Competition with Forward Contracts:
A Laboratory Analysis Motivated by Electricity Market Design

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Appendices

Content

Appendix 1: Experimental Instructions for SF3.2

In this appendix, we give a translation of the Dutch instructions of one of our treatments: SF3.2. Instructions for other treatments were similar. A full set of the (Dutch) instructions is available upon request. Instructions were computerized and programmed as linked HTML pages. Participants could move forward and backward through the instructions by simple mouse clicks. Below, horizontal lines indicate page separations.

INSTRUCTIONS

You are about to participate in an economic experiment. The instructions are simple. if you follow them carefully, you can make a substantial amount of money. Your earnings will be paid to you in guilders at the end of the experiment.

In the experiment, we use the currency 'franc'. At the end of the experiment, we will exchange the francs for guilders. The exchange rate to be used is 1 guilder for 5000 francs. For each 10000 francs, you will therefore receive 2 guilder.

We will use numerical examples in these instructions. These are only meant to be an illustration and are irrelevant for the experiment itself.

ROUNDS

The experiment will consist of 25 rounds today, preceded by 5 practice rounds.

In those rounds, you will be a member of a group. Aside from you, the group will consist of 4 other people. The composition of the group is anonymous. You do not know who is in the group with you. Others do not know that you are in their group. The composition of your group is the same for the whole experiment. You will have nothing to do with people in other groups.

In the practice rounds, there will be no groups. The computer will simulate the choices of other group members. You will therefore not be able to learn anything about the choices of others. The practice rounds are only meant to help you to learn about the problem at hand and the computer program.

In the experiment, you will participate in a market, in which fictitious goods will be produced, exchanged with traders and sold. The final consumers of the good will be simulated by the computer. Some participants today will be producers of the good, others will be traders. There are 2 traders and 3 producers in each group. At the beginning of the experiment your screen will show your type.

The remainder of these instructions will explained these roles, the market and the rules you must abide by.

THREE PHASES

Each round of today´s experiment consists of 3 subsequent phases: production, trade and sales. What follows is a brief overview. Each phase is explained in more detail, below.
In phase 1 (production), all producers must make a decision. They determine how many units they would like to produce in this phase. The numbers in the group are summed up. This number is then offered for sale to the traders in the group.

In phase 2 (trade) traders must decide at what price they would be willing to buy the units offered by the producers. Each trader places a bid for these units. This bid is the price PER UNIT that the trader is willing to pay for all units offered. In this phase it is all or nothing, meaning that the trader with the highest bid obtains all units, the other trader receives nothing. If both traders bid the same amount, a lottery will decide. At the end of this phase, each producer will receive the winning bid for each unit he or she produced.

In phase 3 (sales) the trader with the winning bid in phase 2 and the producers must make decisions. The producers can produce any units not yet produced and offer them for sale on the market. The trader can offer the units purchased on the market. What happens then, will be explained next.

THE BUYERS

In this experiment, the decisions to buy (fictitious) goods in phase 3 are not made by participants but by the computer. This happens as follows.

In each round, the total number of units offered for sale by your group is determined. Then, it is determined at what (minimum) prices – we call these the 'prices asked' – the group members are willing to sell. Next, the computer checks which units can be bought for these prices asked. How this is done, will be explained below.

The per unit price that the computer is willing to pay depends on the number of units the computer buys. The relationship between this number and the price is given in a table. You will see this in the upper right area of your screen. An example is given on the following page.

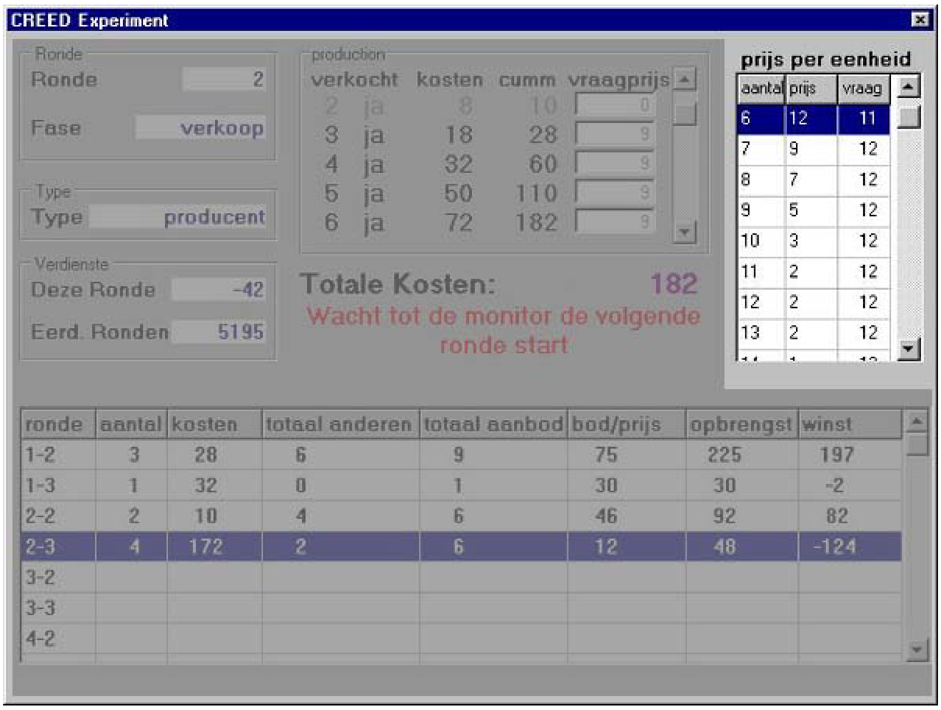


figure 1: Table with the per unit price.

Above, you see an example of the computer screen we will use. The numbers you see will be different in the experiment. Focus on the 'sharp' picture, in the upper right part.

The table you see in the upper right corner is only an example. Later, you will be able to scroll along the table with your mouse, this is not possible in these instructions. You will find a print out of the table to be used in the experiment in an envelop on your desk. This table is the same for everyone. You may open the envelop now. For now, only look at the table 'Price per Unit'.

There are three columns in the table above. The left column (with the heading 'number') gives the number of units. The right column will be explained later. Consider the middle column (with the heading 'price'). Here you see the price PER UNIT that goes with the corresponding number. If the computer buys this number of units, this is the price that the computer will pay per unit. Below, we will explain how the number bought is determined.

The numbers in the table serve only to illustrate. In the experiment, completely different numbers will be used. In this example, if a group sells 8 units, each participant in that group will receive 7 francs per unit sold. If you sold 3 of the 8 units, you will get 3x7=21 francs. Note that the price per unit decreases as the group produces more. **NOTICE**: Here, we have not discussed the prices asked. This gives the minimum price you wish to receive for a unit. You will never be forced to sell for a price lower than your price asked. This is extensively explained, below.

This is the way in which sales in phase 3 take place. Producers also offer units to traders in phase 1. This is what we will discuss next.

PHASE 1 and PHASE 2

In phase 1, all producers decide how many units they would like to offer to the traders. In this phase, they do not know which price they will receive per unit. This depends on what traders bid in phase 2. After every producer has decided how many units to offer to the traders in the group, the total is summed up. Note that producers do not ask prices in phase 1: the price is always determined by the traders' bids.

Next, in phase 2, the traders bid a price PER UNIT. The trader with the highest bid receives all units offered at that price. If neither trader bids a price higher than zero, nothing is sold. If there are bids, then all units are produced and delivered. The trader then pays each producer for the goods delivered.

THE PRODUCERS (SELLERS)

At the beginning of the experiment, each producer will receive 5000 francs as a starting capital. You will see this amount on your screen (at 'previous earnings') when the experiment starts. In each round, each producer must then decide how many units of the good he or she wishes to produce and for each unit what the minimum price is that he or she wishes to receive for that unit. How this is reported, will be explained below.

There are costs related to producing goods. These costs are not constant per unit, they are increasing. This means that the costs of the second unit are higher than those of the first unit, etc.

NOTICE: The units in phase 1 and 3 add up. For example, someone who produces 3 units in phase 1 and sells them to the traders, starts phase 4 with the fourth unit. This has consequences for the production costs.

On the next page, you will see how the costs per unit will appear on your screen.

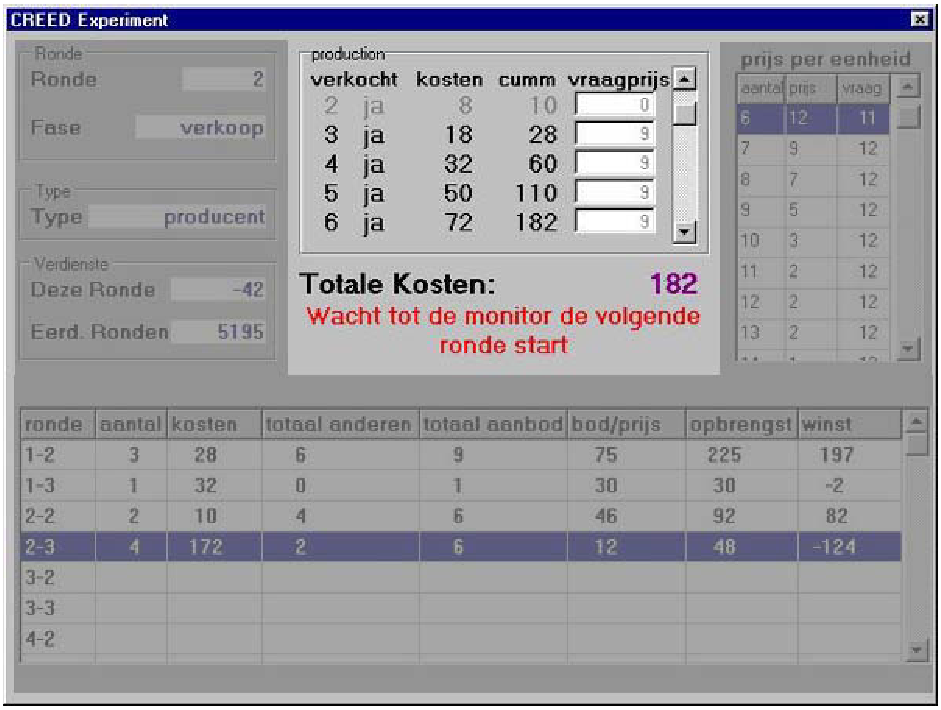


Figure 2: Costs per unit

The table you see above in figure 2 (in the center), is only an example. Later, you will be able to scroll along the table with your mouse, this is not possible in these instructions. You will also find a print of the table to be used in the experiment in an envelop on your desk. Have a look at the table 'Costs per Unit'. This table is the same for everyone.

In the first column, you see the number you are willing to produce ('unit'). The second column ('costs') gives the costs of that unit. You cannot produce a unit without producing the preceding ones. For example, if you want to produce the fifth unit, you must also produce the first, second, third and fourth units. Note that the costs are only determined by your own production. In no way are your costs affected by what other producers in your group do.

To determine the total costs of a certain level of production, you must add up the costs of every unit. To help you calculate these total costs, you will find the total costs for the number of units produced under 'cumulative'.

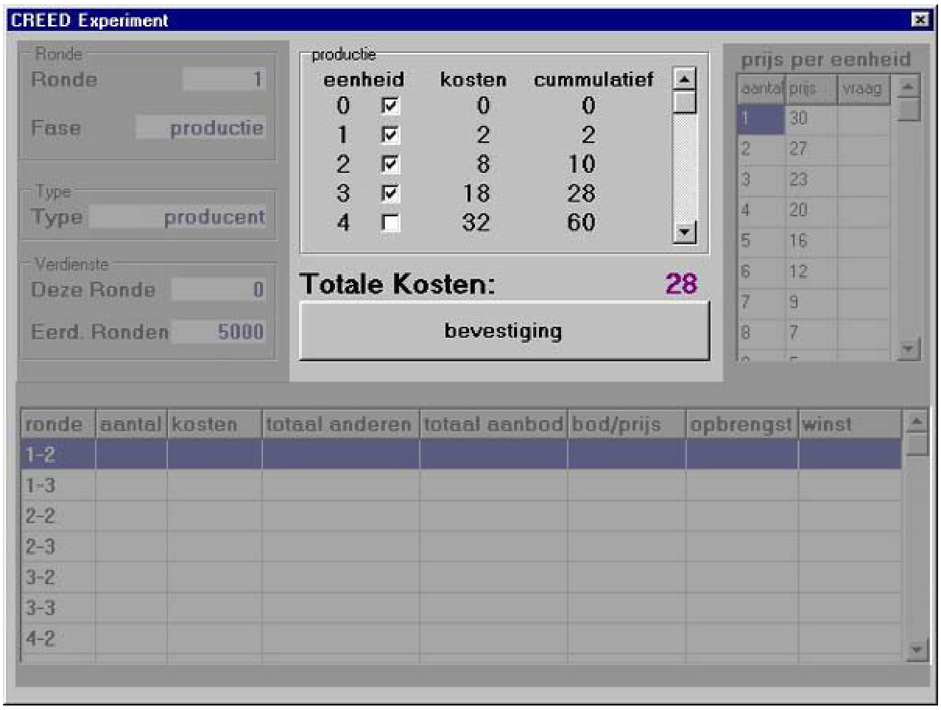


Figure 2: Costs per unit

In the table on your screen that gives the costs, you will also be able to indicate your production decision. This is different in phases 1 and 3.

In phase 1, you only need to indicate how many units you wish to offer to the traders. You do this by clicking one of the numbers under 'sell'. If you click 3, for example, you indicate that you want to produce and sell 3 units (to be more precise, units 1, 2 and 3). These three units will therefore be marked, if you click on 3.

Each producer can sell (in phase 1 and 3 together) a maximum of 30 units per round.

After you have chosen a number, you need to confirm. This holds in both phase 1 and phase 3. As long as you have not confirmed, you can still change your decision. Note that you decision is not final until you have confirmed it. The experiment will not proceed to the next phase until everyone has confirmed his or her production decision. You also need to confirm if you decide to produce zero units.

Figure 2: Costs per unit

The way in which you indicate your production decision in phase 3 is completely different. You offer units to buyers (the computer) and not to traders. In phase 3, you will see that the units you sold in phase 1 can no longer be chosen. For example, if you sold 2 units to the trader, you can only click on 3, 4, 5, etc.

You offer units in phase 3 by indicating for each unit, at what price (the ‘price asked’) you are willing to sell it. You may ask different prices for distinct units.

If you offer a unit for sale, you must also offer all preceding units. For example, if you indicate a minimum price asked for unit 3, you must also offer units 1 and 2 (if you did not sell these in phase 1). Here, you must take the following rule into account. Your price asked for a unit must always be higher than or equal to the price asked for the preceding unit. Note that your production costs are also higher. In the example above, the first unit costs 2, the second 8 and the third 18. Your price asked for the second unit may not be lower than for the first unit. Your price asked for the third unit may again not be lower than your price asked for the second unit, etc. Each producer can produce at most 30 units.

Your price asked may be lower than the costs. Note that you may make a loss on that unit in that case. For example. assume that your price asked for the first three units is 15. Assume that the three units are indeed bought by the computer at a price of 15. The first unit has production costs 2. You make a profit of 15-2=13. The second units costs 8. Your profit is 15-8=7. The third unit costs 18. You make a loss of 18-15=3.

All units for which you ask a positive price are offered on the market. However, a unit is only sold if the computer is willing to pay a price at least as high as your price asked. How this is determined will be explained below. For units that are not sold, there are NO production costs.

You indicate your willingness to sell units by entering in the column with heading “price asked” the amount you wish to receive for that unit. It is up to you to decide how many different numbers you wish to enter, as long as a price asked is not less than the preceding one. You may enter a different number for each unit, the same for all units or anything in between. It is also up to you to decide how many units you want to offer. There is a maximum of 30, however.

To help you when entering numbers, the following happens. If you enter a price for a unit, the same number is automatically entered in all previous units for which no number had been entered yet. For example, if you start by entering a price of 30 in unit 3, 30 is also entered in units 1 and 2. If you then enter 70 for unit 5, 1-3 stay at 30 but 70 is entered for unit 4. You may practice this in the practice rounds. Units where you leave the price at 0 are not offered.

When you are satisfied, you must confirm your choice. As long as you have not done so, you can still change every and any price asked. Note that your decision is not valid until you have confirmed. The experiment will not proceed to the next phase until everyone has confirmed her or his production decision. You must also confirm if you wish to produce zero units. You do so by leaving all prices at zero and clicking the confirmation button.

Every producer can offer at most 30 units per round (aggregated over phase 1 and 3).

In phase 2, producers do not need to make a decision. They must wait until the traders have decided at what price they are willing to buy the goods produced. At the end of phase 2 every producer will receive for every unit produced the amount determined by the traders.

THE TRADERS

At the beginning of the experiment, each trader will receive a starting capital of 45000 francs. In addition, each trader will receive 2000 francs in each round. You will see these amounts on your screen when the experiment starts (at 'previous earnings').

A trader cannot produce goods, but can buy them in phase 2, depending on the supply by the producers in her or his group in phase 1. The trader must then indicate at which price PER UNIT he or she is willing to purchase these goods. How this is done is explained on the next page.

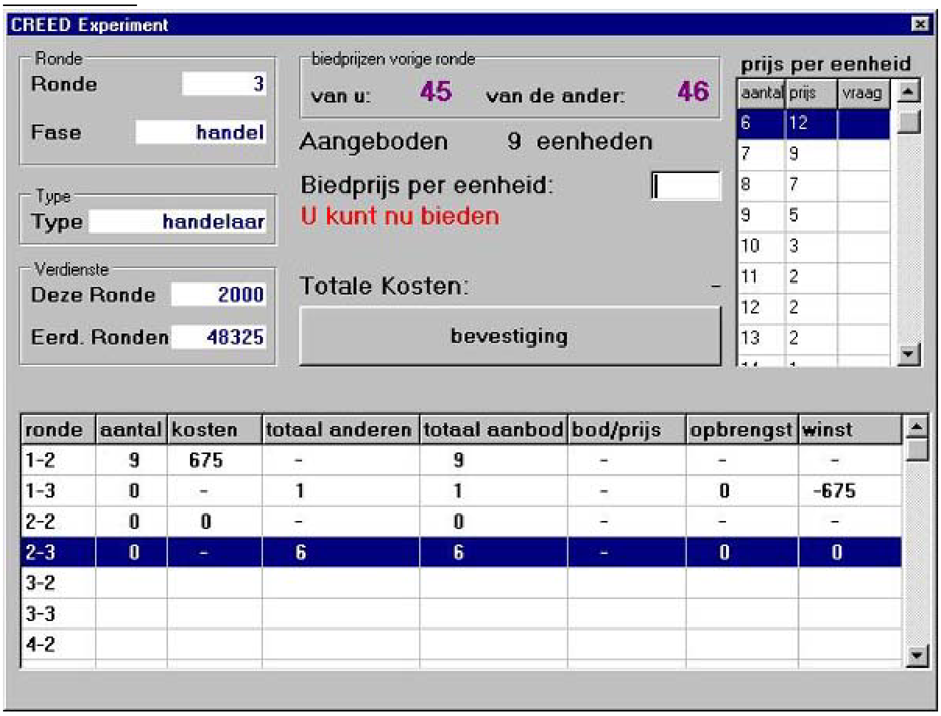


Figure 3: Phase 2

Traders are told what the total supply by their group's producers is in phase 1. Then, each trader bids an amount per unit. For example, if 10 units are offered, this means that a bid of 3 francs implies a total bid of 30 francs. The bid must be confirmed to make it final.

After all traders have decided, for each group it is determined which trader has made the highest bid. This trader receives all of the goods from this group, the other trader receives nothing. If the bids are equal, a lottery determines the winner. Every trader must make a bid.

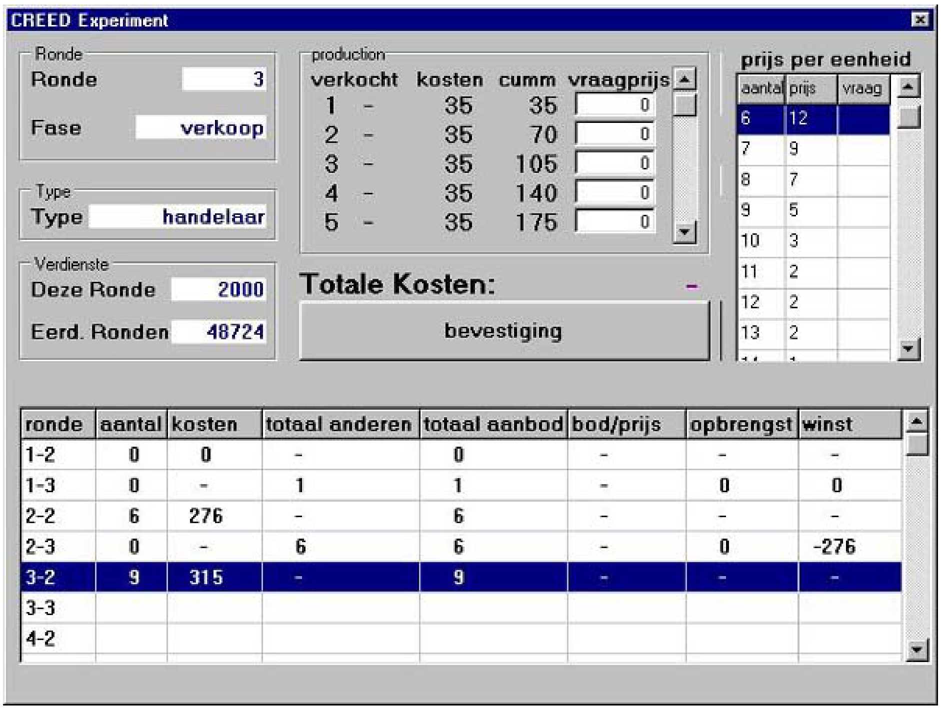


Figure 4: Phase 3

In phase 3, the traders can offer the goods they bought for sale to the (simulated) buyers. They are not required to sell all of the units bought. It does hold that they paid for all units bought in phase 2.

Therefore, in phase 2 the trader pays for the goods bought and in phase 3 the trader receives money for the goods from the buyers (the computer). The difference reflects the trader's earnings.

The trader offers goods in phase 3 in the same way as the producer does. If you offer a unit for sale, you must also offer all preceding units. For example, if you indicate a minimum price asked for unit 3, you must also offer units 1 and 2. Here, you must take the following rule into account. Your price asked for a unit must always be higher than or equal to the price asked for the preceding unit.

Contrary to producers, a trader has no production costs in phase 3. All units bought in phase 2 must be paid. There are no additional costs related to selling in phase 3. A trader who wants to sell as much as possible must therefore enter the lowest possible price. This is asking a price equal to 1.

If a producer were to do so, he or she would make a loss, because there are production costs. There are no production costs for traders, however.

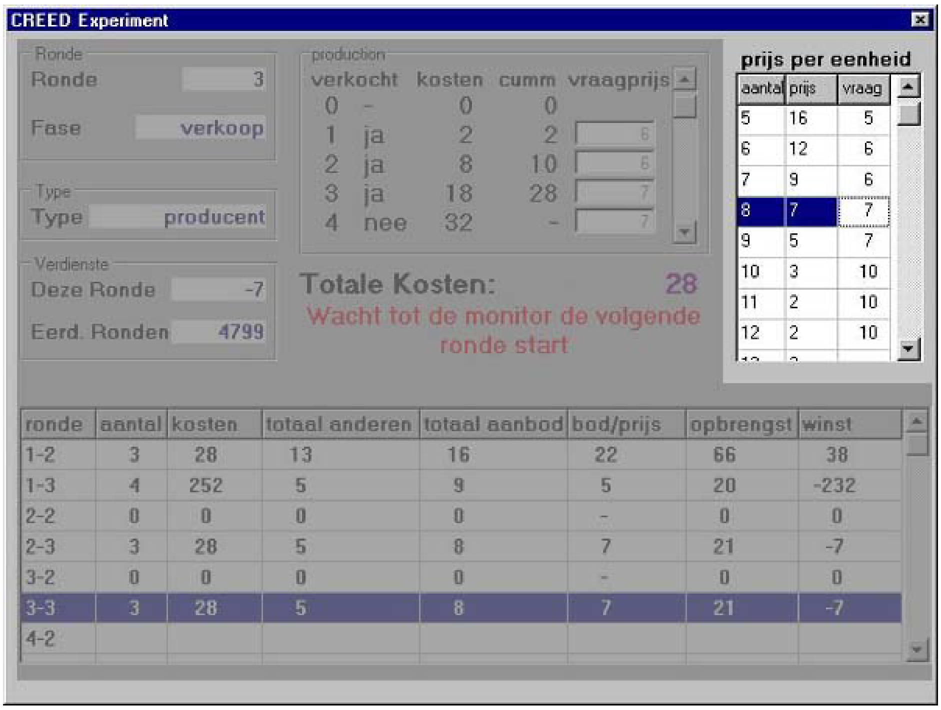
All units for which you ask a positive price are offered on the market. If your price asked is equal to zero, you do not offer that unit. You did pay for that unit in phase 2.

A unit is only sold if the computer is willing to pay a price at least as high as your price asked. How this is determined will be explained below.

You indicate your willingness to sell units by entering in the column with heading "price asked" the amount you wish to receive for that unit. It is up to you to decide how many different numbers you wish to enter, as long as a price asked is not less than the preceding one. You may enter a different number for each unit, the same for all units or anything in between. It is also up to you to decide how many of your units you want to offer. There is a maximum of 30, however.

To help you when entering numbers, the following happens. If you enter a price for a unit, the same number is automatically entered in all previous units for which no number had been entered yet. For example, if you start by entering a price of 30 in unit 3, 30 is also entered in units 1 and 2. If you then enter 70 for unit 5, 1-3 stay at 30 but 70 is entered for unit 4. You may practice this in the practice rounds. Units where you leave the price at 0 are not offered. If you are a trader and want to sell all units, it suffices to enter a price equal to 1 for the last unit you have. That sets the price asked for each unit at 1.

When you are satisfied, you must confirm your choice. As long as you have not done so, you can still change every and any price asked. Note that your decision is not valid until you have confirmed. The experiment will not proceed to the next phase until everyone has confirmed her or his decision. You must also confirm if you wish to produce zero units. You do so by leaving all prices at zero and clicking the confirmation button.



DETERMINING THE NUMBER OF UNITS

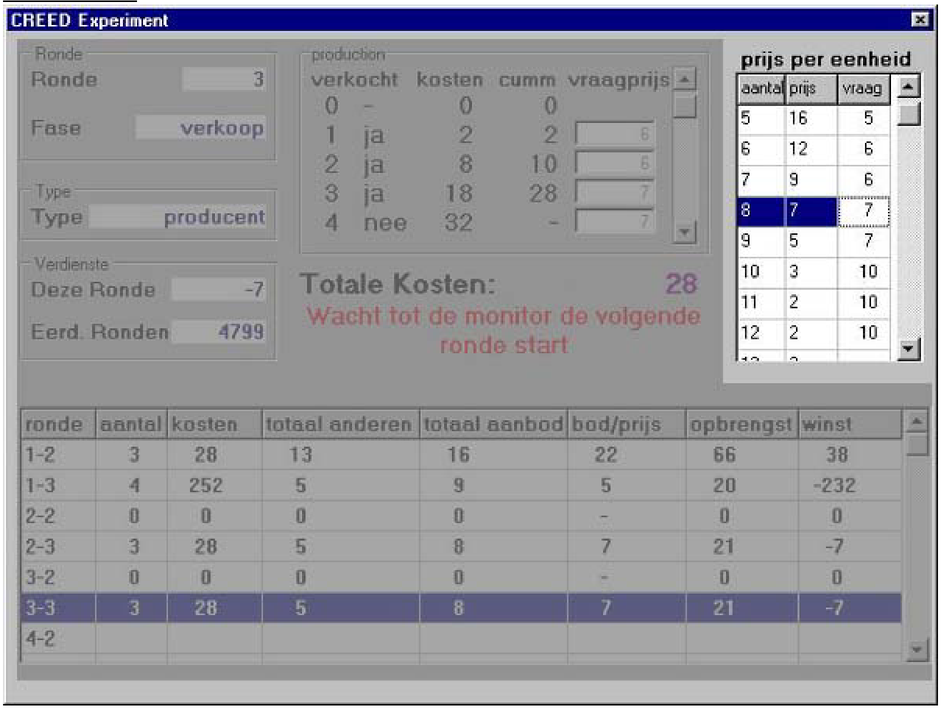
After everyone has confirmed their prices asked in phase 3, the number of units is sold is determined. This is done as follows. The computer combines all prices asked by the various members of a group (three producers and one of the traders) and orders them from low to high.

Then, the computer first checks what the lowest price is that is asked for a first unit. If you ask 12 for your first unit and another member of your group asks 10, than the unit of that other member will be sold first. If two sellers ask the same price, a lottery will determine who will be involved in a transaction first.

If this lowest price asked is lower than the price the computer is willing to pay for that unit (see the table “Price per Unit”), than this unit is bought.

Next, the computer checks what the lowest price is that is asked for a not yet sold unit. If two sellers ask the same price, a lottery will determine who will be involved in a transaction first. If this lowest price asked is lower than the price the computer is willing to pay for that unit (see the table “Price per Unit”), than this unit is bought.
In this way, it is determined how many units can be sold. The price is the same for every unit sold. This is the price that the computer is willing to pay for the number of units sold. You can find this price in the table “Price per Unit”.

On the next page, you will find an example.



DETERMINING THE NUMBER OF UNITS

To show you the result of aggregating the prices asked in phase 3, all prices asked are given from lowest to highest in the right column of the table at the top right on your screen. Later you can scroll along the table. Because you cannot scroll along the screen here, you cannot see that the first 4 units can be sold. You can see in this example that there is a trader or producer (you or someone else in your group) who is willing to sell the fifth unit for at least 5 francs. You see this by noting that for the number 5, there is a price asked of 5 (in the column "price asked").

The computer is willing to pay 16 for the fifth unit (column "price"), so this unit will be sold.

There is someone willing to sell the sixth unit for 6 francs and the computer is willing to pay 12, so this unit is sold as well. The lowest price asked for the seventh unit is also 6, the compute is willing to pay 9, so this unit is sold. The eighth unit can be bought for 7 francs and that is also what the computer is willing to pay. It is sold. For the ninth unit, 7 francs are needed as well, but the computer is only willing to pay 5. This unit is not sold. Further units are not sold either.

All in all, 8 units are sold. The price that the computer is willing to pay is 7 francs. Each unit is therefore sold for 7 francs. Thus, the price is determined by what the computer is willing to pay for the last unit traded.

Depending on your prices asked, you may be able to sell some units while others may not be sold. On your screen, we will indicate with "yes" or "no" for each unit whether or not it has been sold.

Sometimes it may seem as if you do not sell a unit, even though the trading price is higher. In these cases, selling your unit would cause the trading price to drop below your price asked, however. If you can sell a unit for a price higher than the price you ask, this trade will always take place. You will never sell a unit for a price lower than what you ask.

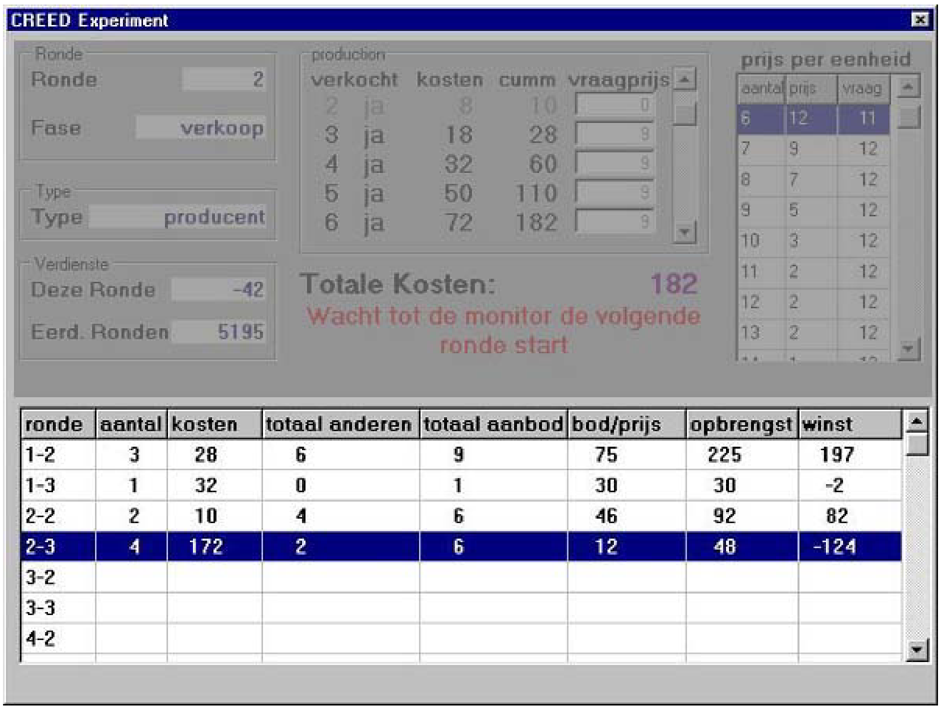


Figure 5: The results of a round

The results of each round are shown in the lower half of your screen at the end of the round.

In the table, you see from left to right:

round: the number of the round; this consists of two rows. The first row refers to phases 1 and 2; the second row is for phase 3.

number: for producers: the number of units (per phase) that you have produced;
for traders: the number of units you have bought in phase 2.

costs: for producers: the (total) costs (per phase) of the goods you produced;
for traders: your total costs (the price bid times the number of units bought).

total others: the total number of units that others in your group have produced or supplied.

total supply: the aggregate supply in your group (number + total others)

bid/price: the winning bid (phase 2) or price (phase 3) per unit in your group

revenue: for producers: (per phase) the price per unit times the number of units you produced;
for traders: the price per unit times the number of units you supplied in phase 3;

earnings: your profit or loss in the round (revenue - costs).

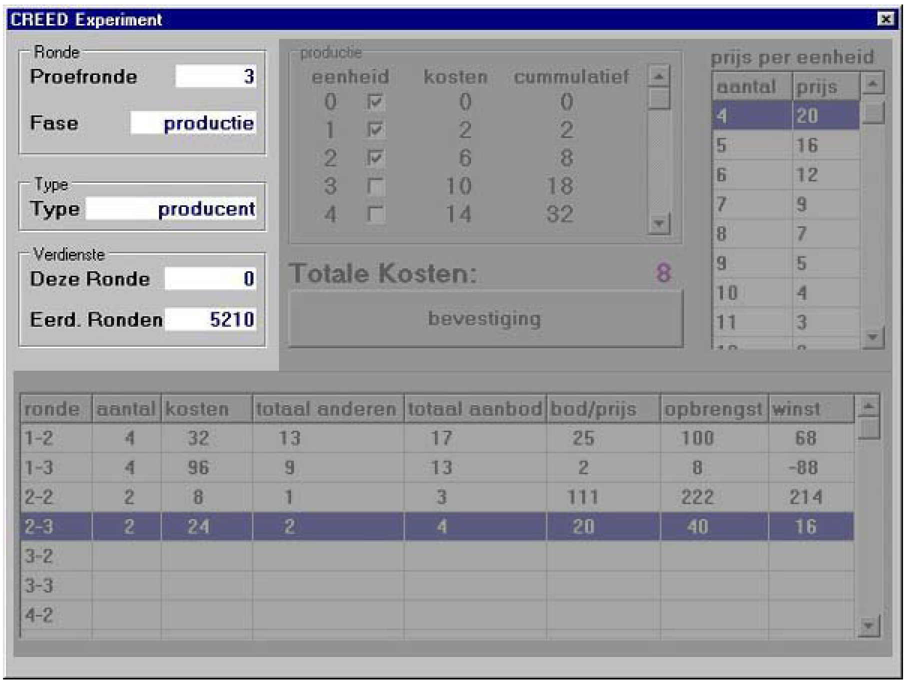


Figure 6: The results thus far

At the end of a round, the profit or loss is added to your earnings thus far. This is shown in the upper left area on your screen, at the earnings in this round. Below this, you see the total of your earnings in previous rounds (plus the starting amount).

You may lose money in a round. If your aggregate earnings should become negative, you will be excluded from further participation in the experiment and you will not be able to produce or trade any more goods. You will go home without earnings. It is under your own control whether or not you lose money.

You have reached the end of these instructions. You may take your time to go through them again. Please wait quietly until everyone has finished.

TABLES SUPPLIED TO SUBJECT IN AN ENVELOP

Costs per Unit

Unit	Costs	Cumulative costs
1	2	2
2	8	10
3	18	28
4	32	60
5	50	110
6	72	182
7	98	280
8	128	408
9	162	570
10	200	770
11	242	1012
12	288	1300
13	338	1638
14	392	2030
15	450	2480
16	512	2992
17	578	3570
18	648	4218
19	722	4940
20	800	5740
21	882	6622
22	968	7590
23	1058	8648
24	1152	9800
25	1250	11050
26	1352	12402
27	1458	13860
28	1568	15428
29	1682	17110
30	1800	18910

Price per unit

number	price
1	1973
2	1946
3	1919
4	1892
5	1865
6	1838
7	1811
8	1784
9	1757
10	1730
11	1703
12	1676
13	1649
14	1622
15	1595
16	1568
17	1541
18	1514
19	1487
20	1460
21	1433
22	1406
23	1379
24	1352
25	1325
26	1298
27	1271
28	1244
29	1217
30	1190
31	1163
32	1136
33	1109
34	1082
35	1055
36	1028
37	1001
38	974
39	947
40	920

number	price
41	893
42	866
43	839
44	812
45	785
46	758
47	731
48	704
49	677
50	650
51	623
52	596
53	569
54	542
55	515
56	488
57	461
58	434
59	407
60	380
61	353
62	326
63	299
64	272
65	245
66	218
67	191
68	164
69	137
70	110
71	83
72	56
73	29
74	2
75	0
76	0
77	0
78	0
79	0
80	0

number	price
81	0
82	0
83	0
84	0
85	0
86	0
87	0
88	0
90	0
91	0
92	0
93	0
94	0
95	0
96	0
97	0
98	0
99	0
100	0
101	0
102	0
103	0
104	0
105	0
106	0
107	0
108	0
109	0
110	0
111	0
112	0
113	0
114	0
115	0
116	0
117	0
118	0
119	0
120	0

Appendix 2: Theoretical Predictions

In this appendix we first derive the theoretical predictions given in table 3 of the main text for the Cournot game. Then, we analyze the supply function competition.

Cournot Competition

The predictions for C3.0 and C4.0 are derived from straightforward equilibrium calculations. We derive the prediction in table 3 for C3.2 in two steps. First, we derive the predictions for a continuous version of the game. Then, we use these as a double check for the predictions numerically estimated for the case where players can only choose discrete quantities.

Continuous Case:

We extend the duopoly model of Allaz and Vila (1993) to oligopolies with *n* producers and (symmetric) quadratic marginal cost functions, $MC(q_i) = cq_i^2$. Total costs are then $C(q_i) = 2\sum_{i=1}^{q_i} l^2$ $= \frac{2}{3}q_i^3 + q_i^2 + \frac{q_i}{3}$. Market demand is known and linear in quantities: $P(Q) = a - b.Q$ with $Q = \sum_{i=1}^{n} q_i$.

The relation between the forward contract market and the spot market is modeled as a two-stage game. In the first stage the producing firms take positions in the contract market represented by f_i, i=1,2,..n. In doing so, they take account of the equilibrium prediction that traders will supply to the spot market everything they obtain on the forward market.[1] Hence, in equilibrium, supply to the spot market is equal to total production.

Producer *i*'s profit for the second stage, when producing $q_i \geq f_i$, is then given by[2]:

$$\Pi_i = (a - b.\sum_{i=1}^{n} q_i).(q_i - f_i) - \frac{2}{3}q_i^3 - q_i^2 - \frac{q_i}{3}.$$

which gives the first order conditions:

$$\partial_{q_i}\Pi_i = 0 \iff -b.(q_i - f_i) + (a - b.\sum_{i=1}^{n} q_i) - 2q_i^2 - 2q_i - \frac{1}{3} = 0,\ q_i \geq f_i, \quad \text{(A1)}$$

To determine the equilibrium quantities $(\tilde{q}_1, \tilde{q}_2, \tilde{q}_3)$ to be produced in stage 2, we solve the system of equations (A1) in terms of producers' forward market positions f_1, f_2, f_3. The solution to (A1) has no analytical expression and is numerically determined. It has 8 roots, but only one of them,

[1] We will return to this assumption, below.

[2] Irrelevant for the maximization problem, we treat production costs as incurring only in the second stage.

$\tilde{q}_1, \tilde{q}_2, \tilde{q}_3$, leads to three non-negative forward positions. These quantities (as functions of f_1, f_2, f_3) determine the equilibrium price $P(\tilde{Q}) = a - b.\sum_{i=1}^{n} \tilde{q}_i$.

Moving to stage 1, we proceed with determining (numerically) the quantities supplied to the forward market. At stage 1, producers know that (in equilibrium) traders will bid the (spot) market equilibrium price for the units on the forward market. The producers' profit (as a function of forward positions and anticipated stage 2 reactions) is then given by:

$$\pi_i = P(\tilde{Q}(f_i, F_{-i})).\tilde{q}_i(f_i, F_{-i}) - \frac{2}{3}[\tilde{q}_i(f_i, F_{-i})]^3 - [\tilde{q}_i(f_i, F_{-i})]^2 - \frac{\tilde{q}_i(f_i, F_{-i})}{3},$$

where F_{-i} denotes the aggregated forward positions of the other producers. Taking the first order conditions $\partial_{f_i} \pi_i(f_i, F_{-i}) = 0$ and solving for f_i, we derive the producers' equilibrium forward positions f_1^*, f_2^*, f_3^*, which are used to determine the equilibrium spot market production levels $\tilde{q}_1, \tilde{q}_2, \tilde{q}_3$ and the market price $P(\tilde{Q})$.

If there is no forward contract market, then $f_i = 0$ and (A1) boils down to the standard Cournot profit maximization program. Table A2.A reports the numerically determined Nash equilibria for C3.0, C3.2, C4.0 as well as the joint profit maximizing (JPM) and Walras (W) scenarios with 3 and 4 producers. The JPM and W cases are determined in the standard way. To be complete, we need to double check that offering all units for sale on the spot market is a best response for traders (as assumed above). It turns out that the best reply is to sell 17.2 units, which is more than the 11.4 units they have. Hence, the corner solution of reselling everything is indeed a best response.

Table A2.A: Benchmarks for the Continuous Case[a]

	JPM (n=3)	**JPM (n=4)**	**NE C3.0**	**NE C3.2**	**NE C4.0**	**Walras (n=3)**	**Walras (n=4)**
q_{ti}^f	---	---	---	5.736	---	---	---
q_{ti}	10.777	8.509	14.406	15.320	12.364	17.071	14.406
q_t	32.330	34.034	43.217	45.959	49.457	51.212	57.623
p_t	1127.08	1081.07	833.143	759.112	664.652	617.283	444.190
Prod.S.	33576.5	34850.0	29389.9	26977.7	27203.4	20772.0	16774.1
Cons.S.	14110.8	15637.6	25214.0	28514.9	33021.3	35405.6	44824.9
TotalS.	47687.3	50488.1	54603.9	55492.6	60224.7	56177.6	61599.0
Eff. (%)	84.9	82.0	97.2	98.8	97.8	100	100

[a] q_{ti}^f = forward production by producer *i*; q_{ti} = total quantity produced by producer *i*; q_t = total quantity produced in the market; p_t = transaction price; *Prod.Sr*=producer surplus (trader surplus is equal to 0); *Cons.S.*= consumer surplus; Total S. =total surplus; *eff* = efficiency.

Discrete Case:

As subjects in our experiment could only supply integer quantities, we base our data analysis on the equilibrium outcomes for the discrete case. This is determined using the GAMBIT software (McKelvey, McLennan and Turocy, 2002).[3]

We start with the cases without a forward market (C3.0 and C4.0). Given the large strategy sets (*i.e.*, 30 possible actions per producer), which would require a considerable time and computing facilities to explore all possibilities, we searched for equilibria in windows of 20 units (*i.e.*, for $q_{ti} \in [0,19]$, $q_{ti} \in [1,20]$, $q_{ti} \in [2,21]$, *etc*. Using this method, we found equilibria in pure strategies. In C3.0, the equilibria entail any two producers supplying 14 units and the third producer supplying 15 units. In aggregate they produce 43 units equilibrium (compare this to the equilibrium production of 43.217 units in the continuous case; *cf*. table A). In C4.0, three producers supply 12 units in equilibrium and the fourth supplies 13 units, for a total of 49 (49.457 in the continuous case). These numbers are reported in table 3 of the main text.

For C3.2, we restrict the window size for the equilibrium search in GAMBIT to 4 units for the forward market and 5 units for the spot market (*e.g.*, we search for $q_{ti}^f \in [0,3]$ and $q_{ti} - q_{ti}^f \in [0,4]$, $q_{ti}^f \in [1,4]$ and $q_{ti} - q_{ti}^f \in [0,4]$, *etc*.). In addition, we reduced the two-stage game to its normal form and searched for an equilibrium of the type (q_{ti}^f, $q_{ti} - q_{ti}^f$) in pure and mixed strategies. The equilibrium that we found when quantities are discrete is partially in mixed strategies: each producer supplies six units on the forward market. On the spot market, each producer supplies 9 units with probability *.944343* or 10 units with probability *.055657*. This yields a total (expected) supply of 45.167. This is slightly lower than the equilibrium quantity for the continuous case (45.959).

Supply Function Competition

We now derive the set of quantities that can be supported by a supply function equilibrium for each of our treatments. In the absence of demand uncertainty, Klemperer and Meyer (1989) show for their set-up that any quantity between (and including) the Cournot equilibrium and the Walras quantity can be supported in a supply function equilibrium. We show that this also holds for each of our treatments. We do show by first deriving for each quantity between and including Cournot and Walras a set of supply functions that yield this quantity as an equilibrium. Then, we show that no quantity outside of this range can be supported in equilibrium.

First, it is easy to see that in each of our treatments, the Cournot quantity is also an equilibrium quantity in the corresponding supply function case. If every player submits a supply function consisting of 1's for the quantity prescribed by Cournot and infinite prices for all other units, then no profitable deviation is possible.

[3] The JPM and W predictions for the discrete case are determined in a straightforward manner.

Second, we can show that the Walras quantity (51 units for n=3; 56 units for n=4, cf. table A2) can also be supported by a supply function equilibrium. First consider the case without forward market. Let all producers bid in their 30 units at the Walras price. If one producer bids in units at higher prices in an attempt to exercise market power, the remaining producers are still offering 60 (n=3) or 90 (n=4) units at the Walrasian price, in both cases higher than the Walras quantity. Hence, no market power can be exercised. A similar argument can be made for the case with forward market. Consider the situation where the trader is bidding the Walras price on the forward market and all producers and the trader are bidding in all (remaining) units at the Walras price on the spot market. In this case, each producer will receive the Walras price for any unit sold and sell the (individual) Walras quantity. Any additional unit sold will yield a loss and given that she cannot affect the price she will not want to withhold units. In other words, her optimum is to sell the Walras quantity, irrespective of whether the units are sold via the forward market or the spot market and she has no incentive to deviate, given the choices of the others. As for the trader, any situation where the quantity sold on the forward market is insufficient to exercise market power on the spot market constitutes an equilibrium where she has no incentive to deviate from (Walras) pricing.

Similar arguments show that any quantity and price between Cournot and Walras can be supported in equilibrium. Again, first consider the case without forward markets. Let Q* be a quantity between Cournot and Walras, with corresponding demand price P(Q*). Let MC(Q*) be the marginal cost (for society) of producing the Q^{*th} unit.[4] Now, let each producer submit a supply function consisting of p=MC(Q*) for q<Q*/n and p=P(Q*) for all other units. Note that this step-function yields price P(Q*) for all units sold. It is easy to see that this set of supply functions constitutes an equilibrium. If a single producer were to withdraw a unit offered at the lower price, the price at which units are sold would not change; hence, this deviation is not profitable. If she were to offer an additional unit at the lower price, the revenue obtained for each unit would decrease by dP(Q*)/dQ*. This is equivalent to offering a Q^*+1^{th} unit in quantity competition. Because Q* is, by assumption, larger than the Cournot quantity, this cannot be profitable.[5] As with the Walras case, the extension to forward markets is straightforward. Assume a trader bidding P(Q*) on the forward market and offering any units obtained for P(Q*) on the spot market. Once again, the producer is indifferent between selling the equilibrium quantity on the forward or spot markets and has no incentive to deviate from this quantity. For the trader, as long as the quantity sold on the forward market is insufficient to exercise market power on the spot market, this bidding constitutes an equilibrium.

[4] Given symmetry, each producer (if n=3) will produce q*=Q*/3 units in case Q* is a multiple of 3 and either q*=round (Q*/3) or q**=q*+1 if Q* is not a multiple of 3. Denote the firm's marginal cost curve by mc (hence, MC is the horizontal summation of all mc's). Then, if Q* is a multiple of 3, all producers face equal marginal costs mc(q*)=MC(Q*). If Q* is not a multiple of 3, some firms face mc(q*), others mc(q*+1)=MC(Q*).

[5] Note that the equilibrium derived for the Walras quantity is a special case of the step-function derived here because MC(W)=P(W). Moreover, this suggests a second set of functions that supports the Cournot quantity in addition to the set derived above: each producer offers c units at MC(C) and the remaining units at P(C), where c denotes the individual Cournot quantity. It is easy to see that this indeed constitutes an equilibrium. Hence, any quantity between and including the Cournot and Walras quantities can be supported by an equilibrium where producers submit this type of step-functions.

Because quantities above the Walras level cannot be part of a supply function equilibrium (at least one producer would be selling units below marginal costs), what remains to be shown is that producers cannot exert more market power with supply function competition than with quantity competition (*i.e.*, no quantities below the Cournot level can be part of an equilibrium.

To show this, we provide a formal proof that the equilibrium quantity in the SF treatments is larger than or equal to the equilibrium quantity in the corresponding C treatments. Let $q_{Cx.y,i}$ denote the quantity produced by firm i=1,..x, in Cournot equilibrium Cx.y (=C3.0; C4.0 or C3.2). Define $Q_{Cx.y} \equiv \sum_{i=1}^{n} q_{Cx.y,i}$. Let $q_{SFx.y,i}$ denote the quantity produced by firm i in supply function equilibrium SFx.y (= SF3.0; SF4.0 or SF3.2). Define $Q_{SFx.y} \equiv \sum_{i=1}^{n} q_{SFx.y,i}$.

Theorem: $Q_{SFx.y} \geq Q_{Cx.y}$.

Proof[6]: Assume that Q* is the quantity produced in a supply function equilibrium SF*, and let

$$Q^* < Q_{Cx.y} \qquad \text{(A2.1)}$$

Assume that firm i produces q_i^* units in equilibrium SF*.

Denote by 1_q a q-vector of 1's (the lowest possible ask), by S_{1_q} ($S^m_{1_q}$) an individual (aggregate) supply function where the first q elements have been replaced by 1_q. In the equilibrium SF*, replace firm i's supply function by the function $S_{1_{q_i}}$, where q_i is short for $q_{SF^*x.y,i}$. Denote the aggregate supply function that this yields by $S^{m*}_{1,i}$. In words: $S^{m*}_{1,i}$ replaces all of i's prices for inframarginal units by 1's, compared to S^{m*}. Using the notation in section 3.4 this gives i's *individual* supply function $S_{1_{q_i*}} = (1,...,1, s_{iq_i*+1},..., s_{i30})$.

Next, consider an aggregate supply function where supply prices for all inframarginal units (i.e., not just for i) are equal to 1, i.e., consider $S^m_{1_{Q*}} \equiv (1,...,1, s^m_{Q*+1},..., s^m_{30n})$.[7]

Note that both of these changes affect the aggregate supply function in SF* only for inframarginal units (in both cases each producer's quantity is the same as in SF*, but the producers may be placed in different orders). Hence, it is easy to see that

$$Q(S^{m*}_{1,i}) = Q(S^m_{1_{Q*}}) = Q^* . \qquad \text{(A2.2)}$$

[6] In the notation in this proof, we suppress subscript t (indicating round).

[7] It is important to note that we are not considering a market maker that sets other producers' supply prices equal to 1. We use $S^m_{1_{Q*}}$ to derive an equivalence in payoffs without assuming that it is ever observed.

Thus, the quantity produced in SF* is the same as in the case where i asks supply prices equal to 1 for inframarginal units, and the same as in the case where all producers ask price 1 for inframarginal units. Using our price setting equation $p_t = p(q_t)$, this implies that market price is the same in these situations as well. Because costs are unaltered if produced quantity does not change, all firms' profits are the same across these situations:

$$\pi_j(S_{1,i}^{m*}) = \pi_j(S_{1_{Q*}}^{m}) = \pi_j(S^{m*}),\ j = 1,..,x. \qquad \text{(A2.3)}$$

Next, we consider whether i can profitably deviate from its original supply function. To do so, replace firm i's supply function by the function $S_{1_{q_i+1}}$ (where q_i is again short for $q_{SF*x.y,i}$). Denote the aggregate supply function that this yields by $S_{1+,i}^{m*}$. In words: in $S_{1+,i}^{m*}$, i replaces all of its prices for inframarginal units by 1's and replaces the first extramarginal unit by a 1 as well. This gives i's *individual* supply function $S_{1_{q_i*}} = (1,...,1, s_{iq_i*+2},..., s_{i30})$.

Finally, consider a supply function where all supply prices for inframarginal units in S^{m*} (i.e., not just for i) are equal to 1, and additionally the first extramarginal unit is priced at 1, i.e., consider $S_{1_{Q*+1}}^{m} \equiv (1,...,1, s_{Q*+2}^{m},..., s_{30n}^{m})$.

Comparing $S_{1+,i}^{m*}$ to $S_{1_{Q*+1}}^{m}$, we once again see that the quantity produced is the same in both cases and, hence, so are the market price and the costs. Therefore, payoffs are the same:

$$\pi_j(S_{1+,i}^{m*}) = \pi_j(S_{1_{Q*+1}}^{m}),\ j = 1,..,x. \qquad \text{(A2.4)}$$

Now, note that a competition between firms offering supply functions consisting of 1's is equivalent to Cournot competition. Because $Q^* < Q_{Cx.y}$, an increase in quantity offered (i.e., in the number of units offered at price 1) from $S_{1_{q_i}}$ to $S_{1_{q_{i+1}}}$ by firm i will increase i's profits:

$$\pi_i(S_{1_{Q*}}^{m}) < \pi_i(S_{1_{Q*}+1}^{m}). \qquad \text{(A2.5)}$$

Combining (A2.3), (A2.4) and (A2.5) yields

$$\pi_i(S_{1+,i}^{m}) > \pi_i(S^{m*}), \qquad \text{(A2.6)}$$

i.e., i can improve her payoffs by switching to a supply function with the first q_i*+1 units offered at price 1, given that the rest stick to their original supply functions. This profitable deviation contradicts the assumption that SF* in as equilibrium. Hence, supply function equilibria with $Q^* < Q_{Cx.y}$ do not exist. Q.E.D.

Appendix 3: Efficiency Analysis

In this appendix, we analyze the possible sources of inefficiency in out experimental setup. To do so, we first consider the situation without a forward market. Total surplus σ_q at production level q (and corresponding price p) can be calculated as the sum of consumer (γ_q) and producer surplus (ρ_q):

$$\gamma_q = \sum_{l=1}^{q} (2000 - 27l - p) \tag{A3.1a}$$

$$\rho_q = pq - 2\sum_i \sum_{l=1}^{q_i} l^2 \tag{A3.1b}$$

$$\sigma_q = \gamma_q + \rho_q \tag{A3.1c}$$

Denoting surplus at the Walras equilibrium by σ_w, the efficiency at production level q is given by:

$$\Omega_q \equiv \sigma_q / \sigma_w \tag{A3.2}$$

From (A3.1b) it follows that realized efficiency not only depends on the level of production, but also on the distribution of production across producers. Aside from the traditional allocative efficiency, a second type of inefficiency can occur in this environment. Because we have quadratic marginal cost functions, production inefficiency will occur if production is not split equally across producers. For any total production level q, define the 'equal split' distributions $Q_q^e \equiv (q_1^e, ..., q_n^e)$ as the production levels q_i^e that fulfill:

$$\begin{aligned} & q_i^e \in \square\ , \\ & \sum_i q_i^e = q\,, \\ & \left| q_i^e - q_j^e \right| \in \{0,1\}, \quad i \neq j \end{aligned} \tag{A3.2}$$

i.e., q is split as equally as possible across producers. Now, we compare producer surplus in the observed distribution of q across producers, $Q_q^o \equiv (q_1^0, ..., q_n^0)$ to that in Q_q^e. Production efficiency at Q_q^o is defined as:[1]

[1] Because it makes a difference how production is distributed across producers, from here onward, the subscript q to the efficiency symbols will refer to the distribution of production (automatically implying the quantity as well).

$$\Phi_q^0 \equiv \rho_q^0 / \rho_q^e \tag{A3.3}$$

where superscript 'o' ('e') indicates that the variable is evaluated at Q_q^o (Q_q^e) and $\rho_q^0 \leq \rho_q^e$. Note that the interpretation of Φ_q^0 as an efficiency measure is not straightforward if $\rho_q^0 < 0$ (or even $\rho_q^e < 0$). In that case producers are making a loss (even if producing efficiently). Because our data only have seven cases with $\rho_q^0 < 0$ (five of which also have $\rho_q^e < 0$), we maintain the interpretation of Φ_q^0 as an efficiency measure.

For the *in*efficiency at Q_q^o, $1-\Omega_q^0$, it easily follows from eqs. (A3.1)-(A3.3) that:[2]

$$1-\Omega_q^0 = \frac{1}{\sigma_w}\left\{(\gamma_w - \gamma_q) + (\rho_w - \rho_q^e) + (1-\Phi_q^0)\rho_q^e\right\} \tag{A3.4}$$

Eq. (15) shows that there are three possible sources of inefficiency. The first term in brackets reflects the loss in consumer surplus due to an inefficient production level. The second term gives the loss in producer surplus due to an inefficient level of production, (hypothetically) assuming this level is produced efficiently.[3] The third term in brackets describes the efficiency loss caused by production inefficiency.

Next consider the situation with a forward market. Note that no surplus is *created* by traders. They do not produce, nor consume anything. In the forward market, they can attempt to obtain some of the surplus created by producers, however. As shown by Allaz and Vila (1993), their profit is zero in equilibrium. The intuition is that the two traders are bidding in a common value auction with (in equilibrium) certainty about the value of the units they buy and will therefore bid the value. In practice, traders can cause a redistribution or a decrease in realized total surplus. The surplus that producers and traders realize, depends on the quantities in the two markets and is denoted by $\hat{\rho}_{q^f,q^{s1}}$ and $\tau_{q^f,q^{s2}}$, respectively. Consumer surplus is created by the total quantity supplied to the spot market, q^s, which is not necessarily equal to the quantity produced, q $(= q^f + q^{s1})$. We now have the following surplus for consumers, producers and traders:

[2] We assume that production is efficient in the Walras equilibrium.

[3] Note that, typically, $(\rho_w - \rho^e) < 0$, *i.e.*, producers gain from restricting production below Walras. Sometimes, $\rho^e < \rho^w$ or even $\rho^e < 0$ because producers are restricting production too much or producing more than the Walras quantity.

$$\gamma_{q^s} = \sum_{l=1}^{q^s} (2000 - 27l - p) \tag{A3.5a}$$

$$\hat{\rho}_{q^f, q^{s1}} = bq^f + pq^{s1} - 2\sum_i \sum_{l=1}^{q_i} l^2 \ , \tag{A3.5b}$$

$$\tau_{q^f, q^{s2}} = pq^{s2} - bq^f \tag{A3.5c}$$

Which gives total surplus:

$$\sigma^0 = \gamma_{q^s} + \hat{\rho}_{q^f, q^{s1}} + \tau_{q^f, q^{s2}} \tag{A3.5d}$$

Note that for $q^{s2} = q^f$, it follows that $\hat{\rho}_{q^f, q^{s1}} + \tau_{q^f, q^{s2}}$ reduces to:

$$(\hat{\rho} + \tau)_{q^s} = pq^s - 2\sum_i \sum_{l=1}^{q_i} l^2 = \rho_{q^s} \ , \tag{A3.6}$$

where ρ_{q^s} is given in eq. (A3.1b). In other words, if traders resell everything, then for any production level *q* (with corresponding market price *p*), a sale of q^f on the forward market at price *b* will yield a redistribution of surplus (as defined in A3.1b) from producers to traders of $(p-b)q^f$ without affecting the aggregate surplus on the supply side of the market. Hence, for efficiency it does not matter how much is sold via the forward market, as long as traders sell everything on the spot market: $q^{s2} = q^f$.

A decrease in realized surplus will occur, if traders do not resell on the spot market all goods they buy on the forward market. Consider production level $q \ \ (= \sum_i q_i)$, forward production quantity q^f , and spot market quantity $q^s \ \ (= q^{s1} + q^{s2})$. By comparing the surplus at observed production Q_q^o to the surplus at the Walras production level (with all forward trades resold on the spot market), we obtain:

$$\begin{aligned}
1 - \Omega_q^0 = \ & \frac{1}{\sigma_w}\left\{(\gamma_w - \gamma_{q^s}) + (\rho_w - \hat{\rho}_{q^f, q^{s1}} - \tau_{q^f, q^{s2}})\right\} = \\
& \frac{1}{\sigma_w}\left\{(\gamma_w - \gamma_{q^s}) + (\gamma_q - \gamma_{q^s}) + (\rho_w - \rho_q) + p(q)q - p(q^s)q^s\right\} = \qquad \text{(A3.7)} \\
& \frac{1}{\sigma_w}\left\{(\gamma_w - \gamma_{q^s}) + (\gamma_q - \gamma_{q^s}) + (\rho_w - \rho_q^e) + (1 - \Phi_q^0)\rho_q^e + p(q)q - p(q^s)q^s\right\}
\end{aligned}$$

Eq. (A3.7) shows that there are five possible sources of inefficiencies in case of forward markets. As before, the first term gives the consumer surplus lost due to an inefficient level of production. The second term adds to this loss in consumer surplus if traders do not resell all units. The third term is negative and reflects the gain of producer surplus which would occur even if producers produce efficiently and all products are resold. The fourth term reflects production inefficiency. The final term gives the producer surplus lost or gained (at market value) because not all units produced for the forward market are resold. Note that if traders do resell all units, eq. (A9) reduces to (A6), because the second and fifth terms drop out.

Appendix 4: Group-level Results

Tables A4A and A4B provide, respectively, the group level average production levels and efficiencies across the last 10 rounds.

Table B: Average Total Production in the last 10 rounds

Group	C3.0	SF3.0	C3.2	SF3.2	C4.0	SF4.0
1	30.7	38.9	41.8	44.1	41.5	50.7
	(2.06)	(2.85)	(3.91)	(2.38)	(1.96)	(1.06)
2	42.2	43.9	44.8	48.3	47.2	52.0
	(2.86)	(.32)	(2.62)	(2.36)	(2.25)	(0)
3	42.6	46.6	46.7	49.9	49.2	52.5
	(1.58)	(1.43)	(2.87)	(1.60)	(3.55)	(3.10)
4	43.7	47.2	47.6	50.0	50.3	52.7
	(4.35)	(1.87)	(2.84)	(0)	(2.16)	(2.83)
5	44.5	48.3	49.3	50.0	52.0	54.0
	(1.96)	(3.37)	(2.98)	(0)	(3.37)	(1.89)
6	46.9	49.3	49.4	50.4	57.7	54.9
	(1.66)	(2.11)	(3.53)	(1.26)	(3.47)	(.88)
7	47.2	49.8	---	---	58.2	55.7
	(8.23)	(1.62)			(6.02)	(.82)
Average	42.54	46.29	46.60	48.78	50.87	53.21
	(5.57)	(3.80)	(2.91)	(2.41)	(5.86)	(1.74)
Average per producer	14.18	15.43	15.53	16.26	12.71	13.30

Note: Standard deviations are in parenthesis. The average standard deviation is computed on the basis of the values of the average levels for the different groups.

Table C: Average Efficiency in the last 10 rounds

Group	C3.0	SF3.0	C3.2	SF3.2	C4.0	SF4.0
1	79.1	93.1	93.1	96.1	87.3	97.0
	(2.79)	(1.99)	(2.50)	(2.64)	(1.45)	(.28)
2	96.1	93.8	94.0	96.5	96.2	95.4
	(2.88)	(1.31)	(3.85)	(2.46)	(1.39)	(.32)
3	96.7	97.9	97.8	99.3	96.7	97.4
	(1.02)	(.94)	(1.55)	(.88)	(1.59)	(1.70)
4	96.0	99.0	98.6	99.8	96.4	97.4
	(2.56)	(.69)	(1.65)	(.17)	(1.75)	(1.14)
5	97.6	95.6	98.6	99.5	97.8	96.0
	(.97)	(8.31)	(1.00)	(.17)	(.70)	(6.72)
6	97.9	98.8	98.3	99.5	98.0	97.5
	(.67)	(1.21)	(.86)	(.55)	(1.03)	(1.74)
7	95.9	99.1	---	---	95.4	99.2
	(1.22)	(.65)			(2.12)	(.55)
Average	94.2	96.8	96.7	98.5	95.4	97.1
	(6.68)	(2.57)	(2.48)	(1.67)	(3.67)	(1.20)

Note: Standard deviations in parenthesis. The average standard deviation is computed on the basis of the values of the average levels for the different groups.

Appendix 5: Individual Supply Functions

In this appendix, we have a closer look at the supply functions submitted for the spot market by participants in our SF-sessions. It appears that most producers submitted 'proper' supply functions, i.e., the prices they asked varied over the units.

The submitted functions changed across rounds. A comparison of individual supply functions between the first 10 and the last 10 rounds suggests a change from mostly increasing functions with steps over the whole range of units towards functions that were more flat and functions with a large flat part for initial units towards the end of the experiment. Most of the latter had a hockey stick shape. We define a supply function as having a hockey stick shape if the first x% of the prices submitted are equal to p_1 and the last y% are larger than p_1, with $60 \leq x \leq 99$ and $0<y<40$. In SF3.0 the proportion of flat and hockey stick functions doubled from 38% in rounds 1-10 to 76% in rounds 15-25. In SF3.2 this proportion grew from 58% to 83% and in SF4.0 from 29% to 47%.

To investigate in more detail the supply functions submitted by experienced participants, Figures A5A, A5B and A5C report each individual's average supply function submitted over the last 10 rounds. Each panel shows the results for one market. Average supply functions are indicated by colored lines. Note that each participant in one of the SF sessions is represented by exactly one line.[1] The average function for an individual was obtained by calculating for each unit the average price asked in rounds 15-25, not considering rounds in which no price was asked for a unit. Note that this method may yield supply functions that are not monotonically increasing. A producer who offered *k* units at a high price in five rounds and offered *k*+*l* units at a lower price in five other sessions will have a higher average supply price for the first *k* units than for the last *l*.

The horizontal thin (black) lines in each market denote the average price realized in the final 10 rounds. The dot markers indicate individual average quantities sold at this price. For presentational purposes, these markers are shown on the average price line, though actual (average) realized prices may differ across individuals. For SF32, the markers stand for average total quantities sold, i.e., on the forward and spot markets.

The graphs show quite some variation across individuals, especially in the cases without forward markets. As mentioned above, most functions do exhibit a flat range for initial units, however. With forward market, there is less variation across producers. This is largely due to the fact that initial units are sold on the forward markets, hence, not included in the supply function. Most producers submit their remaining units using a flat function around the trading price. Many traders, on the other hand, offer all units at price 1 (the lowest supply price allowed). For them, this is the best guarantee to resell all units. Note that the marginal cost for supplying any unit is zero for traders. They submitted these functions in more than 90% of the cases in the last 10 rounds. When doing so, they always sold all units.

[1] Due to a computer bug, we have no data on the supply functions submitted in the first two SF3.2 sessions. The results reported are based on the remaining sessions.

To compare the supply functions submitted in various treatments, we estimate aggregate supply functions using regression methods. For each group, we constructed the supply function for each of the last ten rounds. These supply functions were then used to estimate an aggregate supply function for each treatment. We estimated the price for each quantity with a cubic spline (and an intercept term). Figure A5D plots the estimated supply functions. It shows that supply functions are flatter as competition increases, which confirms our finding that suppliers bid more competitively as competition increases. Note also that the estimated supply functions exhibit higher prices for SF3.2 than for SF4.0 at any quantity level produced.

To illustrate the difference between traders and producers, we estimated an aggregate supply function for each of them separately. The plot of the estimated function for producers lies well above that of the traders. Nevertheless, this function is relatively flat for the first forty-odd units at a price of about 500. This seems to indicate a willingness to sell these units at a constant price (below the equilibrium price) and to charge higher prices for subsequent higher cost units. The estimated supply function for traders has a flat segment at low quantities, which again reflects them offering units at price equal to 1.

Figure A5A: Individual Average Supply Functions: Last 10 rounds of SF30

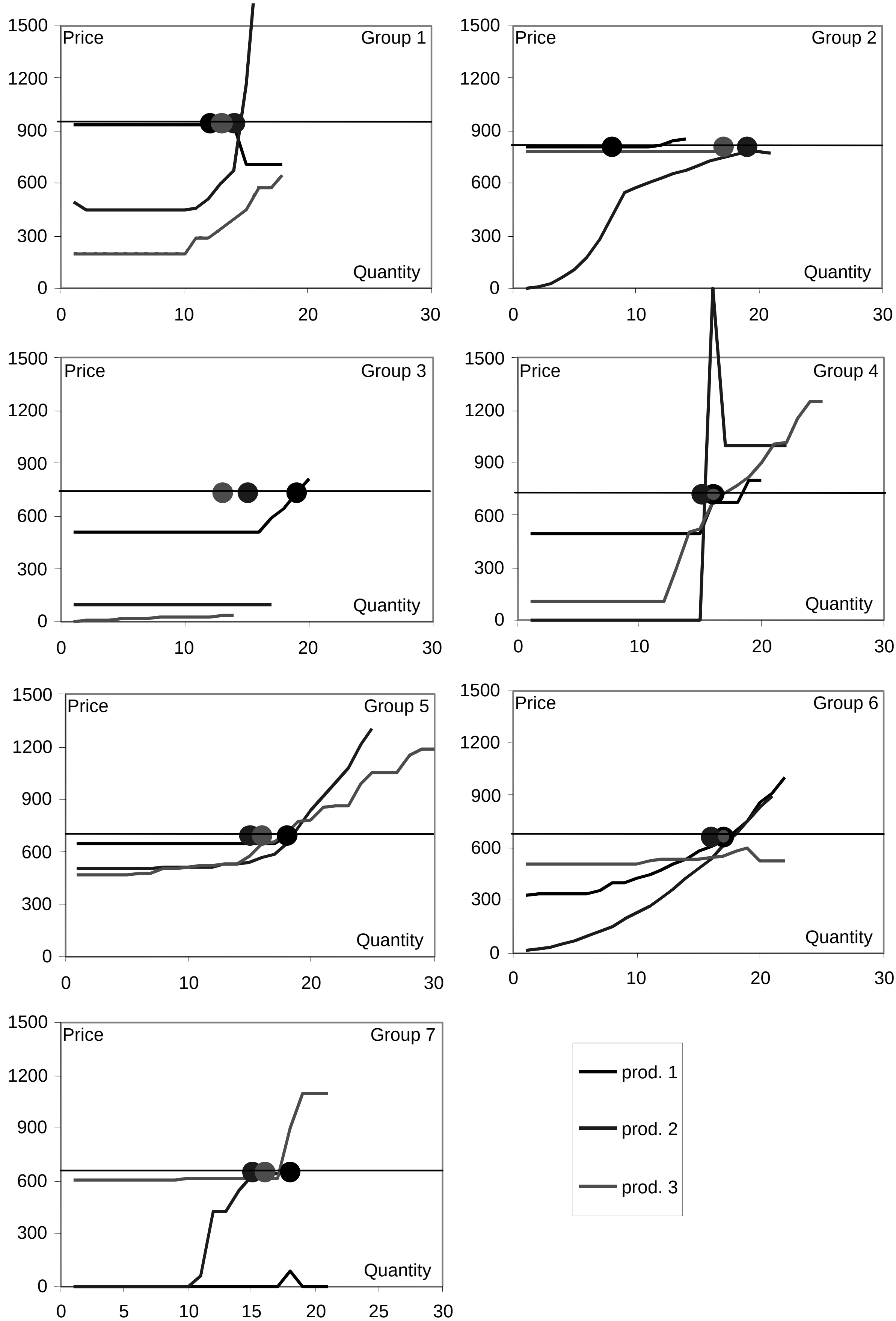


Figure A5B: Individual Average Supply Functions: Last 10 rounds of SF32

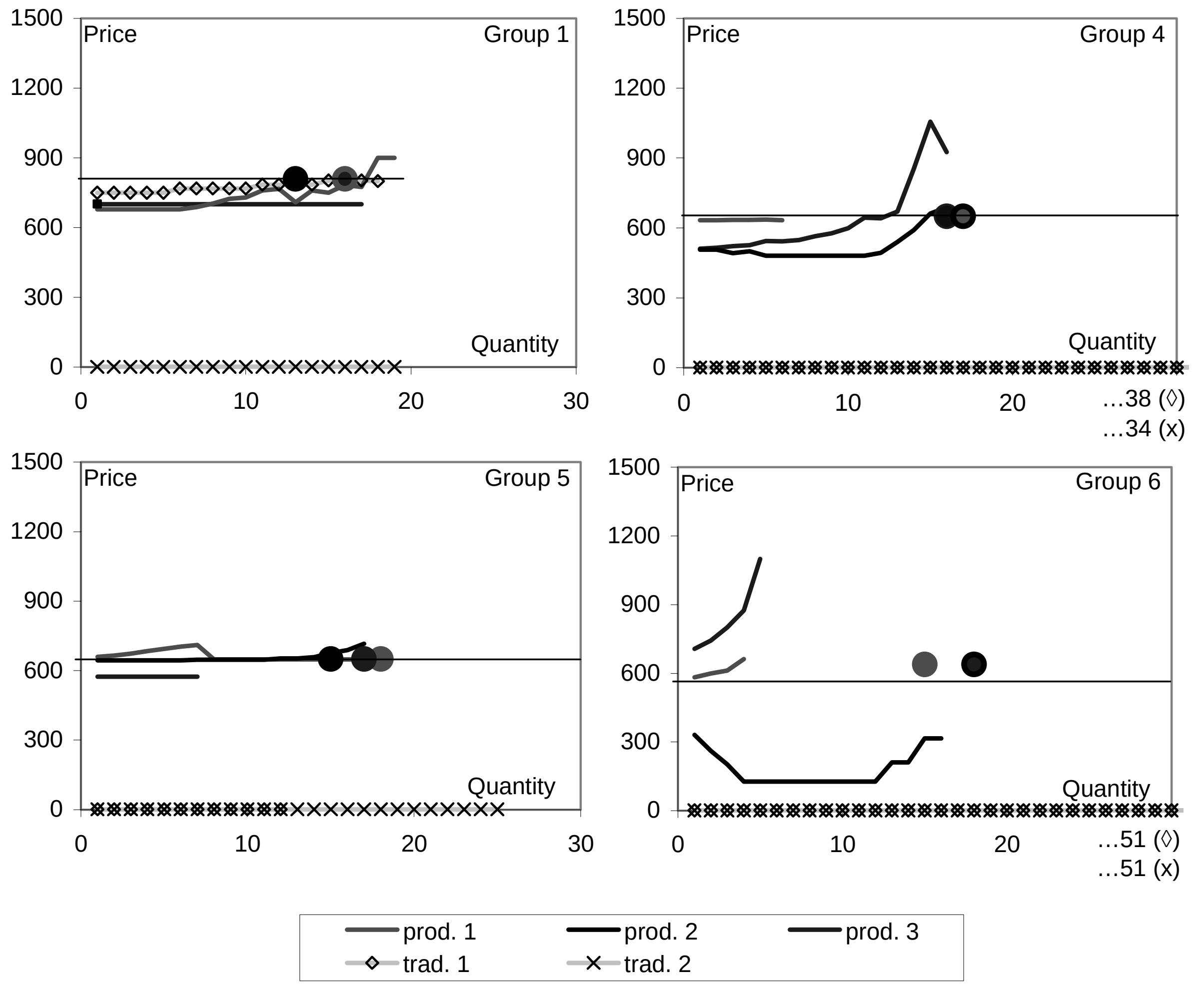


Figure A5C: Individual Average Supply Functions: Last 10 rounds of SF40

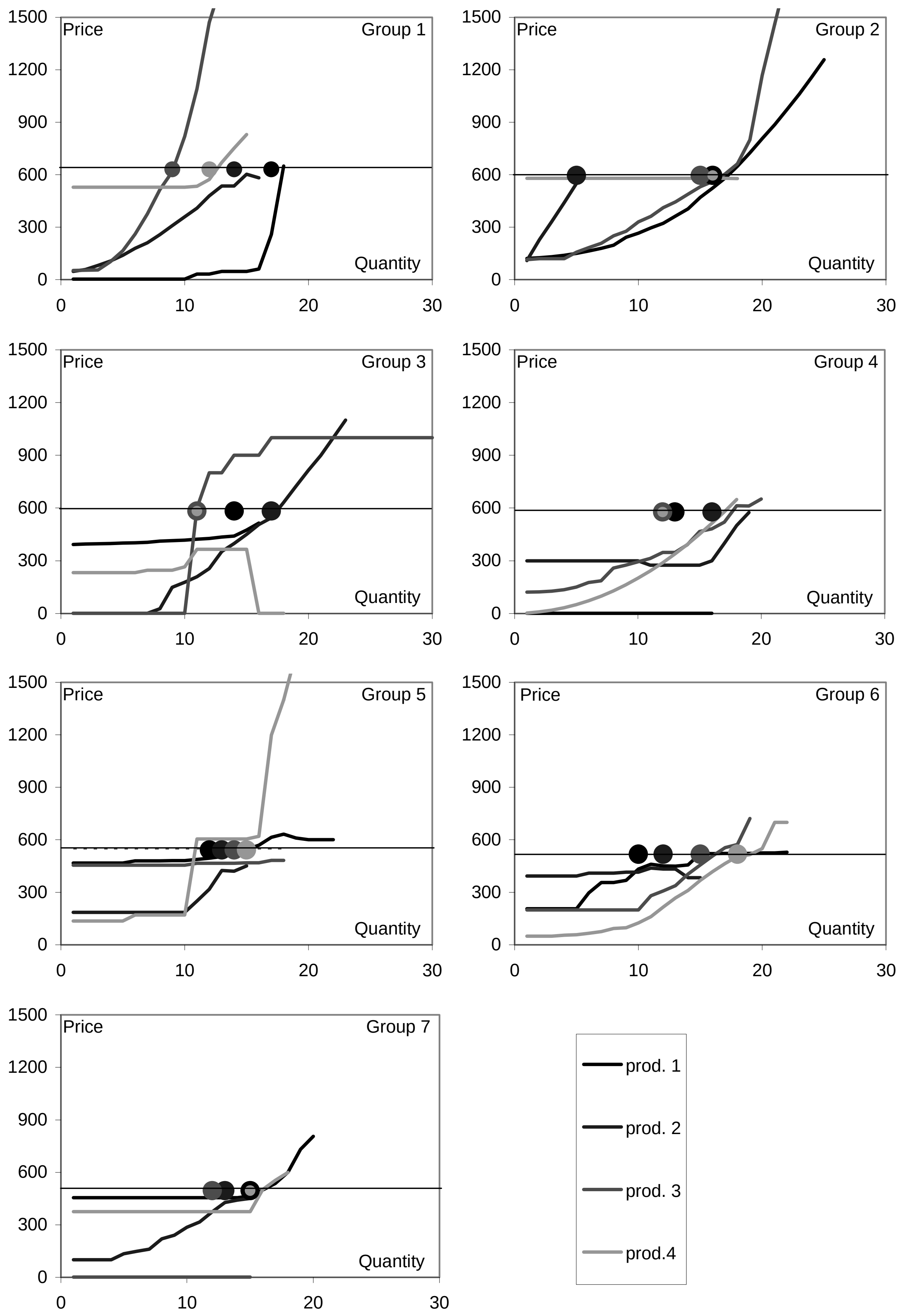


Figure A5D: Estimated Aggregate Supply Functions in the last 10