EXPERIMENTAL “BEAUTY CONTEST” GAME AND SIMULTANEOUS DECISION-MAKING WITHIN VARIOUS GROUPS

Alexander Rymanov

1Department of Corporate Governance and Finance, Novosibirsk State University of Economics and Management, Kamenskaya st., 52/1, 630099, Novosibirsk, Russia
E-mail: rymanov@yandex.ru

Abstract. The paper examines experimental guessing “p-beauty contest” game. The objective of the study is to conduct an experimental study of simultaneous decision-making by subjects within various groups in the “p-beauty contest” guessing game, and to estimate the influence of various factors. The interaction of factors was evaluated. The contribution to this study extends the analysis of simultaneous decision-making by individuals within various groups to the conditions of the “p-beauty contest” game. The subjects simultaneously took decisions, while being part of a group of three subjects, and as part of a group of six subjects. The results from the experiment showed that the subjects make more rational decisions, being in the larger group. The four-factor (a p-value, a group size, a period, and number of subjects) experimental design shows that the Factors “p-value” and “Number of subjects” main effects were significant. Further, the Factor “p-value” by Factor “Group size,” the Factor “Group size” by Factor “Period,” the Factor “Group size” by Factor “Number of subjects,” and the Factor “Period” by Factor “Number of subjects” interactions were also significant.

Keywords: behaviour, experiment, competition, guessing game, imperfect competition, simultaneous decision-making.

JEL Classification: C91, C72.

1. Introduction

Motivation. Many decisions in the economy are made by participants, formally, or conditionally entering into small groups. It can be competitive firms in the markets with a low level of competition in the industry, participants in competitive procedures (auctions, tenders, competitions) with a small number of participants, as well as employees of one organization.

The competitive character of such relations is correctly described by the model of the game for guessing the “p-beauty contest” guessing game. “P-beauty contest” game. The “p-beauty contest” game can be described as follows. In each period, the subjects in the game select numbers within the range from 0 to 100. Next, the average value is determined, which is multiplied by the coefficient – “p-value” (in this study, the two values are 0.67 and 0.8). The resulting number is a winning number. A subject whose number is closest to the winning number is the winner. Then the game repeats the required number of periods.

Background literature. The first study from the a game-theoretic model of the “p-beauty contest” game was considered by Moulin (1986).

The first report on a laboratory experiment based on this game was published by Nagel (1995).

A series of field experiments using the “p-beauty contest” game was conducted by A. Bosch-Domenech, R. Nagel, and R. Selten via the readership of the business newspapers Expansion, Financial Times, and the scientific journal Spektrum der Wissenschaft (Bosch-Domenech & Nagel, 1997a, 1997b; Bosch-Domenech, Garcia-Montalvo, Nagel, & Satorra, 2002; Selten & Nagel, 1998). Another field experiment to estimate box-office revenues for movies examined by Court et al. (2018).

Most of the experimental studies of the “Beauty contest game” are devoted to the analysis of the impact of various values of the game parameters: p-value (Nagel, 1995; Camerer, 2003; Ho, Camerer, & Weigelt, 1998), the number of subjects, use the other indicator (median, maximum, minimum) instead of the mean (Duffy & Nagel, 1997).

The problem of measuring steps of iterated reasoning is examined by Stahl and Wilson (1995), Nagel (1995), Stahl (1996, 1998), Camerer and Ho (1999), Gneezy (2005), Rubinstein (2007), Hafner-Burton, Hughes, and Victor
Groups of subjects and mixing of subjects in groups. The experiment involved two groups of three subjects, and one group of six subjects. Each period groups of three subjects were formed in random. In each period, the compositions of the two groups, consisting of three subjects, changed.

The experiment consisted of two sessions: with different values of the Factor A “p-value” (0.67 and 0.8).

Each session consisted of five periods. In each period, the subjects simultaneously took decisions on the choice of numbers, while being part of a group of three subjects, and as part of a group of six subjects. Economical paired design was used.

Factors. As a result, in the full factorial design, the following factors were used: the Factor A “p-value” (0.67 and 0.8), the Factor B “Group size” (3 and 6 subjects), the Factor C “Period” (1–5), the Factor D “Subjects” (1–6).

Disclosure of information on winning values to the subjects. After each period, the instructor in private informed the subjects of the winning numbers:

a) p-value × the average number for the two groups of the three subjects;

b) p-value × the average number for a group of six subjects.

Therefore, in each period, each subject received information about the winning numbers:

Therefore, in each period, each subject received information about the winning numbers: the winning number of a group of three subjects (which included the subject) and the winning number of a group of six subjects.

3. Results and discussion

3.1. Average numbers in sessions
Consider average figures selected by subjects (see Table 1).

Table 1. Average figures selected by subjects

| Number of subjects in the group | p-value |
|---------------------------------|--------|
| 3                               | 0.67   |
| 22                              | 0.8    |
| 41                              |        |
| 6                               | 25     |
| 34                              |        |

Consider the session of the experiment in which the value of the Factor A “p-value” is set to 0.67. Subjects selected different numbers from a group of three subjects, and in a group of six subjects. The average for the three-person group was 22. The average for the six-person group was 25. Thus, in groups of three subjects, participants on
average selected smaller numbers than in groups of six subjects.

Consider an experiment session in which a higher value for Factor A is set (“p-value” = 0.8). In this session, on the contrary, in groups of three subjects, participants on average selected higher numbers than in groups of six subjects: 41 and 34, respectively.

3.2. The significance of the main factors and the interaction of factors

The significance of the main factors. Consider the significance of the main factors. The Factor A “p-value” main effect, $F = 37.23, p < 0.0001$, was significant.

The Factor B “Group size” main effect, $F = 0.70, p = 0.4062$, was nonsignificant.

The Factor C “Period” main effect, $F = 0.30, p = 0.8785$, was nonsignificant.

The Factor D “Subjects” main effect, $F = 3.88, p = 0.0034$, was significant.

The significance of interaction of factors. Consider the significance of the interaction of factors.

The Factor A “p-value” by Factor B “Group size” interaction, $F = 4.07, p = 0.0471$, was significant.

The Factor B “Group size” by Factor C “Period” interaction, $F = 4.14, p = 0.0043$, was significant.

The Factor B “Group size” by Factor D “Subjects” interaction, $F = 2.44, p = 0.0416$, was significant.

The Factor C “Period” by Factor D “Subjects” interaction, $F = 2.05, p = 0.0135$, was significant.

3.3. The main factors

Consider the results of the experiment in more detail.

The Factor A “p-value” main effect. The value of p-value influenced the choice of numbers by the subjects. And in a session with a smaller value of p-value (0.67), subjects selected lower numbers. This was typical for groups of three subjects (see Figure 1), and for groups of six subjects (see Figure 2).

By the end to the game (5th period), there were significant differences in numbers. Namely, subjects chose lower numbers when they were in the group of six subjects (see Figure 4).
The Factor B “Group size” main effect. During each session of the experiment (from the first period to the fifth period), subjects selected higher numbers when they were in a group of three subjects (see Figure 5).

When the subjects were in a group of six subjects, they chose lower numbers from the period to the period (see Figure 6).

The Factor C “Period” main effect. During each session of the experiment (from the first period to the fifth period), subjects selected higher numbers when they were in a group of three subjects (see Figure 5).

When the subjects were in a group of six subjects, they chose lower numbers from the period to the period (see Figure 6).

The Factor D “Subjects” main effect. The 4th and 5th subjects chose lower numbers compared to other subjects (see Figure 7).

In addition, although at the beginning of the experiment sessions (the first periods), the selected numbers of subjects varied significantly (see Figure 8), then the selected number of subjects differed slightly by the last periods, and the convergence of the selected numbers of subjects was observed (see Figure 9).
3.4. Interaction of factors

The Factor A “p-value” by Factor B “Group size” interaction. In groups of three subjects and in groups of six subjects, the difference in the selected numbers for different values of Factor A (p-value – 0.67 and 0.8) is significant (see Figure 10).

A smaller value of p-value (Factor A) influenced the choice of smaller numbers by subjects.

The Factor B “Group size” by Factor C “Period” interaction. During each session of the experiment (from the first period to the fifth period), the results in the group of three subjects increased, for groups of six subjects, declined. For a session with a smaller p-value (0.67), the results were lower (see Figure 11) than for a session with a higher p-value (0.8) (see Figure 12).

Subjects in smaller groups (three subjects), acted less rationally in this case than when they were in larger groups (six subjects).

The Factor B “Group size” by Factor D “Subjects” interaction. Consider the choice of numbers of the subjects in different groups (a group of three subjects and a group of six subjects). In the last periods (4th and 5th periods) of the experiment with a higher value of the “p-value” Factor (0.8), subjects selected lower numbers, being in larger groups of subjects (a group of six subjects) (see Figures 13, 14).

Accordingly, while in a smaller group (groups of three subjects), the same subjects selected higher numbers. At a different value of the “p-value” Factor (0.67), no pattern was revealed.
Figure 11. The Factor B “Group size” by Factor C “Period” interaction (p-value = 0.67)

Figure 12. The Factor B “Group size” by Factor C “Period” interaction (p-value = 0.8)

Figure 13. The Factor B “Group size” by Factor D “Subjects” interaction (p-value = 0.8, the fourth period)

Figure 14. The Factor B “Group size” by Factor D “Subjects” interaction (p-value = 0.8, the fifth period)

Figure 15. The Factor C “Period” by Factor D “Subjects” interaction

The Factor C “Period” by Factor D “Subjects” interaction. At the end of each session (the 4th and 5th periods), the convergence of the numbers was observed (see Figure 15).

4. Conclusions

The experiment made it possible to assess the behavior of subjects in a difficult situation. This is due to the need for decision-making, being simultaneously in the large group and in the small group. In general, the results of the experiment showed that the subjects make more rational decisions, being in the larger group. The following results were obtained in more detail.

The study estimates various factors of the “p-beauty contest” game. The estimation of the
main effects of factors and the effects of interaction of factors made in the study made it possible to identify significant effects.

In a session with a higher Factor A (“p-value” = 0.8), subjects selected lower numbers when they were in a larger group (six subjects).

Larger groups (six subjects) quickly reached more rational solutions, in comparison with smaller groups (three subjects).

In lesser groups (three subjects) during the sessions (from period to period), irrational behavior of subjects was observed.

The 4th and 5th subjects chose numbers more rationally than other subjects.

The low value of Factor A (“p-value”) influenced the choice of subjects by smaller numbers. Subjects intuitively chose smaller values in a session with a lower Factor A value (0.67).

During the experiment, only one of all subjects, being in different groups (3 and six subjects), chose significantly different numbers.

For larger groups (six subjects) at the end of each session of the experiment, there was a descending convergence of the numbers chosen by the subjects. For smaller groups (three subjects), there was an ascending convergence of the chosen numbers.

An additional research may be aimed at studying the behavior of small groups with a different number of subjects.

Acknowledgements
I thank the members of the Organizing Committee, two anonymous referees for helpful comments.

Disclosure statement
I have no conflict of interest to declare.

References
Arruñada, B., Casari, M., & Pancotto, F. (2015). Pro-sociality and strategic reasoning in economic decisions. Frontiers in Behavioral Neuroscience, 9, 140. https://doi.org/10.3389/fnbh.2015.00140

Bosch-Domenech, A., Garcia-Montalvo, J., Nagel, R., & Satorra, A. (2002). One, two, three, infinity, … news.

Bosch-Domenech, A., & Nagel, R. (1997a). Como se le da la Bolsa. Expansion, June 4, 40.

Bosch-Domenech, A., & Nagel, R. (1997b). Guess the number: comparing the financial times and expansion’s results. Financial Times, section Mastering Finance 8, June 30, 14.

Camerer, C. F. (2003). Behavioral game theory: experiments in strategic interaction. Princeton: Princeton University Press. https://doi.org/10.1016/j.socec.2003.10.009

Camerer, C., & Ho, T. (1999). Experienced-weighted attraction learning in normal form games. Econometrica, 67, 827-874. https://doi.org/10.1111/1468-0262.00054

Camerer, C. F., Ho, T. H., & Chong, J. (2004). A cognitive hierarchy model of games. Quarterly Journal of Economics, 119(3), 861-898. https://doi.org/10.1111/0033553041502225

Camerer, C. F., Ho, T.-H., & Chong, J. K. (2015). A psychological approach to strategic thinking in games. Current Opinion in Behavioral Sciences, 3, 157-162. https://doi.org/10.1016/j.cobeha.2015.04.005

Cartwright, E. (2018). Behavioral economics. London: Routledge.
Gueth, W., Kocher, M., & Sutter, M. (2002). Experimental “beauty contests” with homogeneous and heterogeneous players and with interior and boundary equilibria. *Economics Letters*, 74, 219-228. https://doi.org/10.1016/S0165-1765(01)00544-4

Haftner-Burton, E. M., Hughes, D. A., & Victor, D. G. (2013). The cognitive revolution and the political psychology of elite decision making perspectives on politics. *Perspectives on Politics*, 11(2), 368-386. https://doi.org/10.1017/S1537592713001084

Haltiwanger, J., & Waldman, M. (1985). Rational expectations and the limits of rationality: an analysis of heterogeneity. *American Economic Review*, 75, 326-340.

Haltiwanger, J., & Waldman, M. (1989). Limited rationality and strategic complements: the implications for macroeconomics. *Quarterly Journal of Economics*, 104, 463-483. https://doi.org/10.2307/2937806

Hernán, R., & Kujal, P. (2015). Gender differences in cooperation and competition. In P. Branas-Garza & A. Cabrales (Eds.), *Experimental economics*. London: Palgrave Macmillan. https://doi.org/10.1057/9781137538192_10

Ho, T., Camerer, C., & Weigelt, K. (1998). Iterated dominance and iterated best-response in experimental “P-beauty-contests”. *American Economic Review*, 88(4), 947-969. Retrieved from http://www.jstor.org/stable/117013

Ho, T. H., Noah, L., & Camerer, C. F. (2006). Modeling the psychology of consumer and firm behavior with behavioral economics. *Journal of Marketing Research*, 43, 307-331. https://doi.org/10.1509/jmkr.43.3.307

Koch, C., & Penczynski, S. P. (2018). The winner’s curse: conditional reasoning and belief formation. *Journal of Economic Theory*, 174, 57-102. https://doi.org/10.1016/j.jet.2017.12.002

Kocher, M. G., & Sutter, M. (2005). The decision maker matters: individual versus group behaviour in experimental beauty-contest games. *The Economic Journal*, 115, 200-223. https://doi.org/10.1111/j.1468-0297.2004.00966.x

Kocher, M., Sutter, M., & Wakolbinger, F. (2014). Social learning in beauty-contest games. *Southern Economic Journal*, 80(3), 586-613. https://doi.org/10.24248/0038-4038-2010.150

Li, S. (2017). Obviously strategy-proof mechanisms. *American Economic Review*, 107(11), 3257-3287. https://doi.org/10.1257/aer.20160425

Moulin, H. (1986). Game theory for the social sciences. Series: studies in game theory and mathematical economics (2nd and revised Ed.). New York, NY: New York University Press.

Nagel, R. (1995). Unraveling in guessing games: an experimental study. *American Economic Review*, 85(5), 1313-1326.

Prelec, D. (2006). Rebuilding the boat while staying afloat: the modeling challenge for behavioral economics. *Journal of Marketing Research*, 43, 332-336. https://doi.org/10.1509/jmkr.43.3.332

Rubinstein, A. (2007). Instinctive and cognitive reasoning: a study of response times. *Economic Journal*, 117(523), 1243-1259. https://doi.org/10.1111/j.1468-0297.2007.02081.x

Russell, T., & Thaler, R. (1985). The relevance of quasi rationality in competitive markets. *American Economic Review*, 75, 1071-1082.

Selten, R., & Nagel, R. (1998). Das Zahlenwahlspiel-Hintergrunde und Ergebnisse. *Spektrum der Wissenschaft*, 2, 16-21.

Sheremeta, R. M., & Zhang, J. (2010). Can groups solve the problem of over-bidding in contests?. *Social Choice and Welfare*, 35(2), 175-197. https://doi.org/10.1007/s00355-009-0434-0

Stahl, D. O. (1996). Rule learning in a guessing game. *Games and Economic Behavior*, 16(2), 303-330. https://doi.org/10.1006/game.1996.0088

Stahl, D. O. (1998). Is step-j thinking an arbitrary modelling restriction or a fact of human nature?. *Journal of Economic Behavior and Organization*, 37(1), 33-51. https://doi.org/10.1016/S0167-2681(98)00074-5

Stahl, D., & Wilson, P. (1995). On players models of other players: theory and experimental evidence. *Games and Economic Behavior*, 10(1), 218-254. https://doi.org/10.1006/game.1995.1031

Volker, B., Kübler, D., & Normann, H.-T. (2017). Depth of reasoning and information revelation: an experiment on the distribution of k-Levels. *International Game Theory Review*, 19, 1750021-1–1750021-18. https://doi.org/10.1142/S0219198917500219