Volume 29 Issue 7/2008
ISSN 0144–3054

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European Competition Law Review

Articles

Experimental Economics and Competition Policy: Unilateral and Co-ordinated Effects in Competition Games

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LT Competition law; Economics; Legal education; Teaching methods

1. Introduction

Economics is a complex discipline not easily understood by those who have not invested considerable time in studying it. Given the role of economics in competition law, a basic understanding of fundamental competition concepts is beneficial even for those who are not dealing with the more advanced economic aspects of competition cases or policy. One approach to conveying a basic understanding of essential concepts such as, for instance, the notion of equilibrium (important in the distinction between and analysis of co-ordinated and unilateral effects) can be found in the experimental branch of economics.[1] In this article, experimental economics, or more specifically, an experimental training method for competition practitioners based on experimental tools, is described.[2]

Experimental training is a useful tool allowing economists and non-economists alike to gain an intuitive but thorough understanding of some of the basic models of industrial organisation of relevance in a competition law context. Instead of studying theoretical models, deriving equilibrium and collusive outcomes with formal mathematical tools, the experimental training described here aims to increase the understanding and the intuition of participants in a more accessible and non-mathematical way. The approach allows participants to gain insights into some of the most fundamental economic concepts of competition law: the distinction between price and quantity competition, the impact of different market environments and the number of firms on market outcomes, competitiveness and consumer surplus. This is achieved by putting the participants directly into the role of a manager. They are forced to think through alternative courses of action and their consequences, taking into account the incentives inherent in the structure of the market and the (anticipated strategic) behaviour of competing firms, i.e. the other participants.

In addition to avoiding more or less complex (and possibly dry) mathematics, the experimental approach has the advantage of providing first-hand experience and understanding, not only of the theoretical predictions that are discussed after the sessions, but also of co-ordinated behaviour and more or less overt collusion. The simple models underlying the experimental games allow a discussion of a host of other aspects, such as capacity restrictions, asymmetries in cost, uncertain

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1 For an application of the experimental methods to competition see for instance J. Apesteguia, M. Dufwenberg and R. Selten, "Blowing the whistle" (2007) 31 *Economic Theory* 143 for an application of experimental methods to cartels; D.M. Grether and C.R. Plott, "The Effects of Market Practices in Oligopolistic Markets: An Experimental Examination of the Ethyl case" (1986) 24 *Economic Inquiry* 479 for an ex post analysis of industry practices in a US competition case; and M. Beckenkamp and F.P. Maier-Rigaud, "An Experimental Investigation of Article 82 Rebate Schemes" (2006) 2(2) *Competition Law Review* 1, for an analysis in the context of abuse of dominance. See also the general overview given by C. Engel, "Wettbewerb als sozial erwünschtes Dilemma" in C. Engel and W. Möschel (eds), *Recht und spontane Ordnung. Festschrift für Ernst-Joachim Mestmäcker zum 80. Geburtstag* (Baden-Baden: Nomos-Verlag, 2006), pp.155–198.

2 The description and in particular the data presented here draw on an experimental training session conducted in DG Competition in December 2007 and, to a lesser extent, an experimental training session held at the Slovak competition authority in Bratislava in November 2007.

or fluctuating demand, entry and exit, fixed cost and other important factors for assessing competition cases. It is therefore possible to expand the understanding of participants well beyond the domain of the limited and simplistic theoretical models underpinning the experimental games.

An obvious practical application of experimental training is in merger analysis. The Commission's merger control policy is based on the significant impediment to effective competition (SIEC) test set out in Regulation 139/2004 (the EC Merger Regulation).[3] The horizontal[4] and non-horizontal[5] merger guidelines provide guidance on how the Commission will apply the SIEC test. Among other aspects, they include concentration thresholds formulated in terms of market shares and Herfindahl-Hirschman Index (HHI) levels to provide market participants with guidance about the intervention thresholds the Commission will apply in its merger assessment. The SIEC test and the merger guidelines are motivated by the same basic economic models underlying the experimental training. The HHI thresholds in the Commission's guidelines are set at similar levels to the guidance provided by many other competition authorities around the world. This reflects the fact that many of the common theories of competitive interaction predict that market power is correlated with concentration levels. However, establishing the optimal intervention threshold in merger policy—where consumer harm is prevented without "chilling" the potential benefits, in terms of efficiencies, that mergers can bring about—is a difficult task. This is why concentration thresholds can provide no more than an initial screen for a detailed case-specific competitive assessment.

One way to assess whether the right enforcement level has been applied is to look at how markets have evolved following an intervention or non-intervention decision by the authority. To this end, the Commission has recently begun to assess, on a more systematic basis, the impact that its merger enforcement has had in the market ex post. It also published an ex post review of its remedies policy in 2005.[6]

3 Regulation 139/2004 on the control of concentrations between undertakings (the EC Merger Regulation) [2004] OJ L24/22.
4 See Guidelines on the assessment of horizontal mergers under the Council Regulation on the control of concentrations between undertakings [2004] OJ C31/18, available at *http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:C:2004:031:0005:0018:EN:PDF* [Accessed April 23, 2008].
5 See *http://ec.europa.eu/comm/competition/mergers/legislation/nonhorizontalguidelines.pdf* [Accessed April 23, 2008].
6 See *http://ec.europa.eu/comm/competition/mergers/studies_reports/remedies_study.pdf* [Accessed April 23, 2008].

Table 1: Experimental markets

Experiment	Market setting	Number of firms
M1	Monopoly	1
C2	Cournot	2
C4	Cournot	4
B2	Bertrand	2
B4	Bertrand	4

Experimental economics provides another intuitive method for gaining insights into how markets perform under different competitive conditions, such as the number of competitors in the market and the ways in which they compete. The approach represents an innovative analytical tool mid-way between purely theoretical models and a full ex post assessment of real-world markets.

The following experiments represent an attempt to utilise experimental techniques to familiarise competition practitioners with a legal background with the most common oligopoly models (Bertrand and Cournot games with varying numbers of competitors).

While the experimental set-up used in the training sessions is far too basic to draw direct policy conclusions, the following sections will nevertheless relate the results to elements of the Directorate General for Competition's (DG Competition) merger enforcement policy, highlighting the role that experimental economics could play in this field.

The article is organised as follows: In Section 2, the experimental setup and underlying parameters are described and some insights from a theoretical perspective are provided. Section 3 discusses the results in general and applies them to real-world merger cases. Some concluding remarks can be found in Section 4.

2. Experimental set-up

The experimental training session discussed here consists of five different experiments. In each experiment, participants represent a firm deciding repeatedly over several periods either on the quantity of a homogenous good to be supplied on a market (Experiments M1, C2 and C4) or on the price to be charged for that product (Experiments B2 and B4). Table 1 provides an overview of the different experiments.

Each participant anonymously makes 20 decisions per experiment and 100 decisions overall during the course of the experimental session.

Common to all experimental markets is the underlying cost and demand function. The cost function is linear and increasing in quantity:

$$c(q) = q, \quad 1$$

with marginal cost $c'(q) = 1$. Firm i's profit is given by $\pi_i = pq - c(q)$.

Further, in all settings, the decision variable is constrained between 0 and 100 with 0.01 as the smallest step size. The symmetry of the experiments with respect to the demand function, allowing a direct comparison of quantity and price choices across all experiments, is deliberate as it allows for a comparison of results in terms of market competitiveness (see Section 3). All the games and also the decision experiment (Monopoly experiment) are finite; that is, the number of periods is fixed and known in advance. Besides practical considerations in running the experiments, this guarantees a unique subgame perfect equilibrium in every game.[7]

Monopoly experiment (M1)

In Experiment M1, participants are put into the position of a monopolist. They choose the quantity they want to supply on the market. The demand function is unknown and the only information available to participants concerns the general effect of quantity on price, i.e. the higher the quantity chosen, the lower the price. After each decision, information on price and profit is revealed. In addition, information on the chosen quantity and on total cost is given. This particular information structure is chosen in order to familiarise participants with the idea of supply and (inverse) demand in a monopolistic market. Participants get an idea of the market context, and in particular, the demand function, in a context where strategic interaction with other firms is absent. In addition, the monopoly case also provides the theoretical benchmark for collusion in all other experimental markets. The linear inverse demand function underlying the experimental game is given by:

$$p = D(q) = 100 - q. \quad 2$$

Given the experimental parameters, the profit maximising solution to the monopolist's problem is given by the quantity $q^M = 49.50$.[8]

Cournot experiments (C2 and C4)

A Cournot oligopoly market setting is introduced in Experiments C2 (duopoly) and C4 (quadropoly).[9] Analogously to the monopoly experiment, participants decide on the quantity they want to supply on the market. Further, information about the underlying demand function is revealed to participants beforehand. The introduction of a second (third and fourth) firm(s) adds competition to the monopolistic market in Experiment C2 (C4). The matching of the simultaneously interacting firms—either two in C2 or four in C4—is done randomly, is unknown to participants and remains the same throughout the whole experiment. In a Cournot setting, the market price depends on the overall quantity supplied on the market. The inverse demand function determining the price based on the aggregate quantity supplied in the market is given by:

$$p = D(q) = \max\{100 - Q, 0\}. \quad 3$$

The price on the market is 100 less the total quantity Q supplied on the market by all firms, if total quantity does not exceed 100. Otherwise, the price drops to 0 and firms suffer a loss identical to the production cost. After each decision, participants are informed about the market price, the costs and their profit depending on the quantity chosen.

The individual Nash equilibrium quantity is 33 in Experiment C2 and 19.8 in Experiment C4, resulting

7 A multitude of equilibria is typically encountered in infinitely repeated games or games that end in finite but stochastic time; i.e. have a probabilistic ending. In the games introduced here, there is a unique subgame perfect Nash-equilibrium outcome. Subgame perfection is a Nash equilibrium refinement introduced by Nobel laureate Reinhard Selten. The games introduced here are subgame perfect because the Nash equilibrium of the overall game is repeated in every period, i.e. in every subgame.

8 A profit maximising firm faces the following problem:

$$\max_q\{(100 - q)q - c(q)\}$$

To find the profit maximising quantity (denoted by q^M), the first derivative with respect to the firm's quantity has to be taken and set equal to zero. $\frac{\partial(\bullet)}{\partial q} = 0 \Leftrightarrow 100 - 2q - 1 = 0 \Leftrightarrow q^M = 49.50$. As the demand function is linear, the optimum will be unique because with a linear demand the second order condition is bound to be fulfilled, i.e. $\frac{\partial''(\bullet)}{\partial q} \leqslant 0$.

9 The experimental design is similar to the one introduced by S. Huck, H.T. Norman and J. Oechssler, "Two are few and four are many" (2004) 53 *Journal of Economic Behavior & Organization* 435.

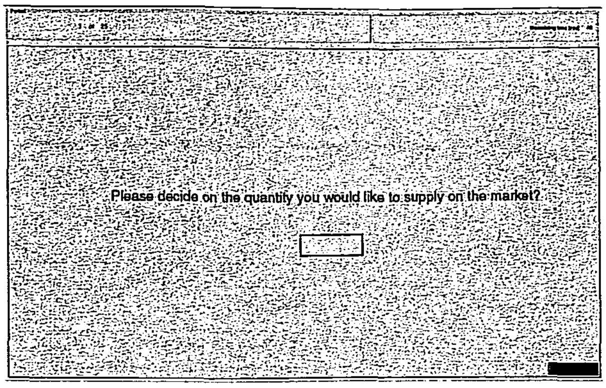

Figure 1: Example of a decision screen

in an aggregate quantity of 66 and 79.20 respectively.[10] The collusive quantity is simply the monopoly quantity q^M split by the number of firms on the market, i.e. $q^{Coll} = 24.75$ in C2 and $q^{Coll} = 12.38$ in C4.

Bertrand experiments (B2 and B4)

In a Bertrand oligopoly setting, participants decide simultaneously on the price they want to charge for their product. Here, only the firm charging the lowest price attracts the entire demand on the market. If firms charge the same price the market demand is split equally among the tied firm(s). In particular, demand (i.e. the quantity sold) on the market for firm i is given by:

$$D_i(p_i, p_j) = \begin{cases} 100 - p_i & if \quad p_i < p_j \\ \frac{1}{m}(100 - p), & if \quad p_i = p_j, \\ 0, & if \quad p_i > p_j \end{cases} \qquad 4$$

where m is the number of firms charging the same price. A further common assumption for Bertrand games is that firms produce to order, incurring production costs $c(q)$ only for an output level equal to their actual sales on the market.

For a finite horizon (as in our experiments), theory would predict that the lowest possible price providing the firm with a positive profit is charged. Given the experimental parameters of the Bertrand markets, the Nash solution is to charge a price of 1.01 in both experiments: B2 and B4.[11] Here, no firm can profitably deviate. If firms agree to collude, they set the price at $p^{Coll} = 50.50$.

Procedure

Our experimental training session was conducted twice. The first session took place at the Slovak competition authority in November 2007 and the second one at DG Competition in December 2007. In both sessions, 24 officials from these institutions (predominantly lawyers) participated.[12] The experiments were programmed using the software Z-tree.[13]

The procedure was as follows: After a short introduction, instructions describing the experimental features and participants' decision tasks were distributed for each experiment separately.[14] Afterwards experimenters answered participants' questions. Then the computerised experiment started and participants decided at their decision screens (see Figure 1 for an example of such a screen).

After each decision, participants were informed on another screen about the demand on the market, their costs and their profit. In Experiments B2 and B4 information was provided about other participants' choices, quantity sold, costs and profits.

3. Results

This section presents results from the second experimental training session, compares them to the theoretical benchmarks outlined earlier, and discusses the link to

10 In contrast to the monopoly situation, a profit maximizing firm i has to take into account the other firm's (j) behaviour. The maximisation problem of firm i, is as follows: $\max\{(100 - Q)q_i - q_i\}$, with $Q = q_i + q_j$. Taking the first derivative gives: $\frac{\partial \pi_i}{\partial q_i} = 0 \Leftrightarrow 100 - 2q_i - q_j - 1 = 0$. Using symmetry ($q_i = q_j$) and solving for q_i yields $q_i^N = \frac{99}{3} = 33$. The generalised n firm Nash equilibrium is given by $q_i^N = \frac{99}{n+1}$. As a result, the Nash equilibrium quantity in the Quadropoly game is given by $q_i^N = 19.8$.

11 This strategic game can be analysed by using backwards induction. If we assume that subjects collude in the periods before the final one, it is rational to undercut the other subject's price in the final period. If firm i believes that firm j will try to undercut i's price in the final period, it is rational for i to set a price which cannot be undercut (but still giving a positive payoff, $p^N = 1.01$). Anticipating this behaviour, firms choose this price in the second to last period and so forth. Collusion unravels from the end.

12 As there were only 12 work stations available in both training sessions, subjects decided in teams of two at their computer screens.

13 See U. Fischbacher, "Z-tree: Zürich toolbox for readymade economic experiments—experimenter's manual" (2007) 10 *Experimental Economics* 171.

14 Instructions are available from the authors upon request.

Table 2: Aggregate market quantities

Exp.	Mean	Median	SD
M	49.37	49.52	2.67
C2	62.96	61.98	4.00
C4	73.56	72.83	6.64
B2	69.43	70.06	8.32
B4	96.27	98.75	4.94

merger policy. Although the data was not collected in a research context under laboratory conditions (for instance, no monetary rewards were given[15] and discussions between participants were tolerated as they were likely to aid the learning process), interesting behavioural patterns, most of them in line with other experimental research, were found.

General

Some basic descriptive statistics are given in Table 2. Comparing the averages across experiments gives a first idea of the degree of competitiveness in different market settings.

It comes as no surprise that the average quantity supplied is smallest in the monopoly setting (M). Almost perfect competition, as indicated by a mean of 96.27 units, can be found in the Bertrand setting with four firms (B4). Further ranking of means shows that more quantity is supplied in the Cournot setting with four firms (C4) compared to C2 and B2. Somewhat surprisingly, however, average aggregated quantity in C4 is larger than the quantity sold in B2, a result that is not in line with the experimental literature[16] and can probably be traced to the loose enforcement of the experimental setting.

In the following, a closer look at firms' behaviour in the different market settings is taken. In the monopoly market participants learn relatively quickly about the underlying demand function. Figure 2 shows participants' quantity decision for each period. After eight periods almost all participants chose the profit maximising quantity ($q^M = 49.5$).

15 Note, however, that the participants with the highest profits throughout received a bottle of wine.

16 See for example the recent review by S. Suetens and J. Potters, "Bertrand colludes more than Cournot" (2007) 10 *Experimental Economics* 71.

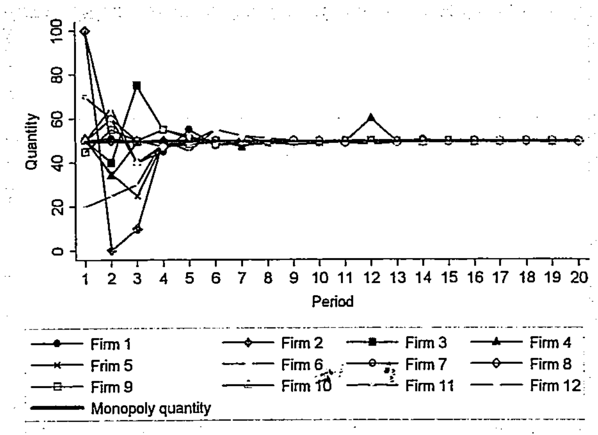

Figure 2: Aggregate quantity on the monopoly markets

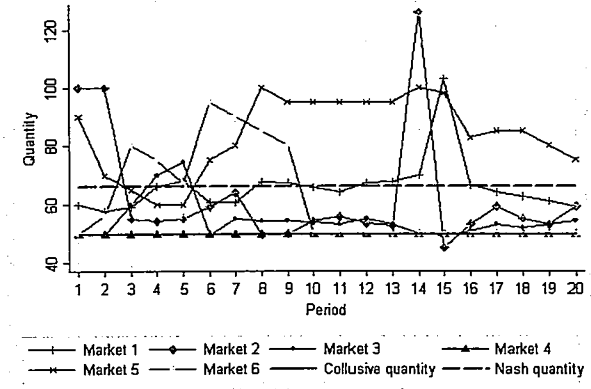

Figure 3: Aggregate quantities supplied on the Cournot duopoly markets

As we want to know if firms' behaviour differs from the theoretical prediction, we apply a two-sided Fisher-Pitman permutation test for paired samples. The null hypothesis that the quantity supplied per period does not differ from the monopoly quantity cannot be rejected for all firms (all p-values < 0.14864).

In contrast to the monopoly experiment, which as a decision experiment does not contain any strategic interaction, the Cournot duopoly game setting allows for strategic interaction between two firms. This results in more diverse patterns of behaviour. Figure 3 shows the aggregated quantities supplied on the six Cournot duopoly markets.

Here, consistent behavioural patterns are difficult to detect. Merely collusive behaviour, meaning that both firms choose $q_i^{Coll.} = 24.75$ in order to split the monopoly profit, can be observed in Market 4. Beside the firms in Market 4, only two firms—one from Market

1 and the other from Market 2—tried to collude without experiencing collusive behaviour from the firm they interacted with. Behaviour in Market 3 is somewhat close to collusion. The firms' quantity choices in Markets 1 and 5 are close to the (aggregated) Nash quantity ($q^{agg.N} = 66$) or even above.

To evaluate the exact scope of firms' collusive behaviour the following measure for each market k and period t is calculated:

$$\rho_{tk} = \frac{p_{tk} - p^{Nash}}{p^{Coll} - p^{Nash}}$$

where p_{tk} is the actual price on the market.

In order to make measures from a Cournot comparable to a Bertrand setting, we transform the quantities chosen in both markets, C2 and C4, into prices. Four cases indicating the degree of collusion can be distinguished:

- if $\rho_{tk} = 0$, firms on market k behave according to the Nash prediction;
- if $0 < \rho_{tk} < 1$, firms' behaviour is partially collusive;
- if $\rho_{tk} = 1$, firms behave entirely collusively; and
- if $\rho_{tk} < 0$, firms act more competitively than in the Nash equilibrium.

Table A1 in the Appendix shows degrees of collusion on the six markets in C2 per period. Behaviour is, as mentioned before, entirely collusive in Market 4, whereas collusion is entirely absent on Markets 1 and 5, with market outcomes tending towards the Nash prediction. On Market 1, firms behave almost according to the Nash prediction and firms are even more competitive on Market 5. Behaviour on Markets 2, 3 and 6 is partially collusive.

Taking a closer look at the aggregated quantities supplied per period in C4, collusive behaviour seems to be more absent than in C2. Likewise, aggregated quantities on Market 3 are even above the aggregate Nash quantity for 13 out of 20 periods.

As shown in fig.4, collusive behaviour only occurred in Period 18. According to the classification for the degree of collusion introduced above, behaviour on Market 3 is more competitive than the Nash equilibrium prediction ($\overline{\rho}_{t3}^{C4} = -0.15$). For Markets 1 and 2 there is a tendency towards the Nash equilibrium as $\overline{\rho}_{t1}^{C4} = 0.42$ and $\overline{\rho}_{t2}^{C4} = 0.33$.

In a Bertrand setting, only the firm with the lowest price on a market is able to sell its product. The prices at which firms sell their products in the experimental

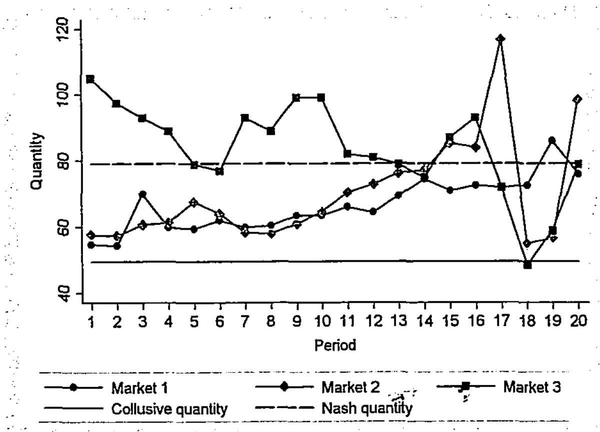

Figure 4: Aggregate quantities supplied on the Cournot quadropoly markets

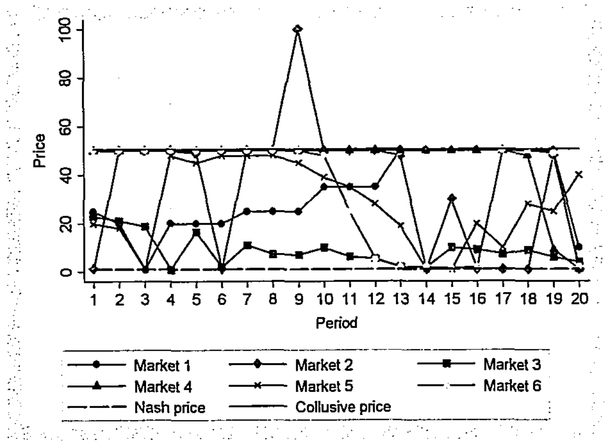

Figure 5: Prices on the Bertrand duopoly markets

Bertrand duopolies (B2) are shown in fig.5. Except for the price on Market 3 being close to the Nash equilibrium prediction, the other market prices tend more towards the collusive price. For most of the markets observed, collusion is, however, far from stable as firms succumb to the incentive of undercutting a competitor's price. This behavioural pattern can be observed on Markets 2, 5 and 6. On Market 4 we observe stable collusion until the second-to-last period where collusion breaks down. Such end-game effects are also often observed in repeated experimental games under laboratory conditions and are likely to occur whenever the number of periods is known to participants in advance.

The extremely collusive behaviour of firms in Market 4 is further indicated by $\overline{\rho}_{t4}^{B2} = 0.99$. For Markets 1, 2, 5 and 6, the average degree of collusion is larger than

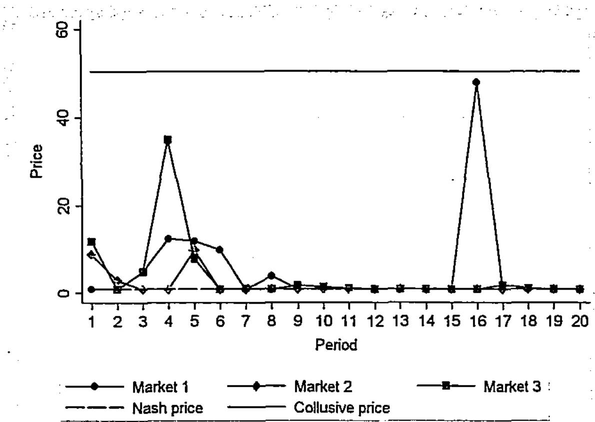

Figure 6: Prices on Bertrand quadropoly markets

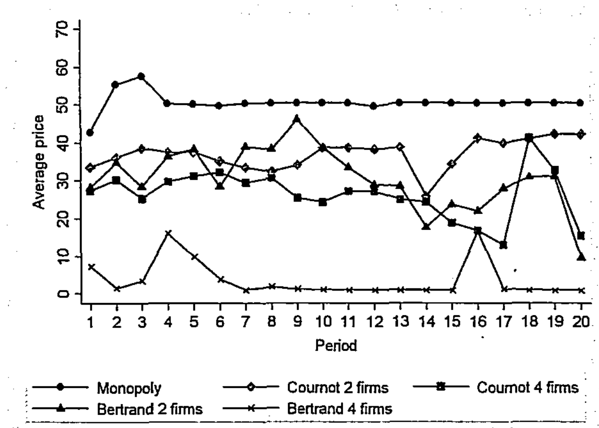

Figure 7: Comparison of prices

0.55, pointing to a (strong) tendency to collude. Market 3 is more competitive, close to the Nash equilibrium prediction ($\overline{\rho}^{B2}_{t3} = 0.16$).

In contrast to the predominant collusive behaviour in B2, more competitive behaviour can be observed when the number of firms is increased to four in a Bertrand setting. Figure 6 shows that almost only for periods one to eight prices are above the Nash equilibrium prediction.

From Period 8 onwards, all chosen prices are in line with the Nash equilibrium prediction. One exception can be observed in Period 16, where "illegal" communication between actors on Market 1 occurred. Values of $\overline{\rho}^{B4}_{tk} < 0.09\ \forall\ k$ confirm that markets are almost entirely competitive.

A comparison of average prices per period on different experimental markets is graphically depicted in fig.7. It comes as no surprise that the highest average prices are observed in the monopoly market (M1) and not in the other market settings. The lowest average price, not larger than 17, can be observed in setting B4. Comparing average prices between C2, C4 and B2 is rather difficult, as they fluctuate within an interval between 10 and 45. Although average prices of C2, C4 and B2 seem to be very similar, the difference between them is significant.[17]

Results highlighted from a merger perspective

Despite the very basic set-up, the experiments highlight some of the competitive effects generated by the models of competitive interaction underlying the Commission's Horizontal Merger Guidelines. The highly competitive outcomes generated by the four-firm Bertrand market with homogenous products are a case in point. Because of these outcomes, such market characteristics are rarely observed in practice as firms will either differentiate their products or exit. Where real-world markets do approximate these highly competitive characteristics, the Commission has, however, sometimes authorised mergers with only three firms remaining post-transaction.[18]

In the two-firm Bertrand setting, it can be observed that the very small number of firms combined with the dramatic profit improvement from a collusive strategy relative to the Nash equilibrium, seems to enable collusion in a majority of cases. In other words, with only two firms competing, most participants managed to improve their profits dramatically over the highly competitive non-collusive Nash outcome. This sheds doubts on claims sometimes put forward by merging parties that "two is enough" in markets where most suppliers offer comparable product characteristics and are not capacity constrained. Conversely, moving from two to four firms makes collusion substantially harder to sustain under both Bertrand and Cournot competition. This outcome is in line with the fact that the Commission has never opposed a merger on the grounds of co-ordinated effects where four competitors remained in the market

17 Test statistics of a two-sided Wilcoxon signed-rank test for paired samples show that the null hypothesis, that averages do not differ can be rejected for all pairwise comparisons at a 5% significance level; i.e. all p-values < 0.0333.

18 For example, the Decision of 15 September 2004 declaring a concentration to be compatible with the common market according to Regulation 139/2004 (COMP/M.3512-*VNU/WPP/JV*), and Decision 2004/322 declaring a concentration to be compatible with the common market and the functioning of the EEA Agreement (COMP/M.3083-*GE/Instrumentarium*) [2004] OJ L109/1. In addition to the three principal competitors there were, however, a number of fringe firms active in these cases.

Table 3: Comparison of profits and consumer surplus

		Firm i's profit		Consumer
		Nash	sym. collusion	Surplus
Market	M	2450.25	2450.25	1225.13
	C2	1089.00	1225.13	2178.00
	C4	392.04	612.56	3136.32
	B2	0.49	1225.13	4899.51
	B4	0.25	612.56	4899.51

after a transaction. At the same time, markets with four or more competitors are almost always characterised by some degree of product differentiation or capacity constraints, giving firms sufficient market power to earn economic returns, even in the absence of collusion.

The diverging outcomes between the Bertrand and Cournot games highlight the important role that the type of competitive interaction plays. Especially under Bertrand competition, the level of product differentiation and the positioning of individual competitors are crucial for competitive outcomes. While the game results are consistent with the hypothesis that consumer surplus falls as concentration levels increase, the magnitude of the fall (and, hence, the level of efficiencies required to prevent consumer harm) varies dramatically between the Cournot and the Bertrand games.

Table 3 compares firms' non-collusive equilibrium profits with the corresponding consumer surplus and the symmetric collusion profits. Consumer surplus is always equal to the monopoly case (1225.13) when firms collude, as perfect collusion only implies splitting the monopoly profits by the number of firms in the market. We observe, in particular, the extremely competitive outcomes of Bertrand competition relative to the Cournot outcome when products are homogenous and firms do not collude. Consumer surplus is significantly higher than under Cournot competition, whereas firms make almost zero profits. Conversely, the rewards of collusion are particularly high in the Bertrand setting. In our experiment, the vast majority of participants managed to sustain a collusive outcome in the two-firm Bertrand game, despite the fact that such behaviour cannot be easily rationalised by game theory—because participants knew the exact number of rounds to be played, each firm's optimal move was to price low in the last round when no more punishment was possible. Applying backwards induction, each firm's optimal move would have been to price low also in the first round, leading to a break-down of collusion right from the beginning. Hence, although in theory firms had no effective co-ordination mechanism that would enable them to collude, they did in practice manage to do so.

The experiments thus highlight the serious limitations of standard game-theoretic approaches typically used in merger investigations to predict whether or not a merger will enable competitors to tacitly co-ordinate their behaviour. As long as rewards for moving from a non-collusive equilibrium to a collusive outcome—even if the collusive outcome cannot be sustained as an equilibrium as in the games presented here—are sufficiently high, participants have regularly managed to sustain collusion in the experimental laboratory. To the extent that such settings are also realistic in actual merger cases, the focus on standard game theoretic necessary and sufficient conditions required for a collusive equilibrium to exist leads to systematic enforcement gaps in co-ordinated-effects merger cases and thus to potential consumer harm. For real-world competition enforcement it may not be enough to rely on largely untested game-theoretic conditions such as the *Airtours* criteria[19] that may underestimate the likelihood of collusion; an empirical approach is required.

4. Concluding remarks

These examples illustrate how experimental economics can provide important insights into the competitive outcomes that can be expected under different market structures and modes of competitive interaction. The results suggest that changing the number of competitors from four to two, and vice versa, can have large effects on behaviour and market outcomes. The experiments, however, also highlight that the type of competitive interaction (e.g. price-setting versus quantity-setting oligopoly) plays an equally important role. They thus seem to vindicate the relatively soft role that concentration thresholds play in the Commission's merger guidelines.

Experimental methods, as presented in this article, are a powerful teaching tool that can allow insights in areas where complexity has led to a predominance of formal, mathematical thought. As stated earlier, the

19 See *Airtours Plc v Commission of the European Communities* (T-342/99) [2002] E.C.R. II-2585 on the assessment of horizontal mergers under the Regulation on the control of concentrations between undertakings.

utility of experiments goes, however, well beyond such pedagogical aims. Although the experiments used for the training sessions can only highlight the potential role experimental economics can play, alongside other techniques such as ex post case studies, in calibrating competition authorities' enforcement practice. The literature on experimental industrial organisation is of growing importance for competition policy and enforcement. More robust insights for such purposes can be found in the experimental literature that provides a controlled experimental environment and more complex (and realistic) game structures, for example by allowing for product differentiation or capacity constraints. In any event, experimental techniques are particularly valuable in areas where traditional game theory systematically fails to explain market outcomes[20] and is certainly one of the economic methods of the future with respect to competition policy and analysis.

Appendix

Table A1: Degree of collusion in C2 per market

t	ρ_{t1}	ρ_{t2}	ρ_{t3}	ρ_{t4}	ρ_{t5}	ρ_{t6}
1	0.38	−2.05	1.00	1.00	−1.45	0.97
2	0.50	−2.05	1.01	1.00	−0.24	0.61
3	0.42	0.67	0.37	1.00	0.06	−0.85
4	0.00	0.71	−0.24	1.00	0.36	−0.55
5	−0.12	0.67	−0.52	1.00	0.36	−0.06
6	0.32	0.42	1.00	1.00	−0.55	−1.76
7	0.32	0.12	0.68	1.00	−0.85	−1.45
8	−0.09	0.99	0.73	1.00	−2.06	−1.15
9	−0.06	0.98	0.73	1.00	−1.76	−0.85
10	0.03	0.73	0.74	1.00	−1.76	0.97
11	0.12	0.64	0.79	1.00	−1.76	0.97
12	−0.06	0.76	0.68	1.00	−1.76	0.97

Table A1: (*Continued*)

t	ρ_{t1}	ρ_{t2}	ρ_{t3}	ρ_{t4}	ρ_{t5}	ρ_{t6}
13	−0.09	0.80	0.80	1.00	−1.76	0.99
14	−0.24	−2.06	0.98	1.00	−2.06	0.99
15	−2.06	1.28	1.03	1.00	−1.94	0.99
16	−0.03	0.79	0.92	1.00	−1.03	0.99
17	0.12	0.42	0.79	1.00	−1.15	0.99
18	0.21	0.67	0.86	1.00	−1.15	0.99
19	0.30	0.79	0.79	1.00	−0.85	0.99
20	0.42	0.42	0.73	1.00	−0.55	0.99
$\bar{\rho}_{tk}$	0.02	0.29	0.69	1.00	−1.10	0.29

Table A2: Degree of collusion in C4 per market

t	ρ_{t1}	ρ_{t2}	ρ_{t3}
1	0.82	0.72	−0.70
2	0.84	0.73	−0.62
3	0.31	0.62	−0.46
4	0.65	0.60	−0.33
5	0.66	0.39	0.01
6	0.58	0.51	0.07
7	0.65	0.70	−0.46
8	0.63	0.71	−0.33
9	0.53	0.61	−0.67
10	0.53	0.49	−0.67
11	0.44	0.30	−0.09
12	0.49	0.21	−0.06
13	0.33	0.10	0.01
14	0.16	0.06	0.14
15	0.28	−0.21	−0.26
16	0.23	−0.16	−0.46
17	0.24	−0.70	0.24
18	0.23	0.82	1.03
19	−0.23	0.76	0.68
20	0.11	−0.65	0.01
$\bar{\rho}_{tk}$	0.42	0.33	−0.15

20 Given the complexity, experimental methods have been used for a long time in auction design and also as a simulation tool to design auction strategies, for instance in spectrum auctions. In the field of competition law, experimental tools are likely to be of particular relevance in co-ordinated effects analysis as there is currently no coherent theoretical approach to the problem.

Table A3: Degree of collusion in B2 per market

t	ρ_{t1}	ρ_{t2}	ρ_{t3}	ρ_{t4}	ρ_{t5}	ρ_{t6}
1	0.48	0.01	0.44	0.99	0.38	0.99
2	0.38	0.99	0.40	0.99	0.34	0.99
3	0.00	0.99	0.36	0.99	0.00	0.99
4	0.38	0.99	0.00	0.99	0.95	0.99
5	0.38	0.97	0.31	0.99	0.89	0.99
6	0.38	0.01	0.02	0.99	0.95	0.99
7	0.48	0.99	0.20	0.99	0.95	0.99
8	0.48	0.99	0.13	0.99	0.95	0.99
9	0.48	2.00	0.12	0.99	0.89	0.99
10	0.69	0.99	0.18	0.99	0.77	0.95
11	0.69	0.99	0.10	0.99	0.69	0.48
12	0.69	0.99	0.09	0.99	0.55	0.08
13	0.99	0.95	0.02	0.99	0.36	0.02
14	0.99	0.00	0.02	0.99	0.00	0.02
15	0.99	0.59	0.18	0.99	0.00	0.01
16	0.99	0.00	0.16	0.99	0.38	0.02
17	0.99	0.00	0.13	0.99	0.18	0.99
18	0.99	0.00	0.16	0.95	0.55	0.99
19	0.99	0.95	0.10	0.16	0.48	0.97
20	0.18	0.00	0.06	0.00	0.79	0.02
$\bar{\rho}_{tk}$	0.63	0.67	0.16	0.99	0.55	0.67

Table A4: Degree of collusion in B4 per market

t	ρ_{t1}	ρ_{t2}	ρ_{t3}
1	0.00	0.16	0.22
2	0.00	0.04	0.00
3	0.08	0.00	0.08
4	0.23	0.00	0.69
5	0.22	0.18	0.14
6	0.18	0.00	0.00
7	0.00	0.00	0.01
8	0.06	0.00	0.00
9	0.00	0.00	0.02
10	0.00	0.00	0.01
11	0.00	0.00	0.00
12	0.00	0.00	0.00
13	0.00	0.00	0.00
14	0.00	0.00	0.00
15	0.00	0.00	0.00
16	0.95	0.00	0.00
17	0.00	0.00	0.02
18	0.00	0.00	0.01
19	0.00	0.00	0.00
20	0.00	0.00	0.00
$\bar{\rho}_{tk}$	0.09	0.02	0.06