Chapter 18

THE CLASSICAL EXPERIMENTS ON COURNOT OLIGOPOLY

ANTONI BOSCH-DOMÈNECH
Universitat Pompeu Fabra, Barcelona

NICOLAAS J. VRIEND
Queen Mary, University of London

Moving beyond the development of game theory and the exercise games for managers that inspired them, two papers – Hoggatt (1959) and Sauermann and Selten (1959, 1960) – explicitly set up controlled experiments on quantity adjusters (or Cournot) oligopolists. "*The experiment can be constructed in such a way that decision-making can be observed throughout, and the assumptions about human behavior implicit in economic theories can be tested*." claim Sauermann and Selten (1960, p. 85). "*We focus on using game situations as a research tool for studying the behavior of human beings in conflict situations"* asserts Hoggatt (1959, p. 192). With these papers, experimental research on oligopolies was born, reaching maturity soon, with Fouraker, Shubik, and Siegel (1961), and Fouraker and Siegel (1963).

Fouraker and Siegel's work is indistinguishable in method and purpose from recent oligopoly experiments. The oligopolistic market used in Fouraker and Siegel's experiments is as simple as it can be, the purpose – comparing the results of two treatments – is clearly stated, while the problems confronted and the solutions applied are not different from today's. It is instructive to note how in a matter of a few years, simplification is preferred to realism. In Sauermann and Selten (1960), firms are complex, decision-making units with several managers, each specializing in a different task. In Hoggatt (1959), firms are simple, one-person, one-decision units, but different among themselves, and the inverse demand function depends not only on current quantities but also on amounts traded in the past. In Fouraker and Siegel (1963), firms are identical one-person one-decision units, and the inverse demand function is linear in current quantities. Clearly, the purpose of Fouraker and Siegel's experiments was to study human behavior, not to decipher the complexities of oligopolistic markets or the behavior of complex organizations.

1. Sauermann and Selten's Results

Although their main task is to explore the motives behind the observed decisions, one of the questions Sauermann and Selten (1959, 1960) focus on is whether tacit cooperation prevails in their experiments.

Handbook of Experimental Economics Results, Volume 1

DOI: 10.1016/S1574-0722(07)00018-2

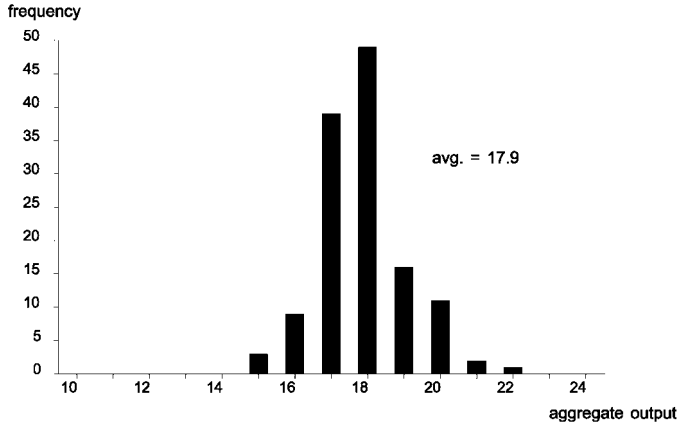

Figure 1. (Based on Sauermann and Selten (1959), Table 8.) *Aggregate output frequencies*. The results correspond to the last 10 periods of 13 experimental sessions of 30 periods each. In the experiments, three firms are involved which cannot communicate among each other. The aggregate output levels that are Pareto optimal are in the 10 to 14 range, but aggregate output seems to stabilize at higher volumes – and, therefore, at lower joint profits – mainly around the Cournot–Nash equilibria, corresponding to aggregate output levels from 16 to 18.

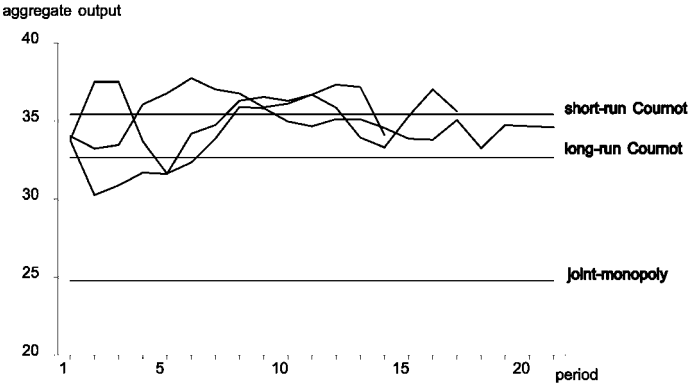

Figure 2. (Based on Hoggatt (1959), Figures 4, 5 and 6.) *Observed time path of aggregate output*. The three curves correspond to the three experimental sessions. In each, three firms confront an industry inverse demand function dependent on quantities traded in the period and in the previous two periods. Firms are informed about the industry demand function and their own costs, but are not told how many firms are competing in the same market. After each period, subjects are told the market price, the total amount supplied and their profits in the period. The three horizontal lines indicate the output levels of the short-run Cournot equilibrium (myopically not taking into account the dynamic nature of the demand function), the long-run Cournot equilibrium (choosing a best-reply to the current output levels, to maximize profits two periods from the current one), and the joint-monopoly profit maximizing output level.

Table 1
Hypotheses (Fouraker and Siegel, 1963, p. 101)

Numbers of bargainers	Possible combinations of bargaining types or signals	Predicted aggregate output Q	
		Incomplete information	Complete information
$N = 2$	*CC*	$Q =$ Cournot	$Q <$ Cournot
	CM	$Q =$ Cournot	$Q <$ Cournot
	CR	$Q =$ Cournot	$Q <$ Cournot
	MM	$Q =$ Cournot	$Q =$ Cournot
	MR	$Q =$ Cournot	$Q >$ Cournot
	RR	$Q =$ Cournot	$Q >$ Cournot
$N = 3$	*CCC*	$Q =$ Cournot	$Q <$ Cournot
	CCM	$Q =$ Cournot	$Q <$ Cournot
	CCR	$Q =$ Cournot	$Q <$ Cournot
	CMM	$Q =$ Cournot	$Q <$ Cournot
	CMR	$Q =$ Cournot	$Q =$ Cournot
	CRR	$Q =$ Cournot	$Q >$ Cournot
	MMM	$Q =$ Cournot	$Q =$ Cournot
	MMR	$Q =$ Cournot	$Q >$ Cournot
	MRR	$Q =$ Cournot	$Q >$ Cournot
	RRR	$Q =$ Cournot	$Q >$ Cournot

Note. $C =$ cooperative, $M =$ simple maximizer, $R =$ rivalistic.

From a questionnaire that subjects had to answer, Sauermann and Selten conclude that a successful theory of oligopoly has to contain explicitly *qualitative* motives (and not only quantitative maximizing arguments). In addition, they claim, *learning* should be incorporated in the theory as the simplest mode of behavior. In their own words, "*learning from experience must be mathematically formulated as a stochastic learning model*" (p. 102). See Figure 1.

2. Hoggatt's Results

Hoggatt (1959) runs three simultaneous experimental sessions in order to observe how the subjects' actual behavior compares with various types of maximizing behavior postulated by economic theory. In particular, he wants to test the Cournot model as a predictor of the outcome of group behavior; the hypothesis being that aggregate output would converge to the short-run Cournot equilibrium. See Figure 2.

Hoggatt (1959) mentions that different treatments may yield different results and suggests further research with treatments involving information and communication, as well as an analysis of learning behavior.

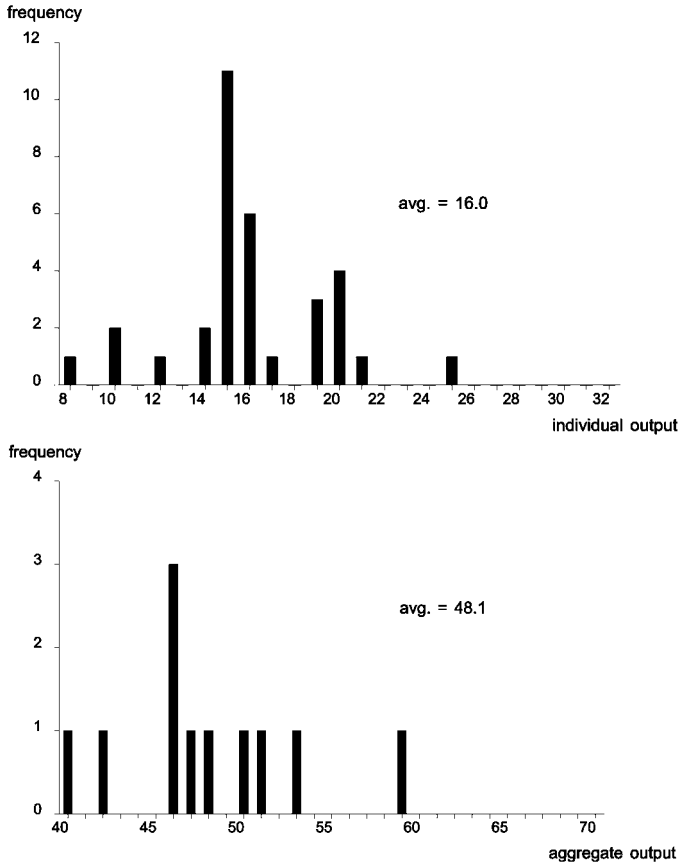

Figure 3. (Based on Fouraker and Siegel (1963, p. 134).) *Quantity choices, triopoly with incomplete information, 11 sessions*. In the triopolies, Pareto's individual output is at 10 (aggregate output at 30), Cournot's at 15 (aggregate at 45) and Walras' at 20 (aggregate at 60). In 9 of the 11 triopolies the aggregate output is closer to Cournot than to either of the alternative solutions.

3. Fouraker and Siegel's Results

Fouraker and Siegel view oligopolies as an example of human conflict between cooperation and defection. Their goal is to infer useful generalizations from the experiments of the effects of information conditions on the resolution of this conflict. While Fouraker and Siegel also consider Bertrand competition, we focus here on their symmetric Cournot games, with subjects – randomly and anonymously matched at the start of the experiment – deciding the amount of output they bring to the market. The market is characterized by a linear demand function, while marginal costs are zero at all output levels, and there are no fixed costs. These specifications are not given

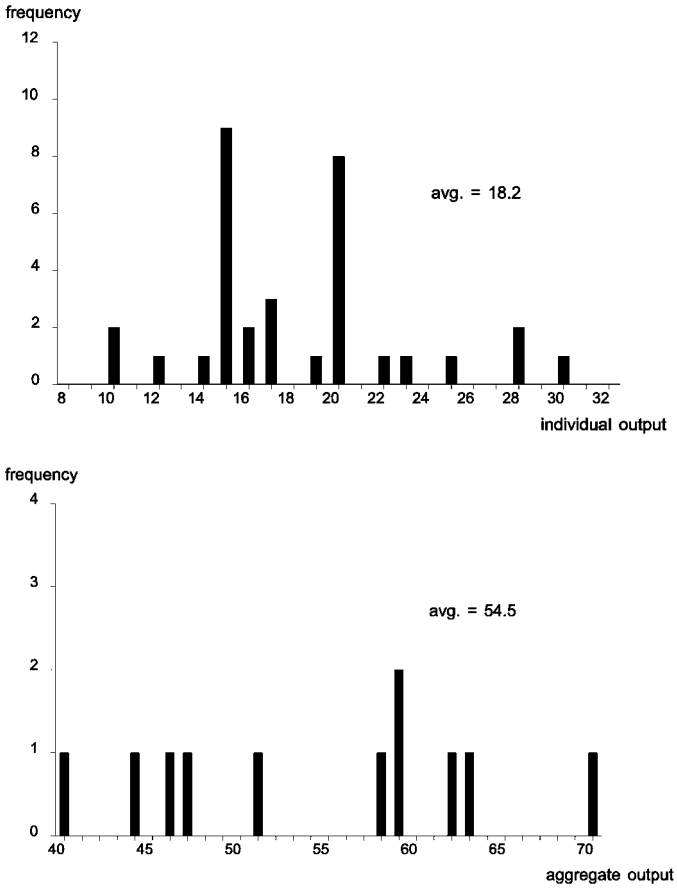

Figure 4. (Based on Fouraker and Siegel (1963, p. 140).) *Quantity choices, triopoly with complete information, 11 sessions*. No clear tendency is revealed by the data. The observations are mainly split between Cournot and Walras, about half favoring the Cournot solution.

to the subjects. Instead the players get a *profit matrix*, which is based on these functions.

In all treatments, 25 periods were played. The first 3 periods were trial periods without payoff, the other 22 were with monetary reward. The number of periods to be played was not announced in advance. But after round 21, it was announced that the next round would be the last one, possibly inducing end effects in round 22. Most results analyzed in Fouraker and Siegel concern period 21. Fouraker and Siegel distinguish three possible attractors. The joint-monopoly output level (Pareto from here on), the Nash (Cournot) output level, and the competitive (Walras) output level. From Table 1, we

Table 2

(Fouraker and Siegel, 1963, p. 150) *Number of times the three alternative solutions were supported*. First, under conditions of *incomplete* information, more choices supported the Cournot prediction than all alternative predictions combined. Under *complete* information conditions, more choices favored alternative predictions than favored the Cournot values. Second, oligopolistic transactions negotiated under complete information are more variable than oligopolistic transactions negotiated under incomplete information

Solution	Experimental session							
	Triopoly, incomplete information		Triopoly, complete information		Duopoly, incomplete information		Duopoly, complete information	
	q_i	Q	q_i	Q	q_i	Q	q_i	Q
Pareto (C)	4	0	3	0	2	0	10	5
Cournot (M)	20	9	15	5	26	14	12.5	7.5
Walras (R)	9	2	15	6	4	2	9.5	3.5

can see that quantity setting oligopolistic behavior depends on the *information available* and the *number* of opponents. Fouraker and Siegel conjecture that there are three types of players: Cooperators C, simple Maximizers M, and Rivalists R. In the case of oligopolies under incomplete information, for the two sizes of N and regardless of the bargaining types, the hypothesis is that the Cournot equilibrium will prevail, because if an individual player does not know the relation between her output and the profit of the other players, she will act as if those profits are some constant and concentrate on naively maximizing her own profit.[1] Under complete information instead, the hypothesis is that the solution is a function of the number of participants, the composition of bargaining types, and the dynamics of the interaction between the players, with the possible outcomes ranging from Pareto to Walras.

Fouraker and Siegel's work – and that of Sauermann and Selten (1959) and Hoggatt (1959) – clearly differentiates between hypotheses, tests and conclusions. Their hypotheses are stated in terms of two characteristics. First, the degree of information available to the subjects, which appears as two treatments called incomplete information (subjects are told of their own profits and *aggregate* output of others) and complete information (they are told about everybody's decisions and profits), and second, the number of players, N, per market, with two different treatments for $N = 2$ and $N = 3$.

[1] Notice that from a game-theoretic point of view, going for the Walrasian output level is the dominant strategy for a Rivalistic player. Hence, while Fouraker and Siegel' hypotheses are formulated with respect to the players' preferences, what they must have had in mind as well is the beginning of a bounded rationality kind of explanation. Fouraker and Siegel do not explicitly consider learning, but they do observe, for example, that a player might be motivated solely by his own profits, and employ the rivalistic *signal* as a means of increasing those profits. Hence, what Fouraker and Siegel call "*the dynamics of the interaction between the players*" seems related to an adaptive learning process concerning the behavior of one's opponents.

We choose to report, for symmetry with the previous results, the triopoly experiments, $N = 3$:

From Figures 3 and 4 it may be concluded, as hypothesized, that oligopolists bargaining under complete information as quantity adjusters show a greater variability of decisions than under incomplete information.

For a summary of Fouraker and Siegel results on Cournot oligopoly we refer to Table 2.

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