Do Forward Markets Enhance Competition? Experimental Evidence †

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Abstract: Allaz and Vila (1993) show that oligopolists have a strategic motive to sell forward. In their model the possibility of forward trading increases competitiveness between firms, raising consumer surplus and welfare. In this study we examine this prediction in a controlled laboratory environment. We investigate how and to what extent the market institution and the number of firms affect competition, in theory and in our experimental markets. Our findings support the main comparative-static predictions of the model but also suggest that the competition-enhancing effect of a forward market is weaker than predicted. In contrast, entry has a stronger competition-enhancing effect.

Keywords: Cournot Competition; Forward Markets; Spot Markets; Experiments.

JEL Classification Numbers: C72, C92, D43, L13

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1 Introduction

Forward contracting has a long history in commodity markets but has also become increasingly important elsewhere, particularly in financial asset trading and in the energy sector. For market design it is of interest whether forward markets have desirable effects on welfare and efficiency. An example is the recent debate on the design flaws in the Californian electricity market. The Market Surveillance Committee, a group of independent advisers to the governing board of the Californian Independent System Operator, recommended to remove any restrictions on forward contracting, suggesting that this would not only prevent seasonal price peaks but also "significantly limit the ability of generators to exercise market power".[1]

The idea that forward markets might enhance competition has also been discussed in the theoretical literature. Allaz and Vila (1993) (henceforth AV) suggest a further, strategic, reason for the existence of forward markets beyond the usual hedging motive. They show that a single firm may obtain a leadership position by selling forward; motivated by this opportunity, all producers offer forward contracts and as a consequence compete more aggressively overall, resulting in more output at lower prices and thereby increasing consumer surplus and total welfare.[2] Relative to an increase in competitive pressure due to entry, the competition-enhancing effect of forward trading is surprisingly strong in AV's framework: introducing a forward market is predicted to have the same effect as *squaring* the number of competing firms. There is some controversy about AV's result. In particular, Harvey and Hogan (2000) and Kamat and Oren (2004) doubt that the competition-enhancing effect holds if firms play the game repeatedly, as is undeniably the case in most real markets. They argue that a dynamic setting may enable firms to commit to keeping their forward positions to a minimum.

In this paper, we report the results of a laboratory experiment, designed to assess the behavioral relevance of AV's predictions in a repeated market. Testing whether and to what extent forward markets improve efficiency in the field requires strategic data, which is extremely difficult to obtain from real firms. Laboratory methods, on the other hand, allow to set and manipulate critical parameters such as

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[1] Wolak, Nordhaus and Shapiro (2000), p.15.

[2] Others have arrived at similar conclusions, see for example von der Fehr and Harbord (1992), Bolle (1993) and Powell (1993); see also the paper by Allaz (1992). The intuition for this intriguing result is that a forward market has some commitment value. Other commitment devices can create very similar effects in oligopolies, for example strategic delegation (see Huck, Müller and Normann, 2004).

the number of competitors, cost functions and demand behavior. Our data comprises observations on forty-six laboratory-controlled experimental markets. Two benchmark conditions were employed where sellers engaged in standard Cournot competition, with either two or four sellers per market. In the AV treatments, the duopolists or quadropolists could first offer units on a forward market before entering the spot market stage. Making transactions on the forward market committed sellers to the production of their contracted quantities but they were free to produce additional units for the residual demand on the spot market.

We find that forward markets enhance competition and efficiency in our experiment. Production levels and consumer surplus are systematically higher in the AV treatments than under Cournot, and prices are significantly lower. However, in contrast to the prediction, we also find that changing the number of competitors in the Cournot markets from two to four is far more effective than introducing the forward trading institution.

To the best of our knowledge we are the first to examine AV's predictions in the laboratory. Previous experimental work has investigated other aspects of forward markets. Sunder (1995) reviews experiments studying the *informational* efficiency of forward markets. Reynolds's (2000) experiment examines the famous Coase (1972) conjecture which has some resemblance with AV's finding. However, there are also important differences, most notably perhaps that in AV's setup a monopolist would not be affected by the introduction of a forward market. Consequently, we focus on competing firms and their strategic interactions, the key elements driving AV's result. Phillips, Menkhaus and Krogmeier (2001) report an experiment where sellers and buyers have access to a forward market and/or a spot market under a double auction trading mechanism. They find that consumer surplus and market efficiency are highest when trading is only allowed on the forward market and lowest when trading is only allowed on the spot market. However, in their design inventory costs provide sellers with an additional incentive to operate on the forward market. Therefore the strategic effect of forward trading is not clear (nor is this the focus of their study).

Since we conducted our experiment a related laboratory study by Brandts, Pezanis-Christou and Schram (2003) has emerged that nicely complements our paper. Their design is also inspired by AV's model, but incorporates competition in supply functions, a quadratic marginal production cost schedule and an oligopolistic trader market linking forward and spot stage. Our design, in contrast, abstracts from costs,

focuses exclusively on quantity competition and uses a simulated, competitive, trader market under the control of the experimenter. With their enriched environment Brandts et al. aspire to mimic some important aspects of real electricity markets, while we are more interested in the principle workings of the forward market institution. For this purpose, the simplicity of our design comprises the advantage that the predictions are very clear and sharply separated out for the different treatments. Interestingly though, the results in Brandts et al. confirm ours. They too observe a competition-enhancing effect as a result of forward contracting, and they also find that a change in market size has a greater effect on competition. We take this as evidence that our findings extend to richer settings.

The remainder of the paper is organized as follows. In the next section we study AV's model for the case of *n* firms. The experimental design is described in Section 3. Section 4 presents the results and Section 5 concludes.

2 The model

Consider first the standard symmetric Cournot model with linear demand and cost and *n* firms. Equilibrium aggregate production and market price are given by

$$X^* = (A - c)n/(n+1), \qquad [1]$$

$$p^* = (A + nc)/(n+1), \qquad [2]$$

respectively, where A is a parameter of the demand function ($p = A - X$) and c is the marginal cost.

Next, consider *n* firms competing in AV's two-stage setting. Since information is complete, there is no risk-hedging rationale for forward trading. As we shall see, however, there is a *strategic* incentive. In the first stage sellers simultaneously choose their forward positions f_i, yielding an aggregate forward quantity $F = \sum f_i$. A forward price, p_F, then emerges as a result of the market process. In the second stage (the spot market) firms compete only for the residual demand—the commitment implied by the forward contracts makes the first stage results strategically irrelevant. The residual demand function is $p_S = A - F - S$ (where S is the aggregate spot quantity). This leads to a equilibrium spot market price of

$$p_S^* = (A + nc - F)/(n+1). \qquad [3]$$

A comparison between Equations [2] and [3] shows that the presence of a forward market lowers the spot market price, i.e. $F > 0$ implies $p_S^* < p^*$. To see that

firms have an individual strategic incentive to make forward transactions, note first that because the spot market price is anticipated by all market participants the forward market equilibrium must yield a contract price equal to the spot price ($p_F = p_S^*$). Therefore firm *i*'s total profit is

$$\pi_i(f_i) = \left(\frac{A-c-F}{n+1}\right)\left(f_i + \frac{A-c-F}{n+1}\right). \qquad [4]$$

The first term in brackets denotes the profit margin, $p_S^* - c$. The second term is firm *i*'s total production level, i.e. its forward position, f_i, and its anticipated spot quantity. Forward contracts signed by firm *i* thus lower the market price as well as firm *i*'s expected spot sales. However, these negative effects are mainly external: firm *i*'s competitors share these costs. Moreover, by signing forward firm *i* benefits individually from an immediate increase in sales. This positive effect dominates and if firm *i*'s competitors refrained from forward contracting, i.e. if $f_j = 0 \; \forall \; j \neq i$, it would become a Stackelberg leader. However, this is not an equilibrium. Solving for the symmetric equilibrium forward position yields

$$f^* = \frac{n-1}{n^2+1}(A-c). \qquad [5]$$

From this the equilibrium levels for all variables can be derived immediately. Table 1 summarizes and compares the results with the Cournot case. A number of comparative-static predictions can be derived from Table 1.

1. An increase in the number of firms implies lower prices and higher output under both market institutions.
2. For a given number of competitors, introducing a forward market enhances competition (higher quantities, lower prices).
3. In terms of production, prices, total profits and consumer surplus adding a forward stage has the same effect as squaring the number of competitors.

Thus, the predicted competition-enhancing effect of forward trading is very strong. It is driven by a prisoner's dilemma-type problem among the firms. If all players refrain from forward trading they achieve moderately high payoffs. However, a single firm could then gain a profitable leadership position at the expense of its competitors. In equilibrium, all firms make forward transactions at relatively low profit levels.

Table 1: **Theoretical results**

	Cournot: Spot market only	*AV: Forward & spot market*
Total forward quantity	—	$\left(\frac{n^2-n}{n^2+1}\right)(A-c)$
Total spot quantity	$\left(\frac{n}{n+1}\right)(A-c)$	$\left(\frac{n}{n^2+1}\right)(A-c)$
Total production	$\left(\frac{n}{n+1}\right)(A-c)$	$\left(\frac{n^2}{n^2+1}\right)(A-c)$
Price	$\frac{A+nc}{n+1}$	$\frac{A+n^2c}{n^2+1}$
Profit per firm	$\left(\frac{A-c}{n+1}\right)^2$	$n\left(\frac{A-c}{n^2+1}\right)^2$
Consumer Surplus	$\frac{1}{2}\left(\frac{n(A-c)}{n+1}\right)^2$	$\frac{1}{2}\left(\frac{n^2(A-c)}{n^2+1}\right)^2$

3 Design of the experiment

3.1 Treatments and predictions

We compare two market institutions, one with standard Cournot competition (C markets) and one in which firms first have access to a forward market and then to a spot market (AV markets). As a second treatment variable we vary the number of firms (two versus four). Thus, we have four session types in a 2x2 design. Simulated buyers determine the market price in all conditions.

To simplify the decision problem for the subjects we abstracted from production costs. This leaves the key characteristics of the theoretical predictions unaltered. Participants chose quantities from the set of whole numbers between 0 and 1000. In the Cournot sessions the price was computed as

$$p_t = \max\{1000 - X_t, 0\} \qquad [6]$$

where X_t denotes the total quantity in period t.

In the forward stage of the AV sessions we provided the artificial consumers with the expectation of Cournot play in the spot stage, exactly as in AV's model. Thus, the forward price was determined by Equation [3] or, for our parameters, by

$$p_t^F = \max\left\{ \frac{1000 - F_t}{n+1}, 0 \right\} \qquad [7]$$

where F_t is the total forward quantity chosen in period t.[3] Thus, our experiment does not test whether real buyers are as sophisticated in predicting spot market outcomes as AV assume in their model. However, AV use this aspect merely as an auxiliary device to demonstrate that the forward market effect is *strategic* in character and not due to hedging. In our experiment we are interested in the behavior of firms and thus try to abstract from imperfections in the trading institution. Buyer behavior can and should be explored, but this should be done separately and we leave this for future research.[4]

The spot market price in the AV sessions was determined by Equation [6]. Payoffs were computed as the sum of revenues from the forward and the spot market. Table 2 lists the predictions derived from the model for all treatments.

Table 2: Equilibrium predictions for all treatments

	C2	*C4*	*AV2*	*AV4*
Total forward quantity	—	—	400	706
Total spot quantity	—	—	400	235
Total production	666	800	800	941
Price (e$)	3.33	2.00	2.00	0.59
Profit per firm (e$)	1111.11	400.00	800.00	138.80
Consumer surplus (e$)	2222.22	3200.00	3200.00	4429.07

3.2 Experimental procedures

The computerized experiments were conducted at the Centre for Decision Research and Experimental Economics (CeDEx) at the University of Nottingham. In total 124 subjects participated in eight sessions (two in each treatment) and no subject took part in more than one session. We collected data on 15 independent markets in each of the two-seller treatments (C2 and AV2) and on 8 independent markets in each of the four-seller treatments (C4 and AV4). In all sessions subjects interacted for thirty periods.

Subjects were paid according to their profits (plus a £2 flat fee). We used an artificial laboratory currency denominated in "experimental dollars" (e$, 1e$ = 100

[3] We refer to a "period" as the complete cycle consisting of the forward stage and the spot stage.
[4] In Brandts et al. two human traders compete on the forward market. However, these traders are not always competitive and typically manage to keep forward market prices artificially low. While this is an interesting result in its own right, we wish to abstract from such complications in our design.

eCents). Because predicted earnings differed substantially across treatments and because it could be expected that the AV sessions would last considerably longer than the Cournot sessions, we adjusted the exchange rates such that expected cash earnings would reflect the time subjects spent in the laboratory. On average, participants earned £9.94 (ca. 15 US$ at the time of the experiment).[5]

Communication between subjects was not permitted and dividers separated the individual workplaces. To make the incentive structure of the situation more transparent we equipped our software with a "results calculator" which participants could use to experiment with hypothetical decisions prior to submitting a real choice.[6]

As outlined in the introduction, one of the main criticisms of AV's static model is that it does not address the dynamic nature of many real-world markets. We therefore decided to employ a fixed-matching protocol which creates a repeated game setting and hence directly addresses the expressed concerns. Thus, the initial (random and anonymous) allocation of participants to separate markets was not altered in the course of a session. This makes our investigation into the empirical relevance of AV's theory more challenging for the model but also more realistic. Of course, because each market has a commonly known finite horizon, the equilibrium predictions are unaffected by repetition.

At the end of each decision round—i.e. at the end of a period in the Cournot treatment and at the end of the forward or spot stage in the AV treatment—a "Results Screen" displayed the total production in the relevant market, the market price and the profit. Before the participants entered the next stage or period a "History Screen" was shown that listed all previous outcomes in the market in a summarized form.

4 Experimental results

4.1 Overview

Table 3 displays a summary of the data at an aggregate level, listing overall averages and standard deviations for each treatment. Comparing the entries in this table with the corresponding theoretical values in Table 2 we note that behavior in both four-seller treatments appears to be somewhat over-competitive (higher-than-predicted production levels, lower-than-predicted prices) while we see a slight tendency towards

[5] The exchange rates were 60 eCents (C2), 20 eCents (C4 and AV2) and 4 eCents (AV4) per penny. A copy of the instructions can be found in Appendix A.
[6] A detailed description of the way the results calculator worked is given in Appendix B.

under-competitive behavior in both two-seller treatments. Overall, behavior is remarkably stable over the thirty periods. There is no indication that the discrepancies between point predictions and data decrease over time.

Table 3: Summary statistics (averages; standard deviations in parentheses)[7]

	C2	*C4*	*AV2*	*AV4*
Total forward quantity	—	—	314.46	768.31
			(174.49)	(132.05)
Total spot quantity	—	—	435.94	239.08
			(113.53)	(67.94)
Total production	620.61	909.22	750.40	1007.39
	(81.26)	(131.99)	(87.12)	(85.87)
Forward price (e$)	—	—	2.29	0.56
			(0.58)	(0.18)
Spot price (e$)	—	—	2.53	0.50
			(0.89)	(0.23)
Average price (e$)	3.83	1.54	2.45	0.54
	(0.76)	(0.53)	(0.85)	(0.19)
Profit per firm (e$)	1103.10	296.06	837.61	122.59
	(119.12)	(99.16)	(182.75)	(40.07)
Consumer surplus (e$)	1980.06	3638.64	2910.13	4481.98
	(481.93)	(460.19)	(602.17)	(180.02)

To formally assess the predictions of the model we employ only non-parametric tests at the level of markets, throughout the results section. Because of the fixed-group design each market can be considered as an independent observation.

Using a two-sided Wilcoxon one-sample signed rank test we find that total production in both quadropoly conditions is indeed significantly higher than predicted (p-value 0.042). In the two-seller treatments the discrepancies between theory and data are marginally significant (p-value 0.074 in C2 and 0.065 in AV2). With respect to prices we can reject the null hypothesis only in C2 (p-value 0.044); the deviations from theory are marginally significant in C4 and AV2 (p-values 0.080 and 0.094) and not significant in AV4 (p-value 0.441).

Note that quantities and prices are generally not perfectly correlated. For example, occasional excessive levels of supply (above 1000 units) can drive up the

[7] The standard deviations reported measure the variation of the means across markets. In the AV treatments we compute the market price per period as the average of the forward price and the spot price, weighted by the number of units sold in each stage.

average production level considerably; prices on the other hand can never fall below zero. Furthermore, in the AV treatment, the average market price depends on how the output is distributed between forward and spot stage.

Consumer surplus and profits are not significantly different from theory with the exception of C4 where profits are 26% lower than predicted (p-value 0.030) and consumer surplus is 14% higher than predicted (p-value 0.059).

Overall, the deviations from theory are not excessive. The most clear-cut discrepancies between predictions and data are found in the Cournot quadropolies where outcomes tend to be more competitive than in Nash equilibrium. There is, on average, a tendency towards less-than-competitive quantities/prices in the duopoly treatments but this does not have a great impact on welfare measures. However, the main characteristic of our duopoly data is the substantial heterogeneity across markets: some pairs of sellers succeed in establishing outcomes near the collusive benchmark, others display behavior close to equilibrium and a few even compete more aggressively than that. The heterogeneity is less pronounced in C4 and AV4; about half the markets are close to predictions while the other half is too competitive relative to theory. These results are in line with findings from previous experimental research on Cournot competition (see Holt, 1995, and Huck, Normann and Oechssler, 2004, for overviews).[8] Our results suggest that the characteristic patterns of Cournot competition carry over to the two-stage AV markets.

4.2 Comparative-static findings

We use a Wilcoxon rank-sum test to test the comparative static predictions. Our null hypotheses state that changes in the number of firms or in the market institution do not have an impact on production, market prices or welfare. We test the null hypotheses against the one-sided alternatives suggested by the model. We also test for systematic differences between the C4 and the AV2 treatment, but use a two-sided alternative because theory does not predict any differences in this case.

Table 4 lists average production, price and total welfare for all markets. We analyze welfare explicitly, unlike in other experimental papers on quantity

[8] Holt (1995, p.404) summarizes: "(1) with Cournot duopolies, outcomes fall on both sides of the Cournot prediction, and some cases of near perfect collusion occur, and (2) with more than two sellers, outcomes are often more competitive than the Cournot prediction."

competition, because in the two-stage AV game the relationship between quantities, prices and welfare is not trivial (output is not a perfect proxy for prices or welfare).

Table 4: Average output, prices and welfare per market

		Total production		*Market price*		*Total welfare*	
	Market	*Cournot*	*AV*	*Cournot*	*AV*	*Cournot*	*AV*
Two firms	*1*	628.73	584.20	3.71	4.11	4286.5	4091.9
	2	541.70	742.03	4.58	2.45	3941.9	4645.9
	3	652.57	800.17	3.47	2.02	4310.1	4784.2
	4	620.50	814.47	3.80	1.99	4258.2	4776.3
	5	697.67	714.00	3.02	2.62	4455.6	4558.5
	6	683.53	719.87	3.16	2.83	4449.4	4566.6
	7	594.17	705.13	4.06	2.32	4143.7	4522.8
	8	675.00	636.00	3.25	3.65	4416.3	4219.6
	9	751.63	772.50	3.08	2.24	4272.2	4618.1
	10	509.17	735.73	4.91	2.44	3783.2	4591.4
	11	461.90	885.57	5.38	1.32	3527.2	4860.5
	12	667.63	885.13	3.32	1.20	4374.1	4924.7
	13	515.83	765.53	4.84	2.31	3817.0	4569.9
	14	629.17	840.67	3.71	1.51	4294.9	4851.8
	15	680.00	655.03	3.20	3.71	4463.9	4198.1
Four firms	*1*	893.67	936.83	1.30	0.60	4880.0	4971.1
	2	1155.63	1048.47	0.86	0.54	4891.1	4972.3
	3	772.97	973.33	2.30	0.70	4694.1	4964.1
	4	1046.57	1190.87	0.93	0.35	4884.3	4978.9
	5	807.33	994.47	2.06	0.31	4755.5	4997.8
	6	814.67	965.47	1.85	0.43	4808.6	4984.7
	7	933.90	919.67	1.29	0.90	4846.7	4926.1
	8	849.03	1030.00	1.71	0.46	4822.8	4983.7

Do more firms imply higher quantities, lower prices and a welfare improvement? The answer is a very clear yes. When the number of sellers is changed from two to four, output increases by 47% in the Cournot markets and by 34% in the AV treatments. Prices decrease by 60% (Cournot) and 78% (AV), and total welfare increases by 15% and 8% respectively. These differences are highly statistically significant (see Table 5 for details on p-values).

Does the forward market enhance competition? Our data again produces clear results in favor of the theoretical prediction. The introduction of the forward market in the duopoly raises quantities by 21%, lowers prices by 36% and increases welfare by 10%. In the case of four firms the increase in production is 11%, the decrease in

prices is 65%, and there is a small (but systematic) increase in welfare of 3%. Again, all these results are statistically significant at any conventional level (see Table 5).

Table 5: Comparative-static analysis—Wilcoxon rank sum test (H_0: no change)

		Total production		*Market prices*		*Welfare*	
versus → ↓		*C4*	*AV2*	*C4*	*AV2*	*C4*	*AV2*
C2	H_1:	C4>C2	AV2>C2	C4<C2	AV2<C2	C4>C2	AV2>C2
	p-value:	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
AV4	H_1:	C4<AV4	AV2<AV4	C4>AV4	AV2>AV4	C4<AV4	AV2<AV4
	p-value:	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
AV2	H_1:	C4≠AV2	—	C4≠AV2	—	C4≠AV2	—
	p-value:	0.008		0.004		0.013	

Thus, we reject the null hypotheses in favor of the central theoretical predictions. At the same time, however, our data also shows that the introduction of forward trading is not as effective as doubling the number of competitors, as suggested by the model. In contrast to the prediction, the two-sided rank-sum test indicates that total production and welfare are systematically higher, and prices systematically lower, in C4 than in AV2. The time series in Figure 1, illustrates how prices in the two-seller AV and the four-seller Cournot condition differ, to some extent, from the theoretical prediction (as discussed in Section 4.1 above) but even more so from each other.[9]

[FIGURE 1 HERE]

4.3 On the use of forward and spot market

In this section we investigate how sellers in the AV treatments make use of forward and spot markets. Forward quantities and prices tend to be somewhat less competitive than the model predicts in AV2 (see Table 3; the p-value is 0.083), but are not significantly different from theory in AV4.

[9] Since AV4 prices are relatively close to the predicted level, one could speculate that the four-seller AV results could be similar to the outcomes of a sixteen-seller Cournot treatment, as theory would predict. However, some experimental evidence indicates that markets with more than two firms tend to be more competitive than theoretically expected, and it has been suggested that "these deviations are increasing in the number of firms" (Huck, Normann and Oechssler, 2004)

Direct comparisons between the outcomes of the experimental spot markets and the corresponding predictions in Table 2 yield similar results. However, the spot market behavior should not be analyzed separately from the outcomes of the forward market, since the level of spot demand is determined by the choices in the preceding forward stage. To show how choices in the two stages are correlated we have plotted the spot output against the forward quantities for all markets and periods in Figure 2. The figure also contains the *ex ante* point prediction for both stages ("equilibrium prediction") and the "*ex post* prediction" (i.e. after observing the empirical forward stage results) for the spot market ("spot stage Cournot path").

[FIGURE 2 HERE]

As the figure shows, forward quantities are highly variable, which is not predicted by theory. On the other hand, the data points are clearly scattered around the spot stage Cournot paths, and the point predictions seem to satisfactorily describe *average* behavior, in particular for the four-seller markets.

What clearly distinguishes AV2 and AV4 in Figure 2 is the occurrence of choices near the collusive benchmark. While these are quite frequent in the duopoly case, market outcomes are far away from the point of joint profit maximization in the four-seller case. One potential explanation for this difference is that players might try to use the forward market stage as a signaling device for collusion (rather than as the commitment device that AV's theory suggests). Since collusion entails that firms choose zero quantities in the forward market stage, making this choice transports a clear message to one's competitor in the duopoly treatment. In the quadropoly case, on the other hand, individual messages of this kind are likely to get lost, as players are only informed about the aggregate forward quantity.

However, even in the two-firm case we have little evidence that players successfully use the forward stage as a signaling device. On the one hand we do find, pooling the data from all AV2 markets, that when firms choose a "small" quantity of up to 50 units in the forward market, about 40% of their opponents' subsequent spot market choices are between 240 and 260 units. Since joint payoff maximization is achieved when the duopolists produce a total of 500 units, this seems to suggest that sending a collusive signal in the forward stage often induces a like-minded response. However, 87% of these "friendly responses" come from only three markets. Thus, it

seems rather that in some markets players simply succeed in upholding a tacit agreement, while in others they do not, much like in the Cournot duopolies. If a tacit collusive agreement is established, this is reflected in the choices in *both* stages. In the more competitive markets, in contrast, the signal from the forward market does *not* trigger the intended reaction. Hence, *per se* the forward market stage does not appear to work well as a coordination device. Overall, as we have seen, the introduction of a forward market stage does have a clear competition-enhancing effect, and the observed outcomes do not differ significantly from the "*ex post*" predictions in AV2.

The four-seller AV spot markets do not display signs of collusion; on the contrary, they are more competitive than under Nash. Relative to "*ex post*" predictions the output is on average 13% higher (p-value 0.030). A closer analysis reveals that this is not because firms choose high quantities too frequently (higher-than-predicted quantities occur in about 50% of the time). Instead, what happens is that overshooting, when it occurs, is more severe than undershooting. Notice that the over-competitiveness in the AV4 spot markets creates arbitrage opportunities, as spot market prices tend to be lower than forward market prices. The difference, however, is not at all substantial, as Figure 3 shows, and is no longer significant when we focus on the second half of the data (periods 16 to 30).[10]

[FIGURE 3 HERE]

5 Conclusions

In this paper we report the results of a laboratory test of a two-stage forward market model developed by Allaz and Vila. Treatments with two and four sellers were conducted and compared with results from benchmark conditions in standard Cournot markets. Our data supports the theoretical prediction that forward markets promote competition. However, the predicted equivalence of introducing a forward market and of increasing the number of sellers from two to four is strongly rejected. Our findings indicate that this is due to the AV2 markets being somewhat *less* competitive than predicted by theory as well as the C4 markets being *more* competitive than predicted (the latter is the stronger of the two discrepancies). In this sense the competition-enhancing effect of the forward market is weaker, and the effect of adding more

[10] The discrepancy between forward and spot prices in the second half of AV2 is not significant either.

competitors stronger, than the theoretical comparative analysis predicts. An obvious candidate for explaining this effect is the notion that implicit collusive agreements are easier to achieve with a smaller number of players. However we do find that forward trading has a clear and substantial positive effect on competition, even in repeated duopoly markets. Thus, in the debate about the empirical relevance of AV's results that was mentioned in the introduction our experiment produces evidence in support of the model.

The present study should be viewed as only a first step in investigating experimentally how serious market designers should take forward trading institutions as a building block for improving efficiency in markets. Experiments may help to disentangle the effects of different motives for forward trading such as hedging, strategic trading as in AV's model or entry deterrence as discussed in Newbery (1998) and Lien (2000), which may all be relevant in the field at the same time. Laboratory studies can also be used to evaluate the importance of particular factors that are relevant for the applicability of AV's theory to real markets and have been identified in recent theoretical developments (see, e.g., Hughes and Kao, 1997, and Ferreira, 2001 and 2003).

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Figures

Figure 1: Theoretical and empirical average prices over time

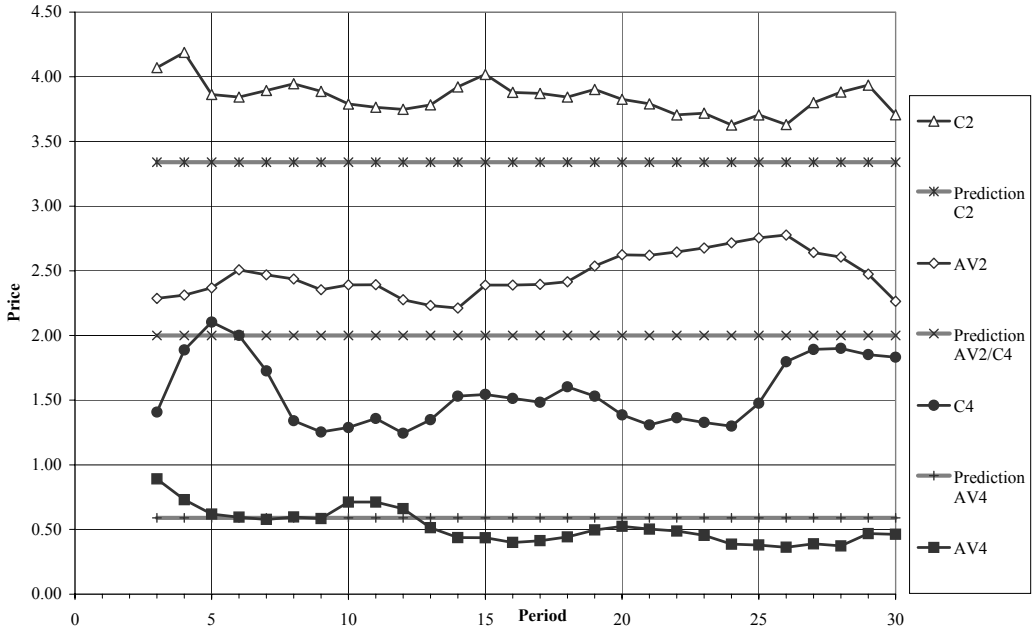


Figure 2a: Forward against spot market quantities (two-seller treatment)

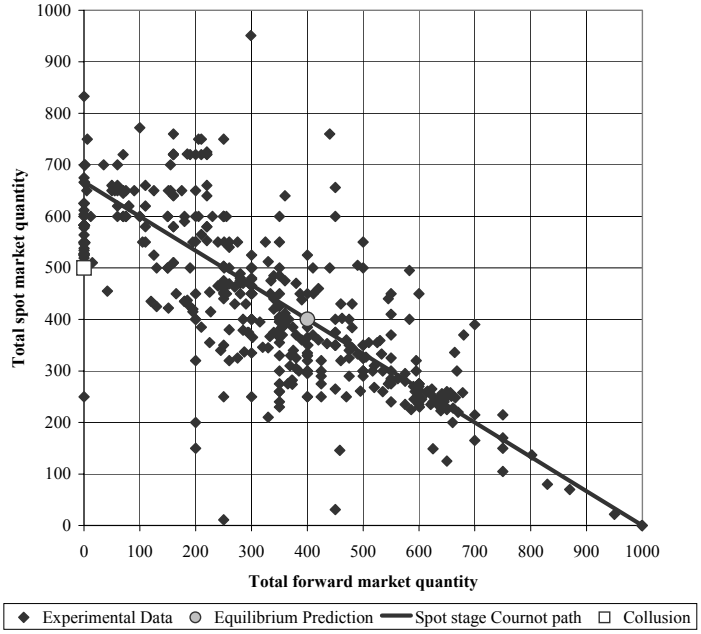


Figure 2b: Forward against spot market quantities (four-seller treatment)

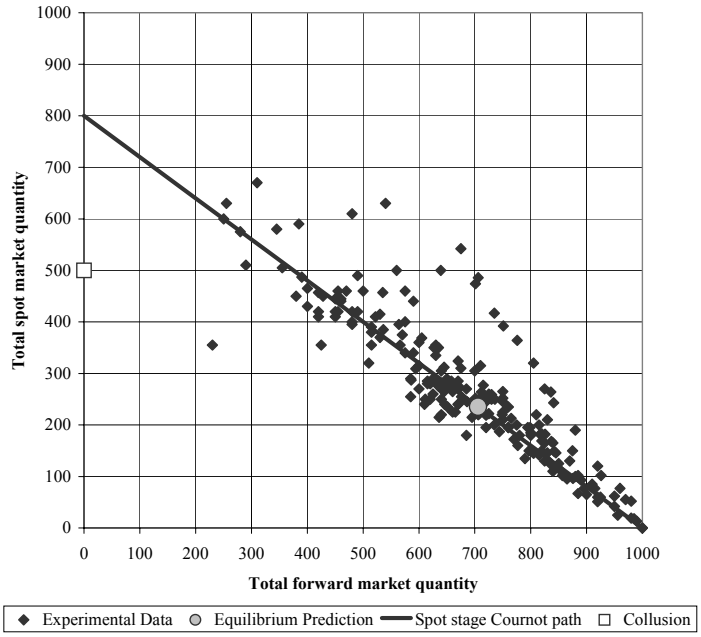
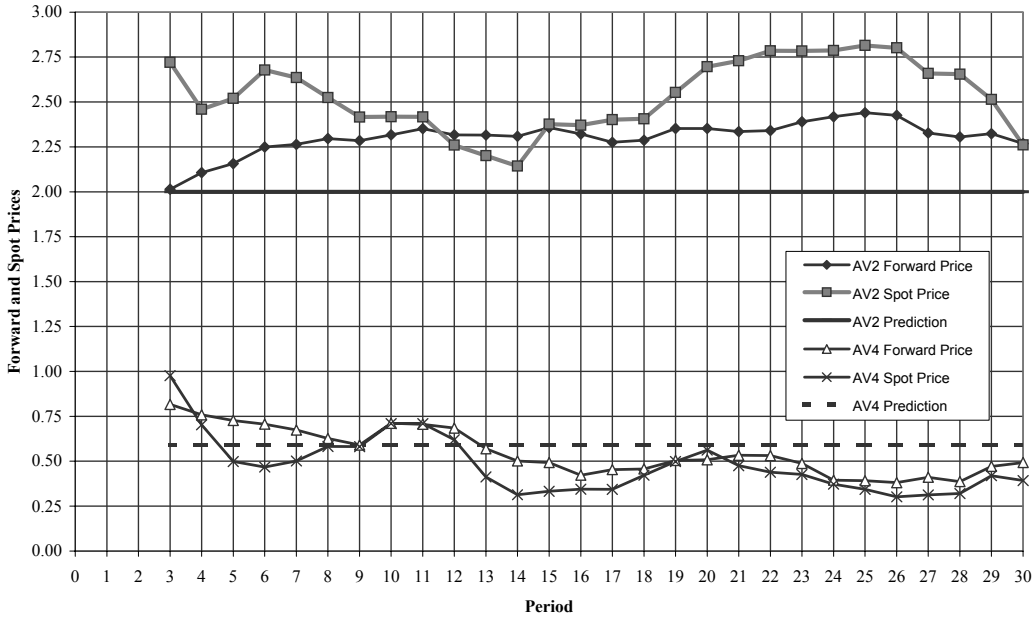


Figure 3: Forward and spot market prices over time

(3-period moving averages)



Appendix A: Instructions

Legend: {…} Two-seller conditions only *[…] Four-seller conditions only*
**…* Cournot conditions only* *#…# A&V conditions only*

Welcome! This session is part of an experiment in the economics of decision making. If you follow the instructions carefully and make good decisions, you can earn a considerable amount of money. At the end of the session you will be paid, in private and in cash, an amount that will depend on your decisions.

General Rules

The session will consist of 30 periods, in each of which you can earn "experimental dollars" (e$). At the end of the session you will be paid £2 plus an additional amount based on your total e$ earnings from all 30 periods. Your e$ earnings will be converted to cash using an exchange rate of *{60e$}[20e$]*#{20e$}[4e$]# = 1p. Notice that the higher your e$ earnings are, the more cash you will receive at the end of the session.

There are sixteen people in this room who are participating in this session. It is important that you do not talk to any of the other people until the session is over.

In this experiment each person in the room represents a firm. During the session [four]{eight} different markets will operate and at the beginning of the session the computer will randomly allocate you to one of these. Similarly, the other firms will be randomly allocated to markets. In your market there will be you and {one}[three] other firm[s]. Your e$ earnings will depend on your decisions and on the other [three] firm{'s}[s'] decisions. The firm[s] you are matched with will be the same throughout this session but you will not learn the identity of the person[s] who represent{s} [these]{this} firm[s].

Description of a period

#Each of the 30 periods consists of two successive stages. The first of these is called Stage A and the second is called Stage B. We will first describe Stage A, then Stage B.

Stage A#

At the beginning of *each of the 30 periods* #Stage A# you have to decide how many units of a good to produce. You make your decision by entering a number (any whole number between 0 and 1000) on your terminal. After all firms have made their decisions, the computer will calculate your profits for *that period* #Stage A#.

Your profits will be equal to the number of units you produce times the market price.

The market price will depend on how many units you and the other firm[s] in your market have produced in total. We will call the total number of units produced in your market "Total Production". The computer will calculate the market price in *a period* #Stage A# using the following formula.

$$\text{Price} = 1000 - \text{Total Production}$$

#{ $$\text{Price A} = \frac{1000 - \text{Total Production in A}}{3}$$ }

[$$\text{Price A} = \frac{1000 - \text{Total Production in A}}{5}$$]#

This formula gives you the market price in eCents (and 1e$ is worth 100 eCents). Thus, if Total Production were zero (that is, if neither you nor the other firm[s] in your market produced anything at all), then the market price would be *1000 eCents (equals 10 e$)*#{333 eCents (equals 3.33 e$)}[200 eCents (equals 2 e$)]#. But note that the higher Total Production is, the lower the market price will be.

If Total Production is equal to or above 1000 units, then the market price is 0. The market price cannot become negative.

At the end of *each period*#Stage A# you will see a “Results Screen”. The Results Screen will show how many units you have produced and how many units the other firm[s] in your market {has} [have] produced [in total]. It will further display the Total Production in your market, the market price*,* #and# the profits you have made in #Stage A#*that period and your accumulated profits from all periods. After the Results Screen, and before you enter the next period, your terminal will furthermore display a “History Screen” that shows the results from all previous periods in a summarised form.*

#Stage B

Stage B is, in principle, identical to Stage A, but with one important exception. The way the market price is computed in Stage B differs from the way it was computed in Stage A. The market price in Stage B is calculated as (this is again in eCents)

$$\text{Price B} = 1000 - \text{Total Production in A} - \text{Total Production in B}$$

That is, the market price in Stage B depends on both Total Production in Stage A and Total Production in Stage B. As before, the higher Total Production is, the lower the market price will be. Also as before, the market price cannot become negative: if Total Production in Stage B is so high that the formula for Price B would yield a negative result, then the computer sets Price B to zero.

Please notice also the following additional rule. If Total Production in the first stage (Stage A) is already equal to or above 1000 units, then there will be no second stage and neither you nor the other firm[s] in your market will be able to produce in Stage B! If this happens your profits for that period are set to zero, and instead of entering Stage B, you and the other firm[s] in your market will be automatically redirected to the next period.

Otherwise, your total profits in a period are computed as the sum of your profits from both stages.

```
  (Price A) x (Number of units you produce in A)
+ (Price B) x (Number of units you produce in B)
-----------------------------------------------
= Your Total Earnings in a period
```

At the end of Stage B, you will again see a Results Screen showing similar information as the Results Screen described above. Additionally it will display your total earnings for that period and your accumulated earnings from all periods. After the Results Screen for Stage B, and before you enter the next period, your terminal will furthermore display a “History Screen” that shows the results from all previous periods in a summarised form.#

Further Instructions

Before you make a decision in *a period*#either Stage A or Stage B# you can experiment with different hypothetical choices by using the “Results Calculator”. You can activate the Results Calculator by clicking on a button on the “Decision Making Screen”. The Results Calculator is easy to use. You simply enter arbitrary numbers for your own production and for the production of the other firm[s]. When you press the Enter key, the Results Calculator will show you the resulting market price#s# and your profits for the hypothetical choices.

#When you are in Stage A, the Results Calculator will allow you to enter hypothetical numbers for both stages. When you are in Stage B, the Results Calculator will only allow you to enter hypothetical numbers for Stage B, and it will take the results from the real Stage A as given when calculating Price B.#

Appendix B: The results calculator

The results calculator works similar to the profit calculator used by Huck et al. in various experiments (e.g. Huck, Normann and Oechssler, 1999). A difference is that our calculator does not provide a button that computes the best response to other firms' choices. The way the calculator could be used differed slightly between the Cournot and the AV treatment. The following describes the variant we programmed for the AV sessions; the Cournot calculator is a simplified version of this.

In the forward stage of a period the results calculator worked as follows. First, the participant could enter a hypothetical own quantity and a hypothetical (total) quantity chosen by the other firm(s) in his or her market. After hitting the Enter key, the screen displayed the resulting forward market price and the hypothetical forward profit for the subject. Then a new window opened that allowed the subject to enter further hypothetical quantities for the second stage (spot market), where the spot price, spot profits and total profits were calculated according to the hypothetical choices of both the forward and the spot stage.

In the spot market stage of a period subjects were only able to feed the results calculator with hypothetical *spot* quantities, and computations were then based on these hypothetical decisions and on the *real* forward quantities.