The Economic Journal, **113** (*April*), © Royal Economic Society 2003. Published by Blackwell Publishing, 9600 Garsington Road, Oxford OX4 2DQ, UK and 350 Main Street, Malden, MA 02148, USA.

Technical Appendix to

IMITATION OF SUCCESSFUL BEHAVIOUR IN COURNOT MARKETS*

Antoni Bosch-Domènech and Nicolaas J. Vriend

Economic Journal, vol. 113 (*April*), pp. 495–524

Appendix A. The Spite Effect and the Cournot Oligopoly

The essence of the spite effect is illustrated by the bimatrix game in Figure A1 (Palomino, 1995), where T and B are the two possible strategies, and the lowercase letters are the payoffs to the row and column player, with $a > b > c > d$. Clearly, (T, T) is the only Nash equilibrium since no player can improve by deviating from it, and this is the only combination for which this holds. Now, consider the strategy pair (B, T), leading to the payoffs (b, c). Remember that $a > b > c > d$. Hence, by deviating from the Nash equilibrium, the row player hurts her own payoff, but she hurts the column player's payoff even more.

Let us now focus on a standard symmetric Cournot oligopoly. There are several symmetrical firms producing the same homogeneous commodity. The only decision variable for firm i is the quantity q_i to be produced. Once production has taken place, for all firms simultaneously, the firms bring their output to the market, where the market price P is determined such that demand equals supply. To give the intuition behind the spite effect in this Cournot game, let us consider a simple symmetric Cournot market in which the inverse demand function is $P(Q) = a + bQ$, where $Q = \Sigma q_i$, and in which the cost function for the individual firm is $TC(q) = K + kq$. Making the appropriate assumptions on the parameters a and b ensures that the demand curve is downward-sloping. We can distinguish three symmetric output levels of the static Cournot oligopoly game specified above for the case in which the

	T	B
T	a, a	c, b
B	b, c	d, d

Fig. A1. *Bimatrix Game with Payoffs* $a > b > c > d$

* We wish to thank Xavier Herrero for his indispensable assistance in organising the experiments, and Tilman Börgers, Gary Charness, Richard Disney, Ido Erev, Jonathan Haskel, Charles Holt, Steffen Huck, Ulrich Kamecke, Francesco Luna, Paul Madden, Paola Manzini, Charles Noussair, Martin Sefton, Tilman Slembeck, Fernando Vega-Redondo, Nir Vulkan, and seminar and conference participants at Venice, Siena, Exeter, Manchester, London (QM), the London Business School, ESA (Mannheim), EARIE (Copenhagen), ESEM and EEA (Berlin), the ESRC Research Seminar in Game Theory (Kenilworth), RES (Nottingham), the Max Planck Institute (Jena), and SAET (Ischia) for discussions or comments concerning earlier versions of this paper. Two anonymous referees and the editor provided many very valuable suggestions. Financial support from the Spanish Ministry of Education and Science under contract PB98-1079 (AB-D), and from the Commission of the European Union under contracts FMRX-CT98-0238 (AB-D) and FMBICT950277 (NJV) is gratefully acknowledged. The usual disclaimer applies.

players have complete information. First, suppose that the two firms collude, maximising their joint-profits. This leads to an aggregate output level called Pareto $Q^P = (k - a)/(2b)$. Second, if the firms behave as price-takers in a competitive market, they simply produce up to the point where their marginal costs are equal to the market price P. Given the specification of the oligopoly model above, this implies an aggregate competitive, or Walrasian, output level of $Q^W = (k - a)/b$. If, instead, the firms realise that they influence the market price through their own output, they produce up to the point where their marginal costs are equal to their marginal revenue. Taking the output level of the other firm as given, this leads to an aggregate Cournot–Nash equilibrium output of $Q^N = (k - a)/\{b[(1/n) + 1]\}$.

To see how a spite effect might influence the outcomes of a Cournot market game, suppose, to simplify for illustrative convenience, that there are only two firms, that fixed and marginal costs are zero (Schaffer, 1989) and let us concentrate on the Walrasian equilibrium. Observe that there are two alternative ways to look at it, based on different behavioural assumptions. In both cases it is the spite effect that makes it an equilibrium. First, suppose that the firms' preferences are such that they do not care about absolute payoffs but only about relative payoffs. Any utility function assigning a higher value to an outcome in which the firm beats the other firm and a lower value to an outcome in which it gets beaten will, after elimination of all weakly dominated strategies, leave only one strategy: producing its equal share of Q^W.

To see why this is the only strategy where a firm is sure it can never be beaten, look at Figure A2 and focus on the Walrasian output Q^W. Suppose firm i produces its equal share of the Walrasian output: $q_i = Q^W/2$. If firm j does the same, aggregate output is Q^W, the market price P is zero and both make a zero profit. What happens when firm j produces more than $Q^W/2$? The price P will become negative, and both firms will make losses. But it is firm i that makes less losses, because it has a lower output level sold at the same market price P. What happens instead if firm j produces less than $Q^W/2$? The price P will be positive and, hence, this will increase firm j's profits. But again it is firm i that makes a greater profit, because it

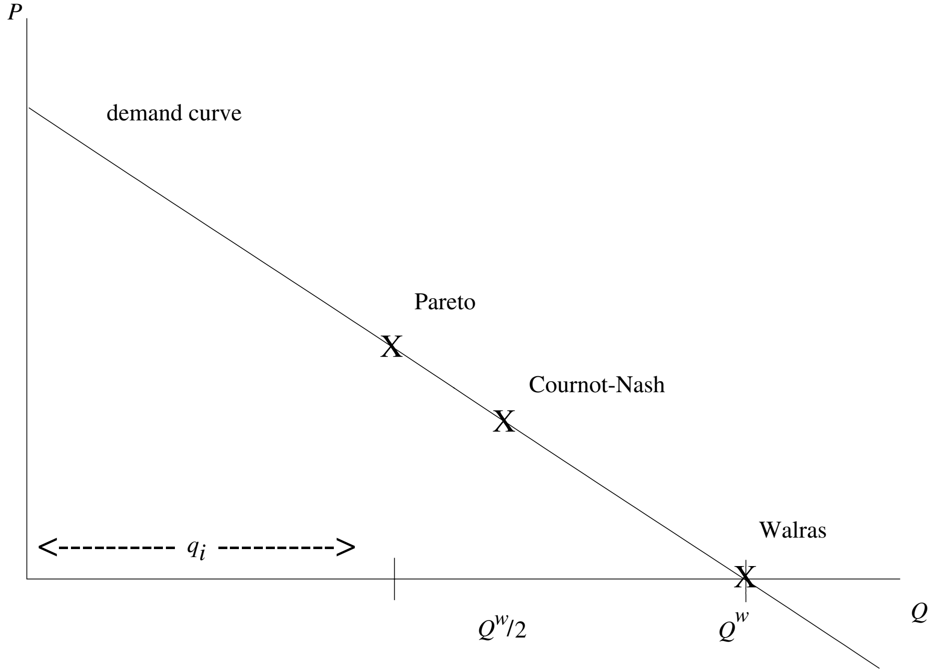

Fig. A2. *Example Cournot Duopoly*

has a higher output level sold at the same market price P. In some sense, firm i is free riding on firm j's production restraint. Hence, the firm that produces its equal share of Q^W will have the highest relative payoff in this Cournot duopoly. Note that this implies in particular the following. If firm i produces its share of the symmetric Walrasian output, while firm j naively chooses the symmetric output level to maximise its absolute payoffs (i.e., its equal share of the Cournot-Nash output), it is firm i that realises the highest profits. Moreover, even if firm j is aware of the fact that firm i is producing at the Walrasian output level, and maximises its profits taking this into account, it is firm i that realises the highest payoffs. If we consider more than two firms, matters become slightly more complicated, but the following holds. Whenever the aggregate output level is below Walras, i.e., on average an individual firm produces less than its share of the Walrasian output level, the price will be positive, and it is the firms with the higher output levels that generate the higher profits. Exactly the reverse holds when aggregate output exceeds the Walrasian output level: the lower a firm's output level, the higher its profits will be.

Now, suppose that the firms do not have a preference for beating their competitors but that they are boundedly rational and tend to imitate successful behaviour in the sense that, with a certain probability, they choose the output levels that led to the highest profits in the past. Whenever the average output is below Walras, it is the highest output firm, realising the highest profit, that is most likely to be imitated, and the other way round. As a result, the market will converge to the Walrasian equilibrium.

Appendix B. Instructions to the Players

Table B1 gives the English translation of the Spanish instructions to the players in the '*easy*' duopoly.

Table B1

Instructions 'easy' Duopoly

Instructions

Introduction

- This is a decision experiment. The instructions are simple and, if you pay attention, you can gain a reasonable amount of money that will be paid to you at the end of the experiment. From now on till the end of the experiment you are not allowed to communicate with each other. If you have a question, please raise your hand.
- Each of you will play a firm that produces a fictitious good that is sold in a fictitious market.
- Within each market there will be only 2 firms that sell the same good. One is your firm and the other is a firm that is identical to yours.
- Who will be this other firm will be decided randomly.
- The other people in the laboratory participate in other markets that have nothing to do with yours. In other words, various markets will operate simultaneously but independently in the laboratory.
- You will never know the identity of the person you are matched with, nor will he be aware of yours.
- The experiment will last 22 consecutive periods and the other firm that participates in your market will be the same during all periods of the experiment.

Decisions and Outcomes

- Each period all firms simultaneously make only 1 decision: the quantity to be produced and supplied to the market. Only integer values from 8 to 32 can be chosen.
- You will get a Table showing the various levels of profit or loss you and the other firms can attain depending upon the quantities chosen by you and the other firm. The quantities one firm (firm X) may produce are listed across the top of the Table, while the quantities produced by the other firm are listed down the left-hand margin. The profits for firm X and for the other firm are given within the body of the Table by the intersection of the quantities produced. The top number in **bold** gives the profit for firm X, whereas the bottom number in *italic* gives the profit of the other firm. Since the two firms are identical, at any moment you can identify either yourself or the other firm with firm X. We will do some exercises with the Table in a moment.

Table B1

Continued

Instructions
• After each period, you will get some information on your screen. At the top of the screen, you will see your output level and that of the other firm in the previous period. At the bottom, you will see the history of your own output levels and profits realised.
• There is no time limit for your period to period decisions. Decisions will ordinarily be made every few minutes or so.
Payment
• Each player gets a fixed fee of 250 Pesetas just for participating in the experiment.
• In addition, each player will be paid according to the total profits realised by his firm.
• During periods 1 to 20, the monetary reward will be 0.035 Pesetas for every profit point realised.
• During periods 21 and 22 (the last 2 periods), the monetary reward will be 0.35 Pesetas for each profit point realised. You will receive a reminder of this higher payoff (10 times as high) at the start of period 21.
• Note that losses realised will be subtracted from the 250 Pesetas.
• At the end of the experiment, we will add up your profits and calculate your monetary rewards. This will be done such that you will not see what other players earned.
Keyboard
• To make your choice of output level, please enter a number. Remember that only integer values from 8 to 32 can be chosen.
• To confirm (or not) your choices, enter Y (or N) with your keyboard.
• Please, before confirming your choices, always make sure that you did not make a typing error.

Table B2 shows the instructions given to the players in the '*hard*' duopoly. We only list the subsection '*Decisions and Outcomes*', which replaces the corresponding subsection in the '*easy*' duopoly. The remainder of the instructions was identical to the '*easy*' version.

The only change made in the instructions of the '*hardest*' duopoly with respect to the '*hard*' version was that the information concerning the market demand was removed, that is, the item marked (•) in Table B2.

Table B2

Instructions 'hard' Duopoly

Instructions
Decisions and Outcomes
• Each period all firms simultaneously make only 1 decision: the quantity to be produced and supplied to the market. Only integer values from 8 to 32 can be chosen.
(•) Given the TOTAL quantity supplied to the market by you and the other firm in a given period, the price is determined by the market. For total output levels from 16 to 64, taking steps of 1, the market prices will be 350 (with total output equal to 16), 346, 342, 338, 334, 330, 326, 322, 318, 314, 310, 306, 302, 298, 294, 290, 286, 282, 278, 274, 270, 266, 262, 258, 254, 250, 246, 242, 238, 234, 230, 226, 222, 218, 214, 210, 206, 202, 198, 194, 190, 186, 182, 178, 174, 170, 166, 162, 158 (64). This market price implies the revenue a firm gets for EACH UNIT it supplied to the market. Assume that all units produced are actually sold.
• For a given period, the costs to a firm producing a certain quantity in that period are as follows, starting with the minimum output of 8, and going in unit steps to the maximum output of 32: 1246 (with output equal to 8), 1420, 1594, 1768, 1942, 2116, 2290, 2464, 2638, 2812, 2986, 3160, 3334, 3508, 3682, 3856, 4030, 4204, 4378, 4552, 4726, 4900, 5074, 5248, 5422 (32).
• The profits to a firm for a given period are simply its revenues minus its costs.
• After each period, you will get some information on your screen. You will see your output level and that of the other firm in the previous period, plus the profits realised by you and by the other firms in the that period. We also indicate (with *****) which firm realised the highest profit in the previous period.
• There is a 1 minute time limit for your period to period decisions. The experimenter will give a warning after 30 seconds, after 50 seconds and after 60 seconds.

The following Table was given to the players in the '*easy*' duopolies, with the **bold** faced numbers indicating the profits for firm *X*, and the numbers in *italic* the profits for the other firm.

		Output Firm X											
PROFITS		8	9	10	11	12	13	14	15	16	17	18	19
Output		**1554**	**1694**	**1826**	**1950**	**2066**	**2174**	**2274**	**2366**	**2450**	**2526**	**2594**	**2654**
other firm	*8*	*1554*	*1522*	*1490*	*1458*	*1426*	*1394*	*1362*	*1330*	*1298*	*1266*	*1234*	*1202*
		1522	**1658**	**1786**	**1906**	**2018**	**2122**	**2218**	**2306**	**2386**	**2458**	**2522**	**2578**
	9	*1694*	*1658*	*1622*	*1586*	*1550*	*1514*	*1478*	*1442*	*1406*	*1370*	*1334*	*1298*
		1490	**1622**	**1746**	**1862**	**1970**	**2070**	**2162**	**2246**	**2322**	**2390**	**2450**	**2502**
	10	*1826*	*1786*	*1746*	*1706*	*1666*	*1626*	*1586*	*1546*	*1506*	*1466*	*1426*	*1386*
		1458	**1586**	**1706**	**1818**	**1922**	**2018**	**2106**	**2186**	**2258**	**2322**	**2378**	**2426**
	11	*1950*	*1906*	*1862*	*1818*	*1774*	*1730*	*1686*	*1642*	*1598*	*1554*	*1510*	*1466*
		1426	**1550**	**1666**	**1774**	**1874**	**1966**	**2050**	**2126**	**2194**	**2254**	**2306**	**2350**
	12	*2066*	*2018*	*1970*	*1922*	*1874*	*1826*	*1778*	*1730*	*1682*	*1634*	*1586*	*1538*
		1394	**1514**	**1626**	**1730**	**1826**	**1914**	**1994**	**2066**	**2130**	**2186**	**2234**	**2274**
	13	*2174*	*2122*	*2070*	*2018*	*1966*	*1914*	*1862*	*1810*	*1758*	*1706*	*1654*	*1602*
		1362	**1478**	**1586**	**1686**	**1778**	**1862**	**1938**	**2006**	**2066**	**2118**	**2162**	**2198**
	14	*2274*	*2218*	*2162*	*2106*	*2050*	*1994*	*1938*	*1882*	*1826*	*1770*	*1714*	*1658*
		1330	**1442**	**1546**	**1642**	**1730**	**1810**	**1882**	**1946**	**2002**	**2050**	**2090**	**2122**
	15	*2366*	*2306*	*2246*	*2186*	*2126*	*2066*	*2006*	*1946*	*1886*	*1826*	*1766*	*1706*
		1298	**1406**	**1506**	**1598**	**1682**	**1758**	**1826**	**1886**	**1938**	**1982**	**2018**	**2046**
	16	*2450*	*2386*	*2322*	*2258*	*2194*	*2130*	*2066*	*2002*	*1938*	*1874*	*1810*	*1746*
		1266	**1370**	**1466**	**1554**	**1634**	**1706**	**1770**	**1826**	**1874**	**1914**	**1946**	**1970**
	17	*2526*	*2458*	*2390*	*2322*	*2254*	*2186*	*2118*	*2050*	*1982*	*1914*	*1846*	*1778*
		1234	**1334**	**1426**	**1510**	**1586**	**1654**	**1714**	**1766**	**1810**	**1846**	**1874**	**1894**
	18	*2594*	*2522*	*2450*	*2378*	*2306*	*2234*	*2162*	*2090*	*2018*	*1946*	*1874*	*1802*
		1202	**1298**	**1386**	**1466**	**1538**	**1602**	**1658**	**1706**	**1746**	**1778**	**1802**	**1818**
	19	*2654*	*2578*	*2502*	*2426*	*2350*	*2274*	*2198*	*2122*	*2046*	*1970*	*1894*	*1818*
		1170	**1262**	**1346**	**1422**	**1490**	**1550**	**1602**	**1646**	**1682**	**1710**	**1730**	**1742**
	20	*2706*	*2626*	*2546*	*2466*	*2386*	*2306*	*2226*	*2146*	*2066*	*1986*	*1906*	*1826*
		1138	**1226**	**1306**	**1378**	**1442**	**1498**	**1546**	**1586**	**1618**	**1642**	**1658**	**1666**
	21	*2750*	*2666*	*2582*	*2498*	*2414*	*2330*	*2246*	*2162*	*2078*	*1994*	*1910*	*1826*
		1106	**1190**	**1266**	**1334**	**1394**	**1446**	**1490**	**1526**	**1554**	**1574**	**1586**	**1590**
	22	*2786*	*2698*	*2610*	*2522*	*2434*	*2346*	*2258*	*2170*	*2082*	*1994*	*1906*	*1818*
		1074	**1154**	**1226**	**1290**	**1346**	**1394**	**1434**	**1466**	**1490**	**1506**	**1514**	**1514**
	23	*2814*	*2722*	*2630*	*2538*	*2446*	*2354*	*2262*	*2170*	*2078*	*1986*	*1894*	*1802*
		1042	**1118**	**1186**	**1246**	**1298**	**1342**	**1378**	**1406**	**1426**	**1438**	**1442**	**1438**
	24	*2834*	*2738*	*2642*	*2546*	*2450*	*2354*	*2258*	*2162*	*2066*	*1970*	*1874*	*1778*
		1010	**1082**	**1146**	**1202**	**1250**	**1290**	**1322**	**1346**	**1362**	**1370**	**1370**	**1362**
	25	*2846*	*2746*	*2646*	*2546*	*2446*	*2346*	*2246*	*2146*	*2046*	*1946*	*1846*	*1746*
		978	**1046**	**1106**	**1158**	**1202**	**1238**	**1266**	**1286**	**1298**	**1302**	**1298**	**1286**
	26	*2850*	*2746*	*2642*	*2538*	*2434*	*2330*	*2226*	*2122*	*2018*	*1914*	*1810*	*1706*
		946	**1010**	**1066**	**1114**	**1154**	**1186**	**1210**	**1226**	**1234**	**1234**	**1226**	**1210**
	27	*2846*	*2738*	*2630*	*2522*	*2414*	*2306*	*2198*	*2090*	*1982*	*1874*	*1766*	*1658*
		914	**974**	**1026**	**1070**	**1106**	**1134**	**1154**	**1166**	**1170**	**1166**	**1154**	**1134**
	28	*2834*	*2722*	*2610*	*2498*	*2386*	*2274*	*2162*	*2050*	*1938*	*1826*	*1714*	*1602*
		882	**938**	**986**	**1026**	**1058**	**1082**	**1098**	**1106**	**1106**	**1098**	**1082**	**1058**
	29	*2814*	*2698*	*2582*	*2466*	*2350*	*2234*	*2118*	*2002*	*1886*	*1770*	*1654*	*1538*
		850	**902**	**946**	**982**	**1010**	**1030**	**1042**	**1046**	**1042**	**1030**	**1010**	**982**
	30	*2786*	*2666*	*2546*	*2426*	*2306*	*2186*	*2066*	*1946*	*1826*	*1706*	*1586*	*1466*
		818	**866**	**906**	**938**	**962**	**978**	**986**	**986**	**978**	**962**	**938**	**906**
	31	*2750*	*2626*	*2502*	*2378*	*2254*	*2130*	*2006*	*1882*	*1758*	*1634*	*1510*	*1386*
		786	**830**	**866**	**894**	**914**	**926**	**930**	**926**	**914**	**894**	**866**	**830**
	32	*2706*	*2578*	*2450*	*2322*	*2194*	*2066*	*1938*	*1810*	*1682*	*1554*	*1426*	*1298*

PROFITS		Output firm X												
		20	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**
Output		**2706**	**2750**	**2786**	**2814**	**2834**	**2846**	**2850**	**2846**	**2834**	**2814**	**2786**	**2750**	**2706**
other firm	*8*	*1170*	*1138*	*1106*	*1074*	*1042*	*1010*	*978*	*946*	*914*	*882*	*850*	*818*	*786*
		2626	**2666**	**2698**	**2722**	**2738**	**2746**	**2746**	**2738**	**2722**	**2698**	**2666**	**2626**	**2578**
	9	*1262*	*1226*	*1190*	*1154*	*1118*	*1082*	*1046*	*1010*	*974*	*938*	*902*	*866*	*830*
		2546	**2582**	**2610**	**2630**	**2642**	**2646**	**2642**	**2630**	**2610**	**2582**	**2546**	**2502**	**2450**
	10	*1346*	*1306*	*1266*	*1226*	*1186*	*1146*	*1106*	*1066*	*1026*	*986*	*946*	*906*	*866*
		2466	**2498**	**2522**	**2538**	**2546**	**2546**	**2538**	**2522**	**2498**	**2466**	**2426**	**2378**	**2322**
	11	*1422*	*1378*	*1334*	*1290*	*1246*	*1202*	*1158*	*1114*	*1070*	*1026*	*982*	*938*	*894*
		2386	**2414**	**2434**	**2446**	**2450**	**2446**	**2434**	**2414**	**2386**	**2350**	**2306**	**2254**	**2194**
	12	*1490*	*1442*	*1394*	*1346*	*1298*	*1250*	*1202*	*1154*	*1106*	*1058*	*1010*	*962*	*914*
		2306	**2330**	**2346**	**2354**	**2354**	**2346**	**2330**	**2306**	**2274**	**2234**	**2186**	**2130**	**2066**
	13	*1550*	*1498*	*1446*	*1394*	*1342*	*1290*	*1238*	*1186*	*1134*	*1082*	*1030*	*978*	*926*
		2226	**2246**	**2258**	**2262**	**2258**	**2246**	**2226**	**2198**	**2162**	**2118**	**2066**	**2006**	**1938**
	14	*1602*	*1546*	*1490*	*1434*	*1378*	*1322*	*1266*	*1210*	*1154*	*1098*	*1042*	*986*	*930*
		2146	**2162**	**2170**	**2170**	**2162**	**2146**	**2122**	**2090**	**2050**	**2002**	**1946**	**1882**	**1810**
	15	*1646*	*1586*	*1526*	*1466*	*1406*	*1346*	*1286*	*1226*	*1166*	*1106*	*1046*	*986*	*926*
		2066	**2078**	**2082**	**2078**	**2066**	**2046**	**2018**	**1982**	**1938**	**1886**	**1826**	**1758**	**1682**
	16	*1682*	*1618*	*1554*	*1490*	*1426*	*1362*	*1298*	*1234*	*1170*	*1106*	*1042*	*978*	*914*
		1986	**1994**	**1994**	**1986**	**1970**	**1946**	**1914**	**1874**	**1826**	**1770**	**1706**	**1634**	**1554**
	17	*1710*	*1642*	*1574*	*1506*	*1438*	*1370*	*1302*	*1234*	*1166*	*1098*	*1030*	*962*	*894*
		1906	**1910**	**1906**	**1894**	**1874**	**1846**	**1810**	**1766**	**1714**	**1654**	**1586**	**1510**	**1426**
	18	*1730*	*1658*	*1586*	*1514*	*1442*	*1370*	*1298*	*1226*	*1154*	*1082*	*1010*	*938*	*866*
		1826	**1826**	**1818**	**1802**	**1778**	**1746**	**1706**	**1658**	**1602**	**1538**	**1466**	**1386**	**1298**
	19	*1742*	*1666*	*1590*	*1514*	*1438*	*1362*	*1286*	*1210*	*1134*	*1058*	*982*	*906*	*830*
		1746	**1742**	**1730**	**1710**	**1682**	**1646**	**1602**	**1550**	**1490**	**1422**	**1346**	**1262**	**1170**
	20	*1746*	*1666*	*1586*	*1506*	*1426*	*1346*	*1266*	*1186*	*1106*	*1026*	*946*	*866*	*786*
		1666	**1658**	**1642**	**1618**	**1586**	**1546**	**1498**	**1442**	**1378**	**1306**	**1226**	**1138**	**1042**
	21	*1742*	*1658*	*1574*	*1490*	*1406*	*1322*	*1238*	*1154*	*1070*	*986*	*902*	*818*	*734*
		1586	**1574**	**1554**	**1526**	**1490**	**1446**	**1394**	**1334**	**1266**	**1190**	**1106**	**1014**	**914**
	22	*1730*	*1642*	*1554*	*1466*	*1378*	*1290*	*1202*	*1114*	*1026*	*938*	*850*	*762*	*674*
		1506	**1490**	**1466**	**1434**	**1394**	**1346**	**1290**	**1226**	**1154**	**1074**	**986**	**890**	**786**
	23	*1710*	*1618*	*1526*	*1434*	*1342*	*1250*	*1158*	*1066*	*974*	*882*	*790*	*698*	*606*
		1426	**1406**	**1378**	**1342**	**1298**	**1246**	**1186**	**1118**	**1042**	**958**	**866**	**766**	**658**
	24	*1682*	*1586*	*1490*	*1394*	*1298*	*1202*	*1106*	*1010*	*914*	*818*	*722*	*626*	*530*
		1346	**1322**	**1290**	**1250**	**1202**	**1146**	**1082**	**1010**	**930**	**842**	**746**	**642**	**530**
	25	*1646*	*1546*	*1446*	*1346*	*1246*	*1146*	*1046*	*946*	*846*	*746*	*646*	*546*	*446*
		1266	**1238**	**1202**	**1158**	**1106**	**1046**	**978**	**902**	**818**	**726**	**626**	**518**	**402**
	26	*1602*	*1498*	*1394*	*1290*	*1186*	*1082*	*978*	*874*	*770*	*666*	*562*	*458*	*354*
		1186	**1154**	**1114**	**1066**	**1010**	**946**	**874**	**794**	**706**	**610**	**506**	**394**	**274**
	27	*1550*	*1442*	*1334*	*1226*	*1118*	*1010*	*902*	*794*	*686*	*578*	*470*	*362*	*254*
		1106	**1070**	**1026**	**974**	**914**	**846**	**770**	**686**	**594**	**494**	**386**	**270**	**146**
	28	*1490*	*1378*	*1266*	*1154*	*1042*	*930*	*818*	*706*	*594*	*482*	*370*	*258*	*146*
		1026	**986**	**938**	**882**	**818**	**746**	**666**	**578**	**482**	**378**	**266**	**146**	**18**
	29	*1422*	*1306*	*1190*	*1074*	*958*	*842*	*726*	*610*	*494*	*378*	*262*	*146*	*30*
		946	**902**	**850**	**790**	**722**	**646**	**562**	**470**	**370**	**262**	**146**	**22**	**−110**
	30	*1346*	*1226*	*1106*	*986*	*866*	*746*	*626*	*506*	*386*	*266*	*146*	*26*	*−94*
		866	**818**	**762**	**698**	**626**	**546**	**458**	**362**	**258**	**146**	**26**	**−102**	**−238**
	31	*1262*	*1138*	*1014*	*890*	*766*	*642*	*518*	*394*	*270*	*146*	*22*	*−102*	*−226*
		786	**734**	**674**	**606**	**530**	**446**	**354**	**254**	**146**	**30**	**−94**	**−226**	**−366**
	32	*1170*	*1042*	*914*	*786*	*658*	*530*	*402*	*274*	*146*	*18*	*−110*	*−238*	*−366*

Figures B1 and B2 present two examples of the screens faced by the players. First, the '*easy*' version of the triopolies in Figure B1.

previous period (period 2):	your production:	20
	production firm X:	8
	production firm Y:	17
next period (period 3):	your production:	... (please Enter)

history:

period	**your production**	**your profit**
1	23	2658
2	20	3786
3	...	...
4	...	...
5	...	...
6	...	...
7	...	...
8	...	...
9	...	...
10	...	...
11	...	...
12	...	...
13	...	...
14	...	...
15	...	...
16	...	...
17	...	...
18	...	...
19	...	...
20	...	...
21	...	...
22	...	...

Fig. B1. *Example Screen 'easy' Triopoly*

The screen faced by the players in the '*hard*' and '*hardest*' triopolies is shown in Figure B2.

previous period (period 2):

	production	**profit**	**best**
you	20	3786	*****
firm X	8	1674	
firm Y	17	3258	

next period (period 3):

your production: ... (please Enter)

Fig. B2. *Example Screen 'hard' and 'hardest' Triopoly*

Appendix C. Description of the Individual Behavioural Rules

1 *BESTREP* myopic best-reply
The myopic-best-reply rule chooses a best-reply against the most recent output choice(s) by the other player(s). In the case where we check only for the direction of a player's choice, this corresponds to what is known as learning direction theory; Selten and Stoecker (1986).

2 *ADPTEXP* adaptive expectations
The adaptive-expectations rule adapts the belief about the (aggregate) output of the other player(s) by taking a convex combination of the existing belief and the most recent (aggregate) output of the other player(s), with a weight of 0.75 on the former and 0.25 on the latter. Then, the rule chooses a best-response against this updated belief.

3 *FICT* fictitious play
The fictitious-play rule chooses a best-response against the relative frequency distribution of past output levels by the other firm(s).[1]

4 *GEOFICT* geometric fictitious play
The geometric-fictitious-play rule is similar to rule 3. But now, in each period, previous frequency observations are discounted, multiplying them by 0.75.[2] Notice that the case of extreme discounting would correspond to myopic best-reply. Also notice that, given the linear Cournot model, for any discount factor between zero and one, this rule is very similar to the adaptive-expectations rule 2.

5 *IMITATE* imitate-the-best
The imitate-the-best rule is a restricted representation of the general class of imitation of successful behaviour on which we focus in this paper. The rule chooses to imitate the output level of the firm with the highest profits in the previous period.

6 *IMAVG* imitate-the-average
The imitate-the-average rule simply imitates the previous average output of the other player(s) in the market. When we consider only the direction of the players' output decisions, this rule is very similar to a rule Fouraker and Siegel (1963) analyse related to aspiration levels. Their '*rivalistic*' hypothesis says that if a firm's output in the previous period was below that of its rival, then it will increase its output in the next period and the other way round. There are two, very different, reasons to look at the imitate-the-average rule. First, it is a dynamic, reciprocating strategy of the type '*give-as-good-as you-get*' (GGG). Notice that in the duopoly this corresponds exactly to the Tit-for-Tat strategy (see, e.g. Axelrod (1984)). Second, Huck *et al.* (1999) argue that the imitate-the-average rule makes sense because players might reason that whereas individual players might go wrong, the average opponent cannot be too wrong.[3]

7 *EXMPL* imitate-the-exemplary
The imitate-the-exemplary rule is due to Offerman *et al.* (1997). The rule chooses the output level from among all those chosen in the previous period, such that if all firms would imitate that exemplary firm, it would lead to the highest profits.

8 *STAY* stay put (imitate oneself)
The stay-put rule simply tells a firm to repeat the same output level as the previous period.

[1] Since our Cournot model is linear, this is equivalent to choosing a best-response against the expected output level for the other firm(s). Hence, our rule also corresponds to what Offerman *et al.* (1997) call '*adapted fictitious play*'.

[2] This parameter value corresponds to Cason and Friedman (2000), who refer to some experimental evidence in this respect.

[3] In addition, they consider this rule because the imitate-the-best rule could not be applied in some of their treatments due to information restrictions.

9 *AVGRL* average reinforcement learning
The average-reinforcement-learning rule selects an output level on the basis of a player's average realised payoffs. For all reinforcement learning rules we use a deterministic version with initial strengths zero, and the target is always the most reinforced output level.

10 *AVGRLD* average reinforcement learning with discounting
The average-reinforcement-learning-with-discounting rule is similar to the previous rule, but now the average reinforcement is a weighted average of previous performances. Each period, previous performance observations are discounted, multiplying their weight by 0.75.

11 *CUMRL* cumulative reinforcement learning
The cumulative-reinforcement-learning rule corresponds to the average-reinforcement-learning rule with average reinforcement substituted by reinforcement on the basis of a player's cumulative realised payoffs.

12 *CUMRLD* cumulative reinforcement learning with discounting
The cumulative-reinforcement-learning-with-discounting rule adds the discounting (as above) to the previous rule.

13 *AVGXRL* extended average reinforcement learning
The extended reinforcement learning rules differ from the standard reinforcement learning rules in that they also consider the payoffs realised by the other player(s) in the market. That is, apart from experiencing payoffs itself, a firm now also reasons about the actions and payoffs it observes of the other firm(s), and reinforces those actions as if tried by itself. Notice that the extended reinforcement learning rules can be seen as a generalisation of the imitate-the-best rule as they consider not only the most recent period but also earlier payoffs. The extended-average-reinforcement-learning rule is based on average payoffs.

14 *AVGXRLD* extended average reinforcement learning with discounting
The extended-average-reinforcement-learning-with-discounting rule is doing the same, but this time earlier payoff observations are discounted (as above) every period. Notice that in case of extreme discounting we would be basically back at the imitate-the-best rule.[4]

15 *CUMXRL* extended cumulative reinforcement learning
The extended-cumulative-reinforcement-learning rule is similar to the extended-average-reinforcement-learning rule, but now based on cumulative payoffs.

16 *CUMXRLD* extended cumulative reinforcement learning with discounting
The extended-cumulative-reinforcement-learning-with-discounting rule adds the discounting of earlier payoff observations (as above) to the extended-cumulative-reinforcement-learning rule.

17 *HILL* hill climbing
The hill-climbing rule works as follows. If a firm had increased its output in the previous period, and its profits went up (down), then the next round its target is the latest output level plus (minus) one.[5] And the opposite if it had decreased its output in the previous period. Obviously this rule cannot be applied in the first two periods. Also, whenever a firm's output or profits had remained unchanged in the previous two periods the rule does not apply (as no gradient can be observed).

[4] The only difference being that initial strengths are zero.
[5] In the case where we only look for the direction of a player's output decision, we also consider a generalisation of this rule, allowing other step sizes as well, without significantly changing the results.

Appendix D. Pseudo-code of the Behavioural Model

Table D1 presents the pseudo-code of the behavioural model that we used for the computational analysis in Section 5. With local experimentation, the parameters are those defining the support on which the output experimentation takes place (X_1 and X_2). In principle they vary in synchronisation from 1 to 25 in steps of 1, but where necessary they are adjusted separately such that the new output cannot exceed the lower and upper output limits. With global experimentation, the parameter is the probability with which a player experiments, using the entire output range. This probability p_tremble ranges from 0.04 to 1.00 in steps of 0.04. Common to both types of experimentation, we vary the probability of imitation (p_imit), considering the values 0.20, 0.50, and 1.00. Notice that as the probability of imitation on the one hand, and either the probability of trembling or the support of the local experimentation on the other hand vary, imitation becomes either more or less prevalent in this behavioural model.

Table D1

Pseudo-code Computational Analysis

```
for all players do
begin
  with probability p_inert do stay put
  else
  begin
    with probability p_imit do
    begin
      planned output:=imitation of most successful;
      if experimentation=local then new output:=planned output + x {with x ~ U(−X1, X2)}
      else if experimentation=global then
      begin
         with probability p_tremble do new output:=x {with x ~ U(min_prod, max_prod)}
         else new output:=planned output;
      end;
     end
     else
     begin
        planned output:=previous output;
        if experimentation=local then new output:=planned output + x {with x ~ U(−X1, X2)}
        else if experimentation=global then
        begin
          with probability p_tremble do new output:=x {with x ~ U(min_prod, max_prod)}
        else new output:=planned output;
        end;
     end;
  end;
end;
```

References

Axelrod, R. (1984). *The Evolution of Cooperation*, New York: Basic Books.

Cason, T. and Friedman, D. (2000). 'Buyer search and price dispersion: a laboratory study', mimeo.

Fouraker, L.E. and Siegel, S. (1963). *Bargaining Behavior*, New York: McGraw-Hill.

Huck, S., Normann, H.-T. and Oechssler, J. (1999). 'Learning in Cournot oligopoly - an experiment', ECONOMIC JOURNAL, vol. 109, pp. C80–95.

Offerman, T., Potters, J. and Sonnemans, J. (1997). 'Imitation and belief learning in an oligopoly experiment', mimeo, University of Amsterdam, Department of Economics.

Palomino, F. (1995). 'On the survival of strictly dominated strategies in large populations', *Institute for Economic Analysis* WP 308.95, Universitat Autonoma de Barcelona.

Schaffer, M.E. (1989). 'Are profit maximizers the best survivors?', *Journal of Economic Behavior and Organization*, vol. 12, pp. 29–45.

Selten, R. and Stoecker, R. (1986). 'End behavior in sequences of finite prisoner's dilemma supergames. a learning theory approach', *Journal of Economic Behavior and Organization*, vol. 7, pp. 47–70.