Observing player behavior in an electricity market game

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Abstract. In this paper we investigate the cooperative behaviour in a serious game. We build on an existing energy market game and use repetitive questionnaires to understand player behaviour.

Key words: Participatory simulation, serious gaming, electricity market, cooperation.

1 Introduction

Computer simulations, formal game-theory models, and other formal structures, many of which can be computer programmed or mathematically studied, depend primarily on numerical data and the logic of mathematics and statistics (Brewer, 1978). However, in many relevant policy issues there is often a lack of data, disagreement on the cause and effect relationships, and complex system behaviour that makes a straightforward appraisal of the situation difficult. Especially when (inter-)human behaviour is an uncertain factor, serious games may help clarify system response to different strategies.

We used questionnaires to capture players’ response to and cooperative behaviour in an existing game that was developed for teaching students about electricity markets. Before describing the use of gaming as a tool for investigating cooperation (section 6), we first describe the history and applications of serious games (section 2), the used Electricity Market Game (section 3), the players and how we gauged their response (section 4), and the outcomes of the questionnaire (section 5).

2 Serious gaming

Stemming from applied mathematics, operations research and systems analysis, the field of (serious) gaming aims to understand the counter-intuitive behaviour of social systems (Forrester, 1971). Whereas increased computing power has enabled ever more complicated representations of reality, studies in policy sciences showed that decision-making was far from rational and comprehensive,

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but rather political and incremental, and even highly erratic and volatile (Mayer, 2009). The toolbox used by system and policy analysts needed to become more human-centred and responsive to socio-political complexity. By allowing for more freedom to the human players, games lend themselves particularly to transmitting the character of complex, confusing reality (Duke, 1980).

Far more than analytical understanding, gaming allows for acquiring social or teamwork skills, gaining strategic and decision-making experience, training in and learning from stressful situations. As an educational tool, business simulation games have grown considerably in use during the past 40 years and have moved from being a supplemental exercise in business courses to a central mode of business instruction (Faria et al., 2009). In broad lines, Stahl (1988) mentions five purposes of games:

1. **Entertainment games** have the purpose suggested by their name; all the positive results of the games are obtained during its play.

2. **Educational games** have teaching, learning and attitude-changing goals; all direct benefits of the game are obtained by the players, but these benefits are usually fairly general and intended to endure over some period of time.

3. **Experimental games** are aimed at investigating hypotheses or theories; they are without specific situational content or context and without any direct intent to apply the results to a practical situation. The main planned benefit of the game lies in reporting its findings to an outside audience of persons interested in the hypotheses or theories examined by the game. Often, these are contrary to what game theory predicts (see e.g. Janssen et al., 2010).

4. **Research games** are played to obtain empirical findings concerning fairly broad areas; the practical application of these results to immediate decision and policy problems is not always apparent. For example, games are played for finding parameters to add to models (Dubois et al., 2010).

5. **Operational games** are played to aid decision-making, planning, and implementation in specific and fairly immediate situations (e.g. by demonstrating principles; generating ideas; changing attitudes (for example, by motivating people); testing models; forecasting; answering ‘what if?’ questions; providing dress rehearsals for future new operations and policies; establishing communication; testing personnel during recruitment.). The findings are reported to the decision-makers concerned, and the main benefits accrue shortly after the play of the game is over.

In general, games can be defined as experience-focused, experimental, rule-based, interactive environments, where players learn by taking actions and by experiencing their effects through feed-back mechanisms that are deliberately built into and around the game (Mayer, 2009). Gaming is based on the assumption that the individual and social learning that emerges in the game can be transferred to the world outside the game. Games can take many different forms, from fully oral, including role-playing, to dice-, card- and board-based, to computer supported (Duke, 1974). They can be designed to play with strict adherence to rules or allowing for more freedom of action. In terms of usability for complex policy making, variants such as free-form gaming seem to
perform much better, especially in terms of usability, client satisfaction, communication and learning and, not unimportantly, cost effectiveness. On one hand there is a need to keep games simple and playable (Meadows, 1999), on the other hand there is a positive relationship between realism and the degree of learning from the simulation.

With the advent of more powerful computers, with high graphic capabilities and network connectivity, the transition to computer supported games allowed for the development of more complex games. The question, however, remains whether technological improvements resulted in games that are better teaching and learning tools. Critics state that gaming has progressed far more in a hardware technological sense than it has progressed either as a teaching method or as a field of research (Faria et al., 2009). Furthermore, the distinction with games for amusement may become increasingly blurred by advances in computer modelling power. This permits the development of simulations and games that are ambiguous in both their degree of representational fidelity and their intent. Such simulations, particularly when widely distributed, are liable to charges of perpetrating misunderstanding, analogous to the excessive confidence with which formal models have long been changed in regular policy processes (Mayer, 2009).

3 Energy market game

The game we have chosen to investigate was developed at Delft University of Technology in the context of a course on energy market design (de Vries et al., 2009; de Vries and Chappin, 2010). Since the liberalisation of the European energy markets in the late 1990s, energy production and transmission were decentralised. This implied a whole new dynamic in the planning of energy generation: power generators would have to compete in a market. The mechanisms of this market are based on basic economic notions of marginal prices. Although this could be explained in a rather abstract and dry fashion, the instructors deemed it more insightful to let students play the role of electricity companies that have to compete on the electricity market. The game has been revised several times between 2008 and 2011 (e.g. including a CO₂ market) and has been played with students and energy company professionals.

3.1 Rules and game play

The players (usually forming a team of 2-3) represent the directors of five competing electricity companies that manage a portfolio of power plants and have to make electricity pricing and investment decisions. They face uncertainties such as future electricity demand, fuel prices, outages, and a possible CO₂ tax (that embodies the main characteristics of the European emissions trading scheme) (de Vries et al., 2009). Each round represents a year, and a period of approximately two decades is simulated in order to give the players insight in long-term consequences of their actions. The company with the highest bank balance at
the end of the game wins the game, because it achieved the highest return on investment.

The game is played and operated through the internet on a dedicated server\(^1\). Each company has its own website (a screenshot is shown in figure 1), part of which provides public information, such as news and market prices, and part of which contains private information, such as the company’s assets and its bank account. Players do not have to be physically together to play the game. This has the advantage that only a limited amount of contact time needs to be spent on the introduction and the final evaluation of the game, and the length of game rounds can be chosen to fit the players’ schedule (de Vries and Chappin, 2010). As the game is played on a normal web browser interface, no special software or hardware (other than a computer with internet connection) is required. The interface is set up in such a way that bids (a list of price/power combinations) can be copy-pasted from spreadsheet software to facilitate calculations.

![Electricity Market Game](image)

**Fig. 1.** Snapshot of the Electricity Market Game: Player/team “Access” observes the power prices in round 8 (Chappin et al., 2010).

Each round, companies have to perform a set of tasks. First, they have to offer electricity to the power exchange. The essence of the offer is a list of power generated (in megawatts) and the price for which this power is offered. Theory stipulates that in a competitive market the price should be at or close to the marginal cost of a power plant (but players are free to set any price for any amount of power – if they can’t deliver they are forced to buy from their competitors to fulfill their offer). Second, the companies decide whether to build new power plants and/or to dismantle old ones. Third, after the CO\(_2\) market has been turned on (which is usually around round 7) they have to acquire a limited amount of CO\(_2\) credits. Without CO\(_2\) credits the companies amass CO\(_2\) ‘debt’ over which they have to pay a fine.

\(^1\) See [http://emg.tudelft.nl](http://emg.tudelft.nl).
To be able to perform these tasks, data and information are available through the web pages. The main information sources include a history of prices of fuels, CO\textsubscript{2} prices, and electricity prices. News items, written by the game operator, provide some degree of insight into future energy price developments and a partial analysis (based on public data available to all participants) of what is happening in the market. The news items (like news papers in real life) are generally only an indication of what might be going on and are therefore a source of uncertainty, although no deliberate false information is fed to the players (for example, the impending CO\textsubscript{2} market, or an increase in coal prices are announced). In addition, detailed characteristics are available on the power plants in their portfolio and the availability of new generators. All revenues and expenses of the companies appear in their bank account: revenues from selling electricity and the costs of each power plant, including fuel costs. The net values of the companies are plotted in the game’s news bulletin, so the players can see how well they are doing.

When the game operator starts a new round, the power market is cleared. The clearing procedure is modelled after European power exchanges: the price/power combinations from all bids are lined up and – starting from the lowest price – are accepted until the power needs are met. This is the so-called ‘bid ladder’ of which two examples can be seen in figure 1. The price from the last bid that gets accepted becomes the clearing price for all accepted bids. CO\textsubscript{2} credits are auctioned off in reverse order: the highest bids are accepted first until all credits are sold off. The clearing price for CO\textsubscript{2} credits is also the last bid that is accepted.

The power companies all start with a comparable set of generators, including coal, gas, wind, and nuclear stations, so that market shares are equal. However, power plants differ with respect to load cost, age, size, capacity, fuel efficiency, and reliability. Existing plants deteriorate with respect to reliability: the chance they fail during a particular round increases over time. New technologies become more fuel-efficient and cheaper over time according to a simple multiplication factor.

Although the power exchange is modelled after European power exchanges, there are two main differences with reality. First, there are no contracts outside the exchange, so the price on the market is uniform for all players. Second, within one round, representing one year, the market is split up in three segments, one containing 5000 hours with base demand, one containing 3600 hours with shoulder demand, and one containing 160 hours with peak demand. This means that there are three electricity prices each year: a base, a shoulder, and a peak price.

Power producers place bids for all their available power plants in each of the market segments. To calculate their bids, players use information on the cost structure of the power plants, the fuel prices, and the wind factor. Bids can be different in the three segments, so the players can try to manipulate the market. Sources for uncertainty are the availability of competitors’ generators and the exact levels of demand, while historical data and news given to the players provide only an indication.
As the simulation package performs all administrative tasks for the game operator (which plants were deployed and which ones remained idle, how much power was sold, and accounting all revenues and costs), he can concentrate on analysing the game while it is played, on coaching the participants, and on checking for any irregularities (such as collusion).

3.2 Premises of the game

Following Stahl’s list of purposes (section 2), the Electricity Market Game is mainly focused on teaching. According to the developers, playing the game will help participants in understanding: the effects of competition, investments in an uncertain environment, the need for policies and evaluating policy designs, the need for policies and evaluating policy designs, and learning to deal with conflicting assumptions (Chappin, 2011). We wanted to validate this assessment by questioning the students involved. Furthermore, this provided a context for investigating the cooperative activities of the players without which the purpose of the cooperation questions would have been too obvious to the participants.

4 Questioning the students

The students that were enquired about the Electricity Market Game were a class following the 2011 fall course Energy and gas market design and policy issues (SPM4520) at Delft University of Technology, consisting mainly of Masters’ students System Engineering, Policy Analysis and Management (SEPAM), other Masters’ programmes at Delft, and Ph.D. candidates from Delft and Eindhoven technical universities. In total 53 students participated in the course and game, of which 32 (60%) answered all the questionnaires during the game. Given the size of the group, there were three games played simultaneously (called the red, blue, and green game) that included the standard five teams with 3 or 4 players per team.

A set of 12 questions was asked at the beginning of the game (round 1), halfway through the game (round 7), and just before the end of the game (round 18). Partially, these questions were aimed at evaluating players’ response (this goal was communicated to the students), but they were also focused at the cooperative behaviour of the students (see appendix 6 for an overview of the questions). All students received a personalised email that linked to an online survey (using LimeSurvey software\(^2\)); this also allowed for sending reminders to students who did not respond promptly.

As collusion is not allowed in markets like the electricity market, and consequently also not allowed in the game, the questions about cooperation were nested in such a way that they only appeared after players admitted communicating with other teams. This way the questionnaire would not lead players towards the behaviour we intended to observe (and having played the game before, we did observe cooperation/collusion quite profusely in earlier instances).

The players were informed that because of the evaluative nature of the questionnaire, none of their answers would be shared with the course professors.

5 Outcomes and discussion

As indicated above, 32 students (60%) answered the questionnaires. Given the non-obligation to participate we can consider this a good response. We chose not to make answering obligatory (as a requirement for passing the course) as we wanted the students to not feel pressured into giving politically correct answers. Since the students made remarks about the high number of game rounds and the associated time pressure to bid, they may have chosen not to answer the questionnaire to save some time. Making the questionnaire obligatory would probably have boosted the response rate close to 100%, but might have invited some quick and easy responses.

First of all, we investigated the (self-reported) understanding of key concepts by the players. Figure 2 displays the answers that were given in the three rounds. We see that for all four topics (bidding procedure, market power, price determinants, and influence of policy) the understanding increased throughout the game, which is what we expect: playing the game actually teaches the concepts. After round 18, 84% of the students claimed to understand all topics reasonably well or fully; even 100% understood the bidding procedure.

The greater understanding also follows from the average time spent per round: while in the first round the students spent close to four hours preparing their bids, in round seven they went down to slightly more than two hours, and in round 18 less than an hour and a quarter. We have reasons to believe that these numbers are still overestimated, as a well-prepared spreadsheet could offer a quick calculation tool (as stated students in response to the question about tools and strategies used: “copy paste old bids”, “re-adjust Excel spreadsheet”).

What is interesting to see is that more students report understanding the relatively easy concept of the bidding procedure than they do with regard to the other topics. This can be explained by the fact that the mechanics of the game and bidding are explained in class, whereas market power and price determinants are more difficult concepts that are partially left to be experienced by the game play. Policy effects can be considered the most complex topic and therefore understanding lags behind the other learning effects.

When looking at the statements (figure 3), we see that the students find both the main parameters of the game and the concepts of the game increasingly clear as the game progresses. We will highlight some of the remarks below that could shed some light on the items that were less clear. From the game developers’ perspective it was good to see that 95% of the players agreed (somewhat) about the excitement of the game; some remarks were made about the repetitive character of the bidding after 18 rounds. It is also interesting to see that although a large portion of the students found little surprise to the game in the beginning (65% disagreed (somewhat)), the unanticipated events, the market response, and the influence of the CO₂ market did surprise the players further along the game.
Fig. 2. Reported understanding of a) bidding procedure, b) the concept of market power, c) price determinants, and d) policy effects in rounds 1, 7, and 18.

Fig. 3. Agreement with statements a) the main parameters in the game are clear, b) the outcome of (one of) the last rounds has surprised me, c) playing the game has led me to better understand the concepts, and d) the game is exciting, in rounds 1, 7, and 18.
Sifting through to comments and remarks, the picture that arose from the questions about understanding and statements is underlined. Whereas in the first rounds the comments about uncertainties are long and winding, in round 18 they become more precise. It is clear that some teams took a more reserved stance, observing market behaviour, while other teams immediately started off with choosing to be low-price, or low on carbon, or cheap base load providers.

"The game really gets interesting while the game is developing and gets more challenging, making you think on investment strategies that can make you win other teams or just to have a higher company values per round. At the same time, economic terms are easier to understand while playing and discussing them with your team mates." A number of players anticipated the arrival of the CO₂ market, while at least one team expected a Fukushima-like massive failure of nuclear installations (and subsequently did not invest in nuclear plants).

The general line of comments supported the notion of fun and excitement. There were some remarks about the game taking too long, the time pressure being too high, and the bidding procedure getting tedious, but in general we find that this part of the questionnaire supported the premises about the game that were suggested by the developers.

The second part of the questionnaire, pertaining to cooperative behaviour, was less successful than expected. Of the 32 students that answered all questionnaires, only one admitted communicating with other teams in the first round. Of the 48 questionnaires that were filled in the first round, only five ≈ 10% reported communication. In round seven for both sets the number was also approximately 10% (3/32 and 4/45), and in round 18, this number was even lower: 2/32 and 3/36.

The communications in the first round mainly took place with teams from the other gaming instances, to compare prices and tactics. In the seventh round the players admitted to talking to other teams in their own game, to see how they responded to the CO₂ market. One player admitted strategising how to work together for “ruining others”, but this didn’t work out because they were stuck in a Prisoner’s Dilemma (no further explanation offered, but we assume they meant that they couldn’t trust the other keeping their bargain). In round 18 other teams were contacted to discuss the uncertainties and the course of the game.

6 Gaming as a tool for investigating cooperation

The questionnaire in the energy market game supported the premises by the developers; the answers regarding the cooperation activities of the teams, however, were very few. We can think of a number of reasons for this limited response:

- Game play is strongly influenced by the rules of the game. Players are encouraged to remain within the bounds of what is allowed and do not step "out of the box".
- Each game is different, not only in terms of measured outcome but also in terms of approach of each team – the host of mentioned calculations and
important uncertainties in the first round suggests this, although later on we found the teams had “discovered” marginal costing. The earlier (unreported) instance of the game in which Delft staff members competed, had a totally different dynamic that may have resulted from a lack of teacher-student relationship and a whole host of additional life experiences that influence game play (as is suggested by Doerner (1980, 1990)).

– Individuals play a large role: aggressive or taunting behaviour may trigger a totally different outcome. We noticed some differences with regard to bidding strategy, but this could equally hold for dealing with the ‘competition’.

The limited outcomes of this experiment do not negate the use of serious games for testing behaviour under uncertain circumstances. It does, however, caution about the definitive conclusions that can be drawn from such experiments: either the cooperation is too strongly suggested by the game set-up and rules, or, as in this case, the options for cooperation are hidden and unclear to the players. Artefacts of the (rules of the) game do not necessarily reflect reality, even though there are ample conspicuous anchors that suggest a clear match.

Although serious games like this one are built using computer models and abstracted notions of market mechanisms, the behavioural part by the players/teams plays an important role. One could argue that the players are free to choose their moves within a framework of options. In this particular game, this framework is somewhat restricted and one could argue that an optimal solution can be played when factoring in a bandwidth for wind and fuel uncertainties (in fact the game operator has a console which shows what the optimal bid would be for each team). Thus, the game is somewhat prescriptive with regard to the winning strategy, which is to be expected of an educational game that aims to convey knowledge. However, humans are limited in their ability to calculate the optimal strategy and have a host of other non-rational (as in: the rationality of the game) reasons for making different choices (a player admitted talking “to teams other friends are in”).

Uncertainties in this game are of the predictable kind (with a probability distribution function); no nuclear meltdowns are planned, nor could they be handled in a meaningful way given the options the players have. The behaviour of the other players is somewhat more unpredictable, although the rules of the game do channel the range of options.

The ultimate question that remains is whether the game accurately captures the uncertainties and the decision space that is experienced in the “real situation” that is simulated. More than the proof of the pudding being in the eating, researchers should remain vigilant in asking the question whether the certainties and uncertainties in the model reflect reality, and to what extent the assumptions of the researchers are biasing the analysis or the behaviour of the players.

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Appendix: questionnaire

- How many hours did your team spend per round on discussing/preparing your investment strategy and bid? This is an estimate. Use the average over the last rounds. If the discussions were short, you may also use decimals (15 minutes = 0.25 hour).

- What did you do to prepare your bid? We are interested in the tools you used and the calculations you did. Describe them in short (1 line per tool or calculation).

- I fully understand the following concepts: a) bidding procedure b) market power c) price determinants d) influence of policy. Please note: this does not influence your mark for this course. We only want to measure whether the concepts are clear. (not at all, not very well, reasonably well, fully)

- Statement: the main parameters in the game are clear. Respond to the statement and add in the comment field what are the main parameters according to you. What is your response to this statement and what are the important parameters? (disagree totally, disagree somewhat, agree somewhat, agree totally)

- Statement: the outcome of (one of) the last rounds has surprised me. Respond to the statement and, if so, clarify what has surprised you. (disagree totally, disagree somewhat, agree somewhat, agree totally)

- Explain what investment strategy you have used in the last rounds (invest or not, choice of type of plant, etc.). Please describe with a few key words/terms.

- Did you read the news messages?
  - Nested Statement: the information in the news bulletins was useful for/influenced our choices. Respond to the statement and explain if necessary. (disagree totally, disagree somewhat, agree somewhat, agree totally)

- Did you communicate / cooperate with other players?
  - Nested What teams did you talk to? Was/is there a specific reason to cooperate with (members of) these teams? For example: you know them, they are the largest/smallest competitor, ... (Use the team letters A,B,C,D,E to refer to teams) (describe)
  - Nested What topics did you address in your communication with other teams? You may choose several options. (capacity, price, game play, investment decisions, bid strategy)
  - Nested Did you make any agreements? What were they? Were they effective? (describe)

- Statement: playing the game has led me to better understand the concepts. Provide your opinion and explain if necessary. (disagree totally, disagree somewhat, agree somewhat, agree totally)

- Statement: the game is exciting. Provide your opinion and explain if necessary (synonyms for exciting could also be: fun, enticing, enthralling, ...) (disagree totally, disagree somewhat, agree somewhat, agree totally)

- Do you have other remarks about the game, the survey, interesting conclusions or observations? (describe)
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