elements to compute it. Even if the generators have or can estimate all this information computing the Nash equilibrium is not an easy task. Agent based models do not use any information to compute the agents' behavior.

The prosperous combination of well-known technical tools, empirical economy and new ideas in computational social and cognitive science offers appealing extensions to traditional game theoretical modelling of electricity markets.

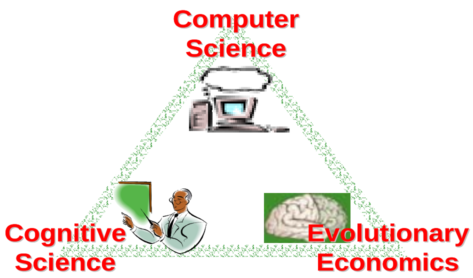


Fig. 3. The theoretical foundation of the Agent-Based Computational Economics (ACE)

To model this learning from experience the reinforcement learning algorithm is introduced here. This learning algorithm was originally developed by Roth and Erev (RE) [10] who describes how people learn individually in games with multiple strategically-interacting players.

The three parameters characterizing the RE algorithm are:

$S(1)$ - Scaling parameter

r - Recency (forgetting) parameter

ε - Experimentation parameter

Agent's strategy is approximated by a discrete grid consisting of *Kmax* feasible actions *k*, where *Kmax* is the same for each agent. In each run, each agent can choose an action *k* randomly, but following a learned probability distribution (P_{jk}). This learned probability distribution is constructed with the actualized propensities of each action *k*.

At the beginning of the first round, each agent *j* assigns an equal propensity $Q_{jk}(1)$ to each feasible actions *k,* given by:

$$Q_{jk}(1) = S(1)\frac{\overline{R_j}}{K_{\max}} \tag{1}$$

where $\overline{R_j}$ is the average profit of agents.

Moreover, at the first run, each agent *j* assigns an equal choice probability $P_{jk}(1)$ to each of its feasible actions k, given by:

$$P_{jk}(1) = \frac{1}{K_{\max}} \tag{2}$$

Each agent *j* then selects a feasible action *k'* in accordance with its current choice probabilities. After this choice, agents are communicated of his reward $R_{jk}(t)$.

Now suppose that agent j is at the end of the *n*th round, for arbitrary positive *n,* and that in the *n*th auction round agent *j* has chosen a feasible action *k'* and his reward is $R_{jk'}(t)$.Agent *j* then updates its existing action propensities $Q_{jk'}(t)$ on the basis of its newly earned profit, as follows :

$$Q_{jk'}(t+1) = (1-r)Q_{jk'}(t) + (1-\varepsilon)R_{jk'}(t) \tag{3}$$

$$Q_{jk'\pm 1}(t+1) = (1-r)\,Q_{jk'\pm 1}(t) + \frac{\varepsilon}{2}R_{jk'}(t) \tag{4}$$

The learning algorithm is based on both psychological principals: the *law of effect* (LOE) and the power *law of practice* (LOP). Depending on the produced results and observed reward, the future agents' action is reinforced or weakened (LOE). Some refinement could be added. For example, a "local reinforcement refinement" improves propensities for actions being beside a successful one. Also, a "cut off refinement" set the propensities to zero when they are under a cut parameter. This accelerates the convergence of the model [10].

5. Simulation of the SEE regional market

5.1. Test grid and parameters

We illustrate the approach described in the previous Section applying it to a realistic case study in southeastern Europe. We chose this region because of high market concentration on the national level and the fact that some countries significantly depend on electricity imports. Therefore issues of available transmission infrastructure and congestions are very important.

We used here a market architecture corresponding to a centralized regional pool with a complete zonal model. Within this framework each agent presents offers as a linear function. The central coordinator accepts agent's offers and chooses the most valuable considering limitations in transmission grid model. Prices and accepted quantities are calculated in day-ahead market for each market round t .The agent-based module with reinforcement learning is used for calculation of quantities and electricity prices in different nodes or zones (regions, countries).

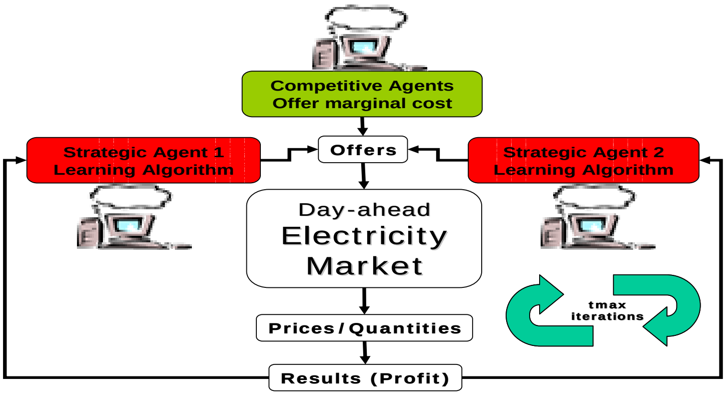
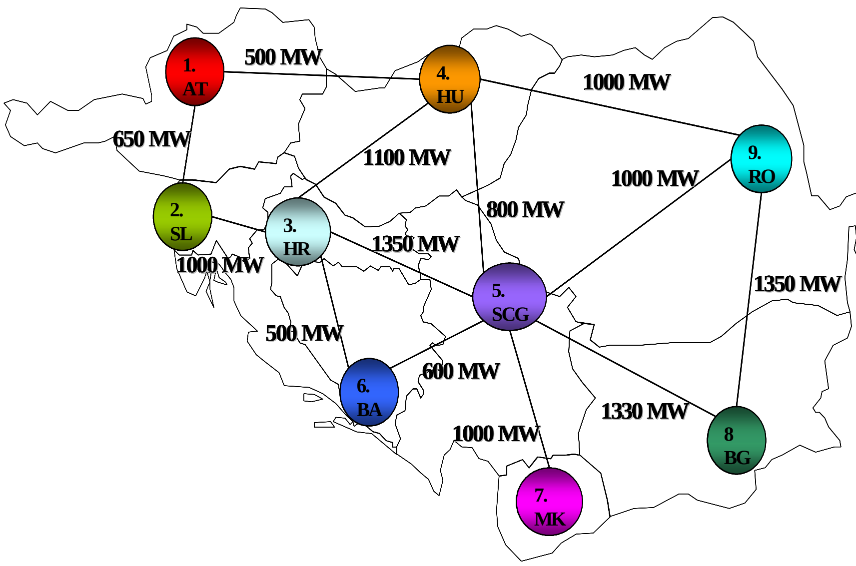


Fig. 4. Regional SEE electricity market structure

The results from day-ahead market are the optimal quantity of electricity each generator has to produce to cover the load while making sure the transmission line is not overloaded. Nevertheless, in the presence of transmission constraints, the cost of producing electricity at nodes differs and thus zonal prices vary by location providing clear locational signals for new investments in generation and transmission.

Figure 5 shows a simplified electricity transmission network of 9 countries (Austria, Bulgaria, Bosnia and Herzegovina, Croatia, Hungary, Macedonia, Romania, Serbia and Montenegro and Slovenia.) used for simulations. Given its negligible installed capacity and load, the Albanian power system is not modeled. Transmission system is represented by 9 nodes connected by 13 transmission lines which are modeled as an adequate equivalence of existing 220 kV, 400 kV and 750 kV lines.



Transmission Lines	Country No. from	Country No. to	Reactance X (app.)	Capacity MW
1	1	2	6,0367	650
2	1	4	5,5975	500
3	2	3	2,7784	1000
4	3	4	57,2880	1100
5	3	5	31,7130	1350
6	3	6	1,6337	500
7	4	5	16,3680	800
8	4	9	19,4370	1000
9	5	6	9,1004	600
10	5	7	4,6921	1000
11	5	8	41,9430	1330
12	5	9	0,8400	1000
13	8	9	20,4339	1350

Fig. 5.The simplified test grid of the regional market in SEE

The Power Transfer Distribution Factors (PTDFs) are calculated using available grid data from SEE Generation Investment Study, project managed by the EC and World Bank [12]. Note that for the transmission capacity the values published by European Transmission Operator (ETSO) for the Winter 2004/5 are used. Our aim was to create a basic research tool which could replicate main physical characteristic of the real transmission grid in SEE without pretending to be an accurate model.

Twenty power producers are represented; twelve of them have high market share in their own national markets: Verbund, Energie Allianz, HSE, HSO, MVM, EPS, 3 in BiH, ESM, NEK and TEL (see Table 1). Remaining generation units act as competitive agents. Each agent owns generation assets characterized by a linear supply curve.

Table 1. Power producers represents with agents

Country	Company	Node
AUSTRIA	Verbund	AUSTRIA
AUSTRIA	Energie Allianz	AUSTRIA
SLOVENIA	Comp_SLOVENIA	SLOVENIA
SLOVENIA	HSE	SLOVENIA
CROATIA	Comp_CROATIA	CROATIA
CROATIA	Croatian strategic HSO	CROATIA
HUNGARY	Comp_HUNGARY	HUNGARY
HUNGARY	MVM	HUNGARY
SERBIA&MONT.	Comp_SERBIA	SERBIA&MONT.
SERBIA&MONT.	EPS	SERBIA&MONT.
BOSNIA&HERZ.	Comp_BOSNIA	BOSNIA&HERZ.
BOSNIA&HERZ.	Croatian	BOSNIA&HERZ.
BOSNIA&HERZ.	Bosnian	BOSNIA&HERZ.
BOSNIA&HERZ.	Serbian	BOSNIA&HERZ.
MACEDONIA	Comp_MACEDONIA	MACEDONIA
MACEDONIA	Macedonian strategic ESM	MACEDONIA
BULGARIA	Comp_BULGARIA	BULGARIA
BULGARIA	NEK	BULGARIA
ROMANIA	Comp_ROMANIA	ROMANIA
ROMANIA	TEL	ROMANIA

Demand functions are assumed to be linear with a demand elasticity of -0.1 at 30 Euro/MWh. Demand load data are drawn from official UCTE website corresponds to the winter peak scenario in January 2005 (Table 2) and adjusted for imports or exports.

Table 2. Demand data corresponding to winter peak scenario in January 2005

Demand load [MW]									
	Countries								
Scenario	1 AT	2 SI	3 HR	4 HU	5 SER	6 BA	7 MK	8 BG	9 RO
Winter January 2005	10521	1102	2684	6146	6894	1861	1370	5265	7810

The mathematical model is formulated as:

$$\underset{qd_i, qp_{i,a}}{Max} \sum_i \int D_i(qd_i) - \sum_i \sum_a \int Of_{i,a}(qp_{i,a})$$

$$\sum_i qd_i - \sum_i \sum_a qp_{i,a} = 0 \qquad (\lambda)$$

$$-\sum_i qd_i * PTDF_{i,l} + \sum_i \sum_a qp_{i,a} PTDF_{i,l} \le CapMax_l \quad (\mu \max_l)\ \forall l$$

$$\sum_i qd_i * PTDF_{i,l} - \sum_i \sum_a qp_{i,a} PTDF_{i,l} \le CapMin_l \quad (\mu \min_l)\ \forall l$$

$$0 \le qp_{i,a} \le QP\max_{i,a}\ \forall i\ \forall a$$

where: $D_i(qd_i) = InD_i - SlD_i\, qd_i$ is the inverse demand curve and $Of_{i,a}(qp_{i,a}) = InP_{i,a} + SlP_{i,a}\, qp_{i,a}$ is the linear offer curve of agent *a* at node *i*.

Prices at different nodes are calculated as:

$$Price_i = \lambda + \sum_l PTDF_{l,i}\ \mu\max_l + \sum_l PTDF_{l,i}\ \mu\min_l$$

6. Results and discussion

6.1. Preliminary settings

For the learning algorithm we set the following parameters: *S(1) =1*; *r* =0.05; *ε* =0,2. The strategic space ($SlP_{i,a}$) is a discrete grid of 100 feasible actions (K_{max}). The grid of feasible actions is constructed for each agent to ensure that they are not limited by the minimum or maximum feasible actions. The learning process is observed in t_{max}=700 market rounds (*t*). The simulation with the same learning process is run T_{max}=10 times.

Fig. 6 shows the evolution of prices in €/MWh in different countries while agents are learning about the best action. It can be seen that in the first round, all strategies have the same probability and the offers are very volatile. But by this methodology (that mimics people's behavior), the agents learn along the time to improve the probability function and to maximize their profit.

At the end (rounds 500– 700) the learning process is stabilized and the agent plays almost all the time his best action which corresponds to the peak of probability.

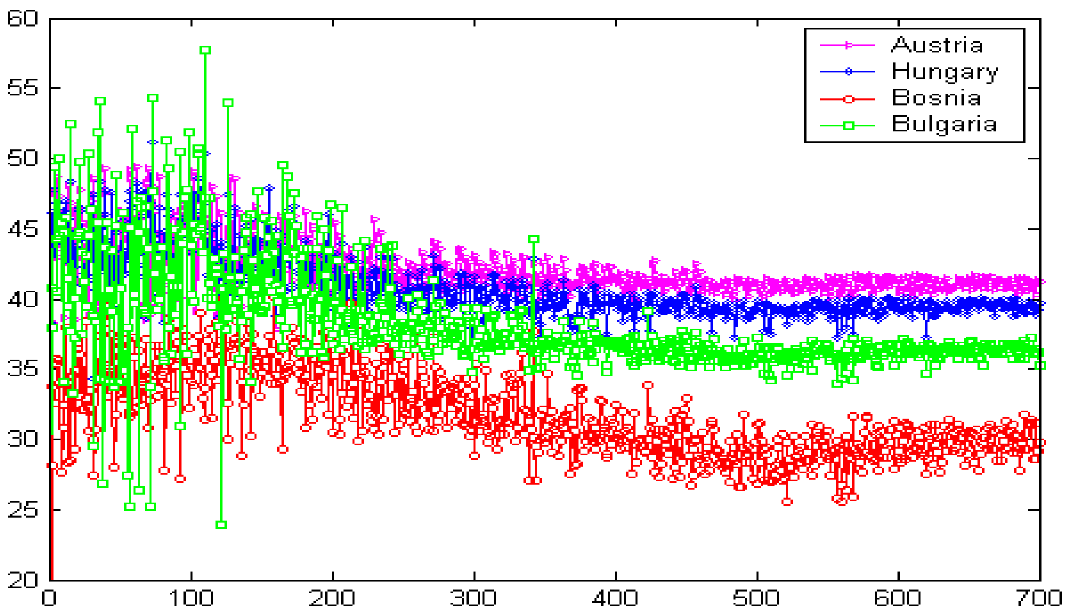


Fig. 6. Electricity prices with agent's learning effect

The average of these last values to evaluate partial T results is taken. This learning process (700 rounds) is rerun 10 times (*Tmax*) and the average of these values is taken for the final results.

6.2. *Strategic scenarios and analysis*

One interesting point, that offers a lot of space for future experimentation, was to model different market structures and market concentration. With respect to biggest power producers in each country, we present here results for two different market structures:

- All agents act competitive and offer marginal cost curve;
- All agents act strategically and offer higher prices (biggest producers except fringe)

In order to mimic the phenomena of transmission capacities restriction due to poor market design and lack of coordination between TSOs, the real test system is analysed taking into account different usage of available transmission infrastructure. We first simulate the system using a complete nodal system representing the maximal transmission capacity (100 % of all line capacities : $CapMax_l$ and $CapMin_l$) and we then define an "economical" grid model where capacities of all lines have been reduced (70 %) to mimic the conservative way in order to evaluate capacity with imperfect market designs. Even if this is a rough approximation, this could give insights about agent behaviors and the importance of available transmission capacity in enhancing level of competition.

The results with obtained electricity prices in different scenarios are presented in Fig. 7. It can be seen that even agents without perfect rationality and perfect information (using a simple reinforcement learning algorithm) can take more advantage of their market power when they act strategically. This is aggravated when available transmission infrastructure is not optimally used because of poor markets design. As logic, for reduced transmission capacities prices are higher in average. This means, when transmission capacities are reduced due to inefficient market design or occurring congestions, production firms with high market share can profit more of their market power. We want to emphasize here more the relative change in electricity prices, so the obtained absolute value for electricity prices need not always correspond to reality.

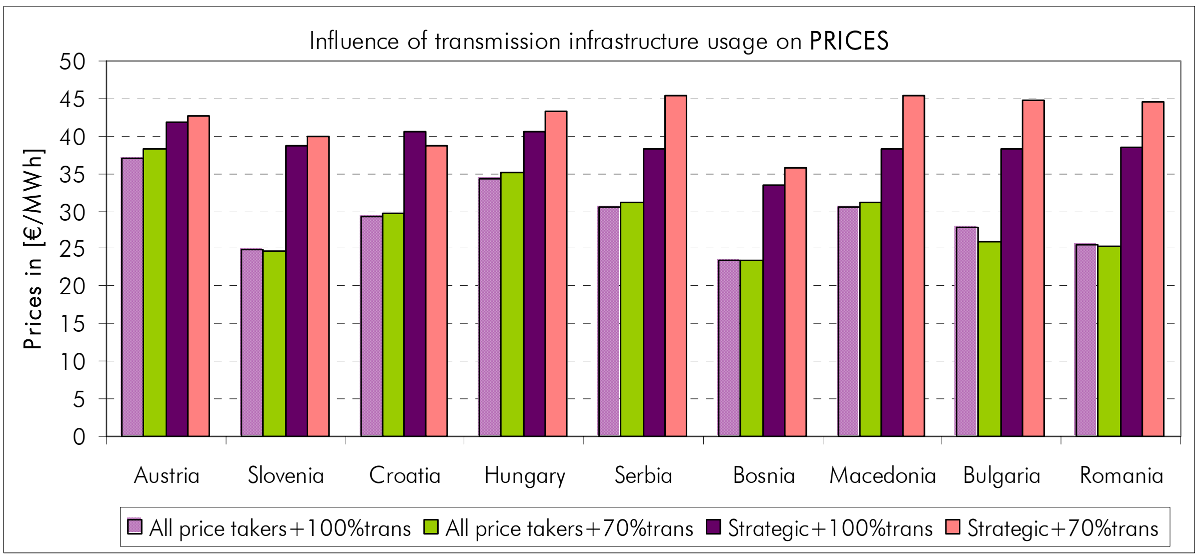


Fig. 7. Influence of transmission infrastructure usage on prices (in €/MWh)

The first scenario with perfect competitive market structure (all agents offer just marginal costs and 100% of transmission infrastructure) is used as a competitive benchmark for the other ones. In the scenario when transmission capacity is reduced and power producers having high market share act strategically, the prices and welfare losses are higher but they drop down with better usage of transmission infrastructure and when market structure is less concentrated.

The consumer and producer surplus (profit) and their change depending on transmission infrastructure usage are shown in Table 3.

Table 3. Market efficiency depending on transmission infrastructure use[2]

Peak Winter Case	Economic metrics				
	Consumer Surplus	Generators Profit	Transmission Revenue	Social Welfare	Change in Welfare
All price takers+100%trans	**6,51** (0,0)	**0,47** (0,0)	**0,02** (0,0)	**7,00** (0,0)	**0,00%**
All price takers+70%trans	**6,50** (0,0)	**0,48** (0,0)	**0,02** (0,0)	**7,00** (0,0)	**-0,11%**
Strategic+100%trans	**6,14** (0,0)	**0,81** (0,0)	**0,01** (0,0)	**6,96** (0,0)	**0,00%**
Strategic+70%trans	**5,98** (0,0)	**0,94** (0,0)	**0,01** (0,0)	**6,93** (0,0)	**-0,47%**

The difference in welfare (%) between cases with different transmission capacities (70% and 100%) is five times smaller in percentage for competitive benchmark cases than for strategic cases. Figure 8 shows the changes in consumer and generator surplus depending on how the available transmission infrastructure is used.

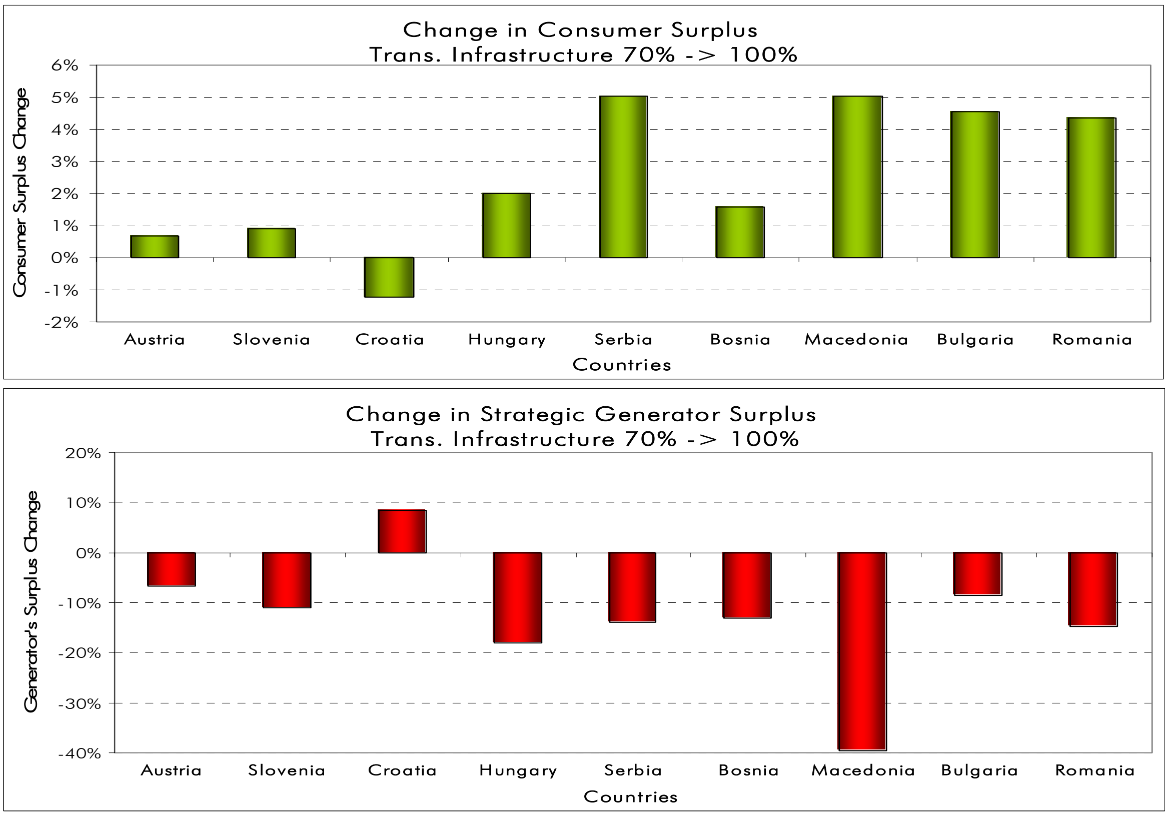


Fig. 8. Changes in Consumer and Generator surplus (profit)

[2] Units [10^6 euros]

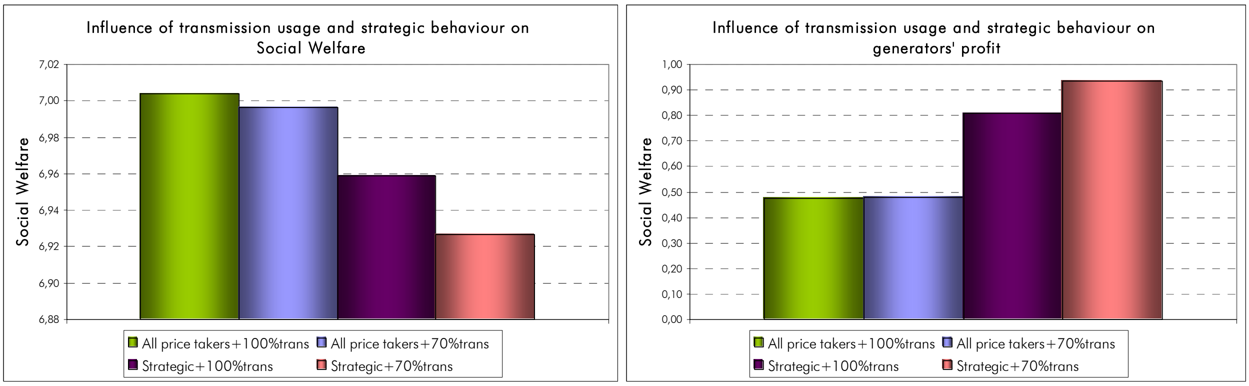


Fig. 9. Changes in social welfare and generators' profit

Figure 9 shows to what extent the transmission infrastructure usage improves the total social welfare in SEE market. The principal factor influencing the change in global welfare is the assumption of strategic behavior of agents and the other is the simplistic representation of the reduced effective transmission capacities. Future works which will take into account more detailed market design and imperfection will serve to clear this points.

7. Conclusions

The preliminary results reported here show two of the key issues for development of future regional Southeast European Electricity Market. The first one is the importance of the improvement of the market structures within each country. The second one corresponds to the importance of the use of more efficient methods to deal with transmission constraints. Both factors are extremely important in Europe. A better use of transmission infrastructure improves both competition between "national champions" and market efficiency. But also other measures (market power mitigation) would be taken to improve market structure within countries and to achieve a maximal efficiency.

It can be see that in the case when the transmission infrastructure is not used optimally, either limited in an "artificial" way by inefficient allocation methods or by real congestion, the electricity prices are higher and the welfare decrease. The first important conclusion is that the welfare losses are bigger for the strategic than for the competitive case. This shed in light the double function of transmission infrastructure in electricity markets - to equalize prices and to improve competition. The optimal use of transmission infrastructure plays an important role in the development of the regional SEE electricity market. Only such regional market can be fully competitive delivering a bigger welfare and giving opportunity to all players for big profit with reasonable risk.

The simulation generate very useful scenarios for benchmarking and could be applicable for *"what happen if?*" studies of future regional SEE market and price developments giving very useful hints for producers, transmission operators, investors and regulators. In addition, there has been hardly any research in the field of transmission infrastructure usage and dynamic strategic behaviour on the market price and efficiency in Southeast European electricity markets.

Although the algorithm used in these models seems to be sensitive to the tuning of some weights or parameters, a lot of research is still needed to prove the potentials of this new method in solving complex power system problems. The paper represents just the first step in the model development. However, the future research will include a more complete market illustration with more trustworthy transmission grid and production costs data.

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