Vertical Mergers and Price Leadership
An Experiment

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While an influential line of research maintains that vertical mergers lead to higher prices in the input market through a "raising-rival's-cost" effect, this result has been challenged on the basis that it depends on the assumption that integrated firms can commit not to compete in the input market. We argue that price leadership can work as a commitment device for integrated firms. When an integrated firm is the price leader, the prediction is that the input market will become monopolized. This outcome is subgame perfect, meaning that there is no commitment problem. We test this prediction in experiments, comparing the price-leader data to treatments involving simultaneous moves and variants without vertical integration. We find that when integrated firms act as price leaders, the input market is indeed fully monopolized. After several periods of play, we impose an unexpected change: Subjects no longer play the sequential leader-follower game but move simultaneously. Integrated firms then no longer charge higher prices. In other words, integrated firms do not learn to charge high prices and achieve Pareto-superior outcomes.

A. Introduction

One of the main arguments in the literature on vertical integration is that such mergers may be anticompetitive due to a "raising-rival's-costs" effect. This argument was first formalized by Ordover, Saloner and Salop (1990), henceforth referred to as OSS (1990), and it goes as follows. When a vertically integrated firm forecloses nonintegrated downstream firms, that is, when it withdraws from the input good market, upstream competition becomes weaker. This reduction of competition implies higher input costs for the nonintegrated downstream firms. Since the downstream unit of the integrated firm benefits when rivals' costs are raised, the integrated firm is better off pursuing such a foreclosure strategy compared to the case where it actively competes.

While OSS (1990) has been rather influential in the theoretical industrial organization literature[1], it has also been criticized. Hart and Tirole (1990), as well as Reiffen (1992), have pointed out that the outcome hinges on the premise that integrated firms can commit not to supply nonintegrated downstream rivals. Without this commitment, vertically integrated firms will compete just like the other upstream firms. In the static Nash equilibrium without commitment, nonintegrated downstream firms are not foreclosed and equilibrium prices are the same with and without the vertical merger.

The motivation for this paper is the insight that integrated firms arguably have an incentive to *seek* commitment whereas non-integrated firms will not. Even when considering the critique by Hart and Tirole (1990) and Reiffen (1992)'s that commitment is unavailable in the static simultaneous-move model, it is evident that integrated firms may look for (or invest into) the sort of commitment which OSS (1990) assume in a *deus-ex-machina* fashion. So even if commitment is unavailable in the standard game, integrated firms might still strive for commitment in extended settings.

To illustrate this issue, we propose a model of price leadership. In this model, the integrated firm is the price leader. It chooses the input price first, and the non-integrated firm chooses second. According to the SGPN prediction, monopolization of the input market occurs. This outcome is Pareto-superior from the firms' perspective compared to a game with simultaneous moves. Non-integrated firms would also never want to become price leaders because this would result in zero profits for both firms. Therefore, integrated firms benefit from being the price leader and will seek such an opportunity.

We complement the theoretical analysis with experimental data. We implement the variant where the integrated firm is the price leader and we compare this variant to (i) a treatment without price leadership but with vertical integration and (ii) a treatment without price leadership and without vertical integration. This allows us to evaluate the impact of price leadership in conjunction with vertical integration. To study learning effects, we replace the sequential leader-follower game with simultaneous

1 Salinger (1988), Hart and Tirole (1990) and OSS are seminal among the "new" foreclosure theories. Martin, Normann and Snyder (2001) and Rey and Tirole (2007) contain reviews of foreclosure theories.

moves after several periods of play and let subjects play the treatment without price leadership (but still with vertical integration).

We find that, when integrated firms are the price leader, they indeed charge a price above the monopoly level and the second movers best respond by charging the monopoly price. So as predicted, the input market is monopolized. While this outcome is Pareto-superior to the static Nash equilibrium, it turns out that learning effects are weak. When they are no longer the price leader, the integrated firms do not charge higher prices than non-integrated firms. In other words, integrated firms do not learn to commit.

The next section discusses the literature. Section 3 introduces the general model and reports on the simultaneous-move game and the sequential-move game. Section 4 contains the experimental design and Section 5 the procedures. Section 6 reports the experimental results. Section 7 is the conclusion.

B. Related Literature

Following the critique by Hart and Tirole (1990) and Reiffen (1992), various papers have shown that OSS's foreclosure result can be rigorously derived from game-theoretic models. OSS (1992) re-establish their result in a descending-price auction. Riordan (1998) analyses backward integration by a dominant firm with a cost advantage. Choi and Yi (2000) and Church and Gandal (2000) show the result if upstream firms can commit to a technology which makes the input incompatible to nonintegrated downstream firms. Chen and Riordan (2007) investigate the connection between vertical integration and exclusive dealing contracts. Our paper contributes to this literature by showing equilibrium vertical foreclosure in a sequential-move version of the original OSS model.

Along this line of research, various papers have shown that vertical integration can lead to collusive effects. Chen (2001) considers not only the change in incentives upstream but also in the downstream market for the case of a vertical merger. He finds collusive effects but also efficiency gains and an ambiguous result for competitive effects in general. Nocke and White (2007) analyze vertical integration in a market with two-part tariffs upstream and repeated interaction. They show that a vertical merger facilitates upstream collusion. Normann (2009) shows that collusion is easier to sustain in a vertically integrated market also with linear prices. Related to our issue (but not covering issues of vertical integration), Mouraviev and Rey (2011) show that price leadership can facilitate collusion. In a theoretical model, they show that the choice of deciding simultaneously or sequentially about prices can sustain perfect collusion.

Allain et al. (2011) show that the necessity of downstream firms to share sensitive information once they trade with an upstream firm might lead to input foreclosure. In a static game with two upstream firms and vertical integration resembling OSS (1990), the non-integrated downstream firm might be reluctant to exchange information which cannot be protected by property rights. Deals between an integrated upstream supplier and non-integrated downstream firms might not occur due to the concern that information will be leaked the downstream division. Allain et al. (2016) show that vertical integration can create hold-up problems for competitors. If the integrated supplier can commit to be "greedy" or alternatively commits to offer a degraded input to the downstream competitor, hold-up problems occur. On the other hand, they show that even without commitment, foreclosure emerges if the quality of the upstream product is non-verifiable.

More recently, partial vertical ownership, where one firm controls an upstream or downstream company through a partial stake, has been in the interest of researchers. Partial vertical ownership can create stronger incentives for foreclosure than a full merger. This is the main argument put forth by Spiegel (2013) and Levy, Spiegel, and Gilo (2018). See also the extension by Hunold and Werner (2025).

The first experimental study on vertical mergers is Martin et al. (2001).[2] They analyze the commitment problem of an upstream monopolist to restrict the total quantity for downstream firms to the monopoly level (Hart and Tirole, 1990). Public contracts between downstream firms and the upstream monopolist and, alternatively, vertical integration result regularly in monopolization of the input market. In contrast, if firms are independent and contracts are secret, beliefs of downstream firms about the contract offer to the rival determine the

2 Mason and Phillips (2000) analyze the double marginalization problem in a market with two upstream and two downstream firms. They find larger outputs and a higher consumer surplus with both firms vertically integrated as compared to no integration. Durham (2000) finds support for the double marginalization problem if upstream and downstream markets are monopolized, whereas competition downstream eliminates this problem.

outcome. In this case, monopoly power cannot be sustained and market quantity is significantly above the monopoly level. Recently, Moellers et al. (2017) extend this study and analyze the impact of communication on the commitment problem. They find that open communication leads to monopolization whereas bilateral communication between the producer and retailers do not lead to the monopoly quantity downstream.

Normann (2011) analyzes experimentally the effect of vertical integration on selling prices and market foreclosure in an OSS (1990) framework. Although he finds a significant increase in the minimum price paid by the independent downstream firm, there is little evidence for total foreclosure. The integrated firm does not withdraw completely from the input market. However, partial foreclosure (that is, the integrated firm sets a higher price than the non-integrated firm), indeed occurs. Moellers (2016) extends this analysis to one-shot games where firms can choose to reveal their choice history. She finds that integrated firms choose to reveal past prices more often than non-integrated firms. When integrated firms reveal their choice history, prices are higher, as predicted. In an intriguing experiment, Allain et al. (2021) find support for the predictions in Allain et al. (2016). Vertical integration creates hold-up problems, in particular, if commitment is possible.

C. Theory

I. Genereal setup

The basic setup of our model is as in OSS (1990) and comparable to Normann (2009) who, however, analyses the repeated game. There are $n = 2$ upstream firms and $m = 2$ downstream firms. See Figure 1. We call the upstream firms $U1$ and $U2$ and the downstream firms $D1$ and $D2$. The integrated firm will be called $U1$-$D1$. The upstream firms produce a homogeneous input. $D1$ and $D2$ transform the input on a one-to-one basis into a symmetrically differentiated final good.

Downstream firms pay a linear price for the input which constitutes their only cost. Define c_i as the price per unit firm Di pays. There is differentiated price competition at the downstream level and $Q_i\left(p_i, p_j\right)$ denotes the demand function of the final consumers. Because of the one-to-one transformation it determines at the same time the demand of Di for the input good, $i, j = 1, 2$, $i \neq j$. Symmetry implies that sales depend on prices

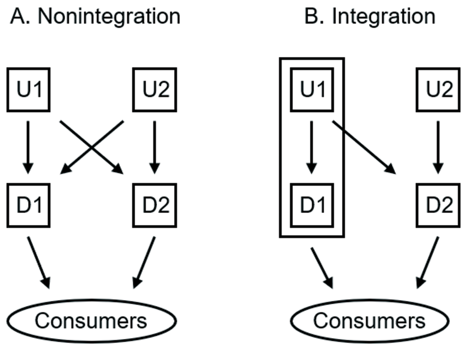

Figure 1: Market Structure

but not on the identities of the firms, that is, $Q_1(p_1, p_2) = Q_2(p_2, p_1)$. Di's profits are

$$\pi_{Di} = (p_i - c_i)\, Q_i\left(p_i, p_j\right), i, j = 1, 2, i \neq j.$$

We impose the following assumptions on demand. Demand functions $Q_i\left(p_i, p_j\right)$ are twice continuously differentiable with $\frac{\partial Q_i}{\partial p_i} < 0$, $\frac{\partial Q_i}{\partial p_j} > 0$, and $\frac{\partial Q_i}{\partial p_i} + \frac{\partial Q_i}{\partial p_j} < 0$, $i, j = 1, 2$, $i \neq j$. These assumptions ensure downward sloping demand with substitute goods where the effect of a change in a firm's own prices dominates the effect resulting from a change of the rival firm's price. Further, we assume that goods are strategic complements, that is, $\frac{\partial^2 \pi_{Di}}{\partial p_i \partial p_j} > 0$. A final assumption is that $\frac{\partial^2 \pi_{Di}}{\partial p_i^2} + \frac{\partial^2 \pi_{Di}}{\partial p_i \partial p_j} < 0$. This assumption implies that own effects dominate cross effects also in terms of the slope of the demand function. Together with the other assumptions, this is sufficient to ensure the existence of a unique Nash equilibrium of the stage game.

Denote $p_i^*\left(c_i, c_j\right)$, i, j=1, 2, $i \neq j$, for the static Nash equilibrium prices at the downstream level. Since input prices $\left(c_i, c_j\right)$ sufficiently describe Nash equilibrium downstream competition, and we will employ $Q_i^*\left(c_i, c_j\right)$ as a reduced form for $Q_i\left(p_i^*\left(c_i, c_j\right), p_j^*\left(c_j, c_i\right)\right)$, and $\pi_{Di}^*\left(c_i, c_j\right)$ for $\pi_{Di} = \left(p_i^*\left(c_i, c_j\right) - c_i\right) Q_i^*\left(c_i, c_j\right)$. We assume costs are such that positive demands $Q_i^*\left(c_i, c_j\right) > 0$ occur throughout.

Given the above assumptions, OSS (1990) show that raising the cost of a downstream rival is profitable. That is,

$$\frac{\partial \pi_{Di}^{*}\left(c_i, c_j\right)}{\partial c_j} = \left(p_i - c_i\right) \frac{\partial Q_i\left(p_i, p_j\right)}{\partial p_j} \frac{\partial p_j^{*}\left(c_i, c_j\right)}{\partial c_j} > 0, i, j = 1, 2, i \neq j, \tag{1}$$

as follows from the envelope theorem.

We finally turn to the upstream level. We assume that that upstream firms, $U1$-$D1$ and $U2$, have constant marginal cost which we normalize to zero. Let w_i denote the price upstream firm i, $i = 1, 2$, charges on the external input market.

II. Simultaneous-move game

Following OSS (1990) and subsequent literature, we begin with the assumption that $U1$ and $U2$ choose input prices simultaneously. With simultaneous moves, upstream firms are perfect Bertrand competitors. This implies that the lower of the two upstream prices constitutes the input price. Given the input price, downstream firms purchase the number of units they require, $Q_i\left(p_i, p_j\right)$, if they procure externally at all. Below, we will specify how much the downstream firms purchase from the two upstream firms when they charge the same price.

When no firm is vertically integrated (Panel A of Figure 1), upstream competition à la Bertrand implies that Nash equilibrium prices are equal to the marginal cost on the input market. This static Nash equilibrium is unique. Both downstream firms purchase the good externally on the input market and they pay the same price for it. So, we have $w_1 = w_2 = c_1 = c_2 = 0$.

Now suppose that $U1$ and $D1$ are integrated (Panel B of Figure 1). The downstream segment of $U1$-$D1$ obtains the input internally at $c_1 = 0$ (Bonanno and Vickers, 1988). For now, we will set aside the reasoning of OSS (1990) and follow the conclusions of Hart and Tirole (1990) and Reiffen (1992) that $w_1 = w_2 = c_1 = c_2 = 0$ just as in the Nash equilibrium without integration.

Proposition 1. In the simultaneous-move game, the U1-D1 merger has no impact because the input market is competitive with or without integration.

Before moving on to the sequential-move case, let us review OSS (1990)'s argument. The novel insight of OSS (1990) was that the vertical integration changes the incentives to compete in the input market. If $U1$-$D1$ can credibly commit to withdrawing from the input market, $U2$ will became the sole supplier of $D2$. $D2$ will pay some $c_2 > 0$ for the input and $U1$-$D1$ earns $\pi^*_{D1}(0, c_2)$. Now, suppose instead that $U1$-$D1$ competes in the input market, as argued above. Then we obtain $c_2 = 0$ and $U1$-$D1$ earns $\pi^*_{D1}(0, 0) < \pi^*_{D1}(0, c_2)$. In other words, $U1$-$D1$ makes no upstream profit in either case, but, when it withdraws from the input market, it makes a higher downstream profit, $\pi^*_{D1}(0, c_2) > \pi^*_{D1}(0, 0)$, due to the raising-rivals'-costs effect (see equation (1)). Hence, $U1$-$D1$ prefers to withdraw from the input market. In the static simultaneous-move game, there is no commitment, however, and $U1$-$D1$ has an incentive to deviate in this situation (as emphasized by Hart and Tirole, 1990, and Reiffen, 1992). It will re-enter the input market, contrary to its claim to withdraw, and undercut $U2$'s input price. As $U2$ will anticipate this deviation, the static Nash equilibrium has both $U1$-$D1$ and $U2$ charging a price equal to marginal cost, that is, $c_1 = c_2 = 0$ just as in the case without integration. $U2$ earns zero profits and $U1$-$D1$ earns $\pi^*_{D1}(0, 0)$ in the static Nash equilibrium.

III. Sequential moves

Now assume that $U1$ is the price leader. $U1$ sets its price, w_1, first and, knowing w_1, $U2$ moves second. Otherwise, the setup is as above.

In any subgame perfect Nash equilibrium of the sequential-move game, $U2$ will play a best response to w_1. To define this best response, we need to define a benchmark, namely the price of the input, w_2, that maximizes $U2$'s profits if it is a monopolist in the input market and $U1$-$D1$ plays its myopic best reply at the downstream level, $p^*_1(0, w_2)$ where $c_2 = w_2$. Denote this price by w_2^{mon} and define formally

$$w_2^{mon} := arg \quad max_{w_2} w_2 Q^*_2(w_2, 0).$$

Accordingly, define $\pi_2^{mon} := w_2^{mon} Q^*_2(w_2^{mon}, 0)$.[3] We can now define $U2$'s best response as

$$w_2^{BR}(w_1) = \min\{\max\{0, w_1 - \varepsilon\}, w_2^{mon}\}.$$

3 The input-good price w_2^{mon} is also central to the analysis in OSS (1990).

In words, $U2$ it will undercut $U1$ price by an infinitesimally small margin, ε, unless w_1 is strictly larger than $U2$'s preferred monopoly price, or unless w_1 is negative.

It is now straightforward to see the impact of price leadership. We know that $U2$ will undercut any input price w_1 set by $U1$-$D1$, so $U1$-$D1$ will not earn anything on the input market. But $U1$-$D1$ earns $\pi^*_{D1}(0, w_2)$. Due to the raising-rivals' cost effect (see (1)), it follows that $U1$-$D1$ will prefer $U2$ to charge a price as high as possible. In any SGPNE, $U1$-$D1$ best responds to $w_2^{BR}(w_1)$ by charging some $w_1 > w_2^{mon}$ strictly. Any price pair $(w_1, w_2 | w_1 > w_2^{mon}, w_2 = w_2^{BR}(w1))$ constitutes a SGPNE. This implies that in any SGPNE the market will be monopolized through price leadership.

It is equally important to show that price leadership will not have any impact when $U1$ and $D1$ are not integrated. Without integration, the price leader will sell a zero amount. Indeed, there exists a SGPNE in which the price leader charges $w_1 > w_2^{mon}$ and $U2$ marginally undercuts this price, taking home the entire profit. (This is an equilibrium for $U1$-$D1$ because the firm is indifferent as it obtains zero profits for all other w_1 values.) Actually, any outcome with $w_1 \geq 0$ is a SGPNE. However, as also argued by Mouraviev and Rey (2011) the equilibria with $w_1 > 0$ and in particular those with $w_1 > w_2^{mon}$ are rather knife edge and not robust with respect to a potential cost of moving first or second, for example. In extended games like those suggested by Hamilton and Slutsky (1990), a cost of moving first would destroy the equilibria with $w_1 \geq 0$ in our game and firms would choose simultaneously in such extended games. We conclude that price leadership will not have any impact without integration.

Proposition 2. In the sequential-move game with $U1$ as the price leader, the $U1$-$D1$ merger results in monopolization of the input market. In contrast, the input market is competitive without the integration.

D. Design

First, let us clarify the scope of our experiment. It focuses solely on the price-setting behavior of upstream firms. The decision to integrate is not part of the experiment – it is given exogenously. Neither the decisions of downstream firms nor consumer decisions are part of the experiment – they are assumed to behave according to Nash equilibrium. The equilibrium behavior of the downstream firms and consumers determines the payoff tables given to the subjects.

Our treatment design is as follows: There are experimental treatments with and without price leadership, and there are treatments with and without vertical integration. We do not conduct a full 2×2 design because the variant with price leadership but without integration is likely to result in an undesirable payoff for the price leader. Table 1 summarizes the design. The treatment labels read as follows. "Sequent-Integ" refers to the sequential-move variant with vertical integration, we conducted "Simul-Integ-After" subsequently and *within subjects*. "Simul-Integ-After" and "Simul-Integ" are the simultaneous-move variant with vertical integration and "Simul-Separ" is the simultaneous-move variant with vertical separation.

Table 1. Treatments and number of participants

Label	Sequent-Integ	Simul-Integ-After	Simul-Integ	Simul-Separ
order of moves	sequential	simultaneous	simultaneous	simultaneous
integrated?	yes	yes	yes	no
# participants	20		40	40

Our experiments are designed to analyze the effects of price leadership, but we also intend to check for learning effects. Specifically, we will examine whether experience as a price leader results in higher prices when the leader-follower sequence is removed. After playing Sequent-Integ for ten periods in the first phase, subjects immediately play Simul-Integ for 15 periods in the second phase (referred to as Simul-Integ-After). The other treatments involve only one phase.

In all treatments, two subjects representing the two upstream firms have to make one single choice in every period. They set a price. Prices must be integers between one and nine, inclusive.

The treatments differ based on the payoff table that is given to the subjects. These payoff tables are derived from a parametrized model (see Appendix). The tables are fully consistent with the analysis in OSS (1990) who indeed use the same parametrized model for some of their analysis.

In the Simul-Separ treatment, the basis for decision-making is the profit table shown in Table 2. Participants play a simple Bertrand duopoly experiment. The firm that charges the lowest price will earn the profits in the "Profit" cells. The high-price firm receives nothing. In the case of a tie, both firms receive half of the profit. The instructions illustrate this with two examples. One example reads, "If you charge a price of 7 and the other firm charges a price of 4, you will get zero, and the other firm will get 81".[4]

Table 2. The payoff table for treatment Simul-Separ (vertical separation)

Price	1	2	3	4	5	6	7	8	9
Profit	39	54	69	81	90	99	90	72	51

In the treatments with vertical integration, Table 3 represents the payoffs. The integrated firm, $U1$-$D1$, is the row player, $U2$ plays columns. $U1$-$D1$

Table 3. Payoffs for $U1$-$D1$ (top) and $U2$ (bottom) for corresponding price pairs (w_1, w_2).

w_2 / w_1	1	2	3	4	5	6	7	8	9
1	85.5, 19.5	105, 0	105, 0	105, 0	105, 0	105, 0	105, 0	105, 0	105, 0
2	66, 39	101, 27	128, 0	128, 0	128, 0	128, 0	128, 0	128, 0	128, 0
3	66, 39	74, 54	118.5, 34.5	153, 0	153, 0	153, 0	153, 0	153, 0	153, 0
4	66, 39	74, 54	84, 69	136.5, 40.5	177, 0	177, 0	177, 0	177, 0	177, 0
5	66, 39	74, 54	84, 69	96, 81	150, 45	195, 0	195, 0	195, 0	195, 0
6	66, 39	74, 54	84, 69	96, 81	105, 90	181.5, 49.5	231, 0	231, 0	231, 0
7	66, 39	74, 54	84, 69	96, 81	105, 90	132, 99	204, 45	249, 0	249, 0
8	66, 39	74, 54	84, 69	96, 81	105, 90	132, 99	159, 90	216, 36	252, 0
9	66, 39	74, 54	84, 69	96, 81	105, 90	132, 99	159, 90	180, 72	223.5, 25.5

4 The experimental markets were designed such that firms still make a positive profit when they both charge 1 (the Nash equilibrium price). The reason is that subjects might be biased against an action with zero profit (Dufwenberg et al., 2007).

always gets a positive payoff, which corresponds to it's the profit of its downstream affiliate and is affected by the raising-rivals-cost effect: the higher min $\{w_1, w_2\}$, the higher this payoff. Otherwise, firms compete for the profit in the input market which is determined by Bertrand rules, as indicated above.

The stage games were repeated several times for each treatment. Specifically, the Simul-Integ and Simul-Separ treatments were repeated 15 times. The Sequen-Integ treatment was repeated ten times, followed by fifteen repetitions of Simul-Integ After. Subjects knew the number of periods and the final period from the instructions in all treatments.

All treatments were conducted under a random matching scheme. This moves the lab setting closer to the static game and precents reputation building, which is possible in the repeated game.

E. Procedures

All treatments were conducted in sessions with ten participants. Five of the participants acted as "firm 1", the integrated firm, while the remaining five participants acted as "firm 2". These roles remained fixed throughout the experiment. In the Simul-Separ treatment, firms are symmetric but the "firm 1" and "firm 2" labels are still given to maintain a comparable matching scheme and set of instructions.

A total of 100 subjects took part in this experiment. There were four sessions of ten participants each for the Simul-Integ treatment, and four for the Simul-Separ treatment. There were two sessions for the Sequen-Integ and Simul-Integ-After treatments. The lower number of sessions for Sequen-Integ and Simul-Integ-After is due to the extremely low heterogeneity in these treatments.

The experiments were computerized and programmed in Z-Tree, developed by Fischbacher (2007). The experiments were conducted at Royal Holloway, University of London. To avoid exchange rates, the payoffs in Tables 2 and 3 represent cash payments in real currency. Subjects' average monetary earnings were £12.50, including a flat payment of £5. Subjects were primarily undergraduate students, many of whom were from faculties other than economics or business studies.

F. Results

Tables 4–6 and Figures 2–4 summarize the results. Table 4 reports the average minimum and posted prices and profits for each firm type in the four treatments. Tables 5 and 6 report results from linear probability regressions: Table 5 analyzes the minimum prices w_{min}, and the prices w_1 and w_2. Table 6 focuses on the probability of monopolization ($w_{min} = 6$), foreclosure strictly defined (probability of $w_1 > 6$), and foreclosure broadly defined (probability of $w_1 > w_2$).

Table 4. Descriptive Statistics

Treatment	Sequent-Integ	Simul-Integ-After	Simul-Integ	Simul-Separ
w_{min}	5.27	2.61	2.33	1.53
	(1.55)	(1.38)	(1.26)	(0.76)
w_1	7.01	3.70	3.36	2.04
	(2.10)	(2.05)	(2.11)	(1.21)
w_2	5.31	3.19	2.90	2.22
	(1.50)	(1.57)	(1.55)	(1.69)
π_1	62.25	54.43	103.44	22.69
	(13.67)	(16.85)	(32.32)	(19.24)
π_2	43.14	17.91	32.74	24.13
	(11.76)	(14.90)	(28.07)	(19.84)

I. Average prices and profits

Price leadership in Sequent-Integ effectively monopolizes the upstream market. The minimum price w_{min} Sequent-Integ does not differ much from the monopoly price, on average it equals 5.27 (the upstream monopoly price is 6). The integrated firm chooses on average a price above monopoly level (7.01) and the non-integrated firm sets 5.31 (see Table 4). As is evident also from Figure 2, the minimum price w_{min} virtually identical to w_2, the price of the non-integrated firm, suggesting that $U2$ indeed best responds.

The effect of price leadership in Sequent-Integ does not carry over to the second phase with simultaneous price choices (Simul-Integ-After), though. When price leadership is removed, the price level drops strongly

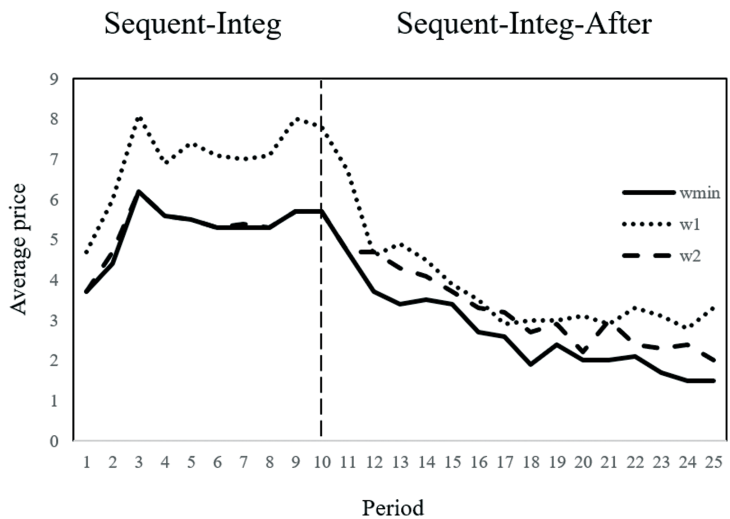

Figure 2. Sequential-Integ and Sequential-Integ-After treatments

(see the right part of Figure 2). The minimum price is less than half as high, we obtain a mean price of 2.61 in Simul-Integ-after. Comparing w_{min}, w_1 and w_2, the treatments Sequent-Integ and Simul-Integ-After differ significantly at the 1 % level (see Table 5, regressions (1), (2) and (3) and the corresponding Wald tests for coefficient differences).

Price leadership is profitable for both firms, but more so for the non-integrated firm. The profit π_2 is more than twice as high in the Sequent-Integ treatment compared to the Simul-Integ-After treatment. The difference is not as pronounced but still substantially positive for the integrated firm. It earns on average 62.25 in Sequent-Integ and 54.43 in Simul-Integ-After (see Table 4).

The experience of price leadership in the Sequent-Integ treatment is not even strong enough to have an impact compared to the treatment with simultaneous moves. The Simul-Integ data are illustrated in Figure 3. When we compare the treatment Simul-Integ-After with the results of treatment Simul-Integ, we do not find significant differences. The minimum price is very similar (2.61 in Simul-Integ-After and 2.33 in Simul-Integ) and average price choices of both firms are only slightly higher in Simul-Integ-After (see also Figures 2 and 3). If we exclude periods 1–3 in Simul-Integ-After and Simul-Integ, the difference gets even smaller. Averages are 2.28 for Simul-Integ-After and 2.25 and the difference between

Table 5. Linear regression on w_{min}, w_1 and w_2

	(1) w_{min}	(2) w_1	(3) w_2
Sequent-Integ	5.49***	7.33***	5.50***
	(0.13)	(0.03)	(0.14)
Simul-Integ-After	2.28***	3.28***	2.85***
	(0.03)	(0.23)	(0.01)
Simul-Integ	2.25***	3.12***	2.78***
	(0.36)	(0.35)	(0.37)
Simul-Separ	1.37***	1.86***	1.95***
	(0.15)	(0.19)	(0.19)
Periods 1–3 × Sequent-Integ	-0.72	-1.06***	-0.63
	(0.60)	(0.22)	(0.69)
Periods 1–3 × Simul-Integ-After	1.66***	2.12***	1.72***
	(0.02)	(0.18)	(0.09)
Periods 1–3 × Simul-Integ	0.44*	1.23***	0.62**
	(0.23)	(0.37)	(0.24)
Periods 1–3 × Simul-Separ	0.78***	0.89***	1.35***
	(0.14)	(0.17)	(0.10)
Obs.	850	850	850
R^2	0.86	0.82	0.81
Coefficient differences			
Sequent-Integ – Simul-Integ-After	3.21***	4.05***	2.65***
Simul-Integ-After – Simul-Integ	0.03	0.16	0.07
Simul-Integ – Simul-Separ	0.88*	1.26**	0.83*

Notes: Each column represents an OLS regression with the dependent variables: minimum price w_{min}, prices w_1 and w_2. We regress on treatment dummies Sequent-Integ, Simul-Integ-after, Simul-Integ, and Simul-Separ as well as treatment specific time trends, that is, interaction terms of a dummy for periods 1–3 and treatment variables. We omit the constant and cluster standard errors at session level. A Wald test on the coefficient differences is performed and the significance level is indicated by the stars, in particular *** 1 % level significance, ** 5 % level significance and * 10 % level significance.

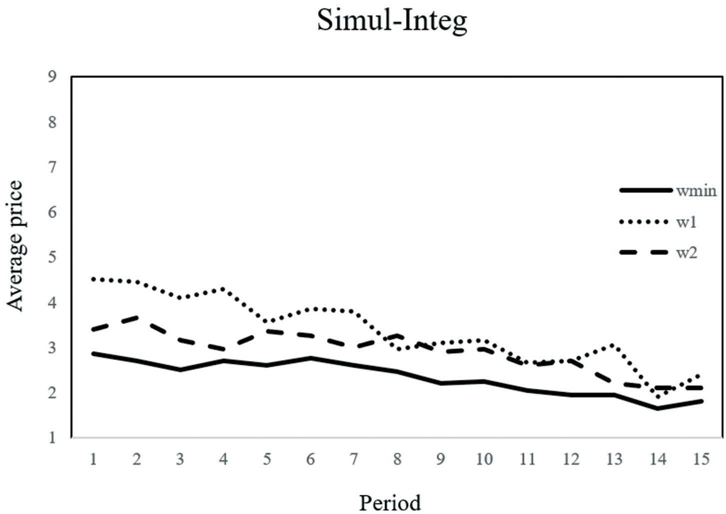

Figure 3. Simul-Integ treatment

the treatments is insignificant (see Table 5, regressions (1), (2) and (3) and the corresponding Wald tests for coefficient differences).

However, vertical integration still has an effect. We find that treatment Simul-Integ increases the minimum price compared to Simul-Separ. The average minimum price equals 2.33 with integration while it is 1.53 without. Regression (1) in Table 5 confirms that the difference is significant at the 10 % level. Price choices of both firms are significantly larger with integration (see also Figures 3 and 4) and the non-integrated firm benefits from the integration of its competitor in Simul-Integ (see Table 3).

II. Foreclosure and monopolization

We now turn to the issues of foreclosure and monopolization of the market. To some degree, the results on the average prices already indicate the extent of foreclosure and monopolization. It will, however, be useful to discuss these issues separately. We analyze monopolization defined as $w_{min} = 6$, foreclosure strictly defined ($w_1 > 6$), and foreclosure broadly defined (probability of $w_1 > w_2$).

We begin with *monopolization* which is OSS's (1990) prediction. For the Sequent-Integ treatment after period three (Table 6, regression (4)), we can see that the probability of monopolization is 69 %. The probability of monopolization then decreases substantially: After the first three periods in Simul-Integ-after we do not observe any monopolization (see Table 6, regression (4)). Monopolization is also practically zero with simultaneous moves. In the Simul-Integ treatment, only 0.67 % of markets are monopolized.[5] Thus, in contrast to OSS's (1990) predictions, vertical integration alone does not lead to monopolization of the upstream market. In Simul-Separ, foreclosure never results in monopolization.

We now turn to the *strictly defined concept of foreclosure*, which is the withdrawal of an integrated firm from the upstream market. In strict foreclosure, the integrated firm sets a price above the monopoly level – that is, a price greater than six.[6] If the integrated firm moves first (Sequent-Integ), it forecloses (in the sense of $w_1 > 6$) after period 3 in 76 % of observations (see Table 6). However, in Simul-Integ-After the integrated firm forecloses only in 4 % of observations. That is, the foreclosure in the first phase does not have a long-term impact on pricing in the second phase. Foreclosure in Simul-Integ-After is insignificant and even slightly below the percent-

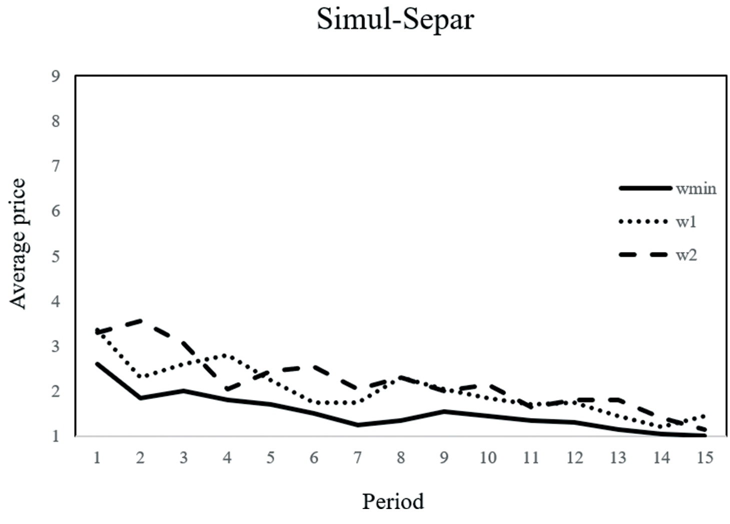

Figure 4. Simul-Separ treatment

5 In Simul-Integ, the foreclosure rate is largely influenced by a single participant who selected it in 12 out of 15 periods.

6 Monopolization occurs when there is strict foreclosure and, in addition, the non-integrated firm charges the monopoly price.

Table 6. Linear probability regressions for monopolization and foreclosure

	(4) $w_{min} = 6$	(5) $w_1 > 6$	(6) $w_1 > w_2$
Sequent-Integ	0.69***	0.76***	0.93***
	(0.02)	(0.01)	(0.01)
Simul-Integ-After	0.00	0.04*	0.43***
	(0.00)	(0.02)	(0.04)
Simul-Integ	0.01	0.08*	0.42***
	(0.01)	(0.03)	(0.01)
Simul-Separ	0.00	0.00	0.30***
	(0.00)	(0.00)	(0.02)
Periods 1–3 × Sequent-Integ	–0.29***	–0.22***	–0.06
	(0.02)	(0.04)	(0.06)
Periods 1–3 × Simul-Integ-After	0.27***	0.22***	0.10
	(0.05)	(0.02)	(0.09)
Periods 1–3 × Simul-Integ	0.00	0.11*	0.13**
	(0.01)	(0.06)	(0.05)
Periods 1–3 × Simul-Separ	0.00	0.00	0.08*
	(0.00)	(0.00)	(0.04)
Obs.	850	850	850
R^2	0.55	0.26	0.53
Coefficient differences			
Sequent-Integ – Simul-Integ-after	0.69***	0.72***	0.50***
Simul-Integ-after – Simul-Integ	–0.01	–0.03	0.01
Simul-Integ – Simul-Separ	0.01	0.07**	0.12***

Notes: Each column represents a linear probability model with the dependent variables: dummies on monopolization ($w_{min} = 6$), foreclosure strictly defined ($w_1 > 6$), and foreclosure broadly defined ($w_1 > w_2$). We regress on treatment dummies Sequent-Integ, Simul-Integ-after, Simul-Integ, and Simul-Separ as well as treatment specific time trends, that is, interaction terms of a dummy for periods 1–3 and treatment variables. We omit the constant and cluster standard errors at session level. A Wald test on the coefficient differences is performed and the significance level is indicated by the stars, in particular *** 1 % level significance, ** 5 % level significance and * 10 % level significance.

age of foreclosure in Simul-Integ. The integrated firm withdraws in 8 % of markets in Simul-Integ (after period three). In Simul-Separ there is no incentive for foreclosure, and there is virtually no foreclosure. The difference between Simul-Integ and Simul-Separ is significant at the 5 % level (see Table 6 regression (5)).

If we look more *broadly at foreclosure strategies*, a similar picture emerges. We consider prices of the integrated firm that are larger than the prices of the non-integrated firm ($w_1 > w_2$). When prices are chosen sequentially, the integrated firm chooses a larger price in 93 % of markets. In Simul-Integ-After the percentage drops by roughly 50 %, the integrated firm sets a higher price in 43 % of markets. In Simul-Integ 42 % of integrated firms choose a higher price than their opponent which is almost identical. Again, we do not observe any effect from Sequent-Integ on Simul-Integ-After (see Table 6, regression (6)). With no vertical integration in Simul-Separ, firm $U1$ sets a higher price in 30 % of markets. Considering the difference between Simul-Integ and Simul-Separ from period four, it is significant at the 1 % level (see Table 6, regression (6)).[7]

III. Effects over Time

We analyze the effects over time by adding dummy variables for periods 1 through 3 to the regressions in Tables 5 and 6. In periods 1 to 3 of Sequent-Integ, we observe a slight upward trend of prices followed by a stable price level over later periods. The difference is between periods 1 to 3 and the following periods is highly significant for w_1, however, it is insignificant for w_{min} and w_2 (see Figure 2, Table 5, regressions (1) to (3)). In the first period of Sequent-Integ, average prices are similar to the treatment Simul-Integ. But in period 3, we observe an average price of 8.1 of the integrated firm and 6.2 of the opponent. In contrast, the overall price level slightly decreases after the first three periods of Simul-Integ. The difference is significant for w_{min} at the 10 % level), w_1 (at the 1 % level), and w_2 (at the 5 % level). Overall, there seems to be an upward trend of prices in Sequent-Integ and a downward trend of prices in Simul-Integ.

7 Note that the fraction of identical prices in markets with integration decreases while $U1$ undercuts the opponent just as often with and without integration. The integrated firm undercuts the competitor in 31.33 % of markets in Simul-Integ-after and 32 % in Simul-Integ. Firm $U1$ chooses a lower price than $U2$ in 29 % of markets in Simul-Separ.

The price level decreases exceptionally in Simul-Integ-after (see Figure 2). While in the first period of Simul-Integ-after (period 11) the integrated firm sets on average a price of 6.7, it drops already in period 12 to an average of 4.6. The difference between periods 1–3 and the following periods is highly significant for w_{min}, w_1, and w_2 (see Table 5, regressions (1) – (3)). As conclude before, that is, the stable price level in Sequent-Integ does not carry over to the phase with simultaneous moves.

Although we find an overall downward trend in Simul-Integ, the observed price difference between Simul-Integ and Simul-Separ holds also with more periods. Normann (2011) shows in a robustness check, that the difference persists if the game is repeated 25 instead of 15 times.

G. Conclusion

One key argument against vertical mergers is that they lead to higher prices in the input market through a raising-rival's-cost effect (OSS, 1990). Whereas Hart and Tirole (1990) and Reiffen (1992) argue that this argument is flawed because it requires commitment, OSS (1992) counter that "*[t]he notion that vertically integrated firms behave differently from nonintegrated ones in supplying inputs to downstream rivals would strike a business person, if not an economist, as common sense*". Who is right and who is wrong? Our paper shows and provides evidence for both diametrically opposed positions.

First, we argue in favor of the OSS (1990) model by suggesting that price leadership can function as a commitment device for integrated firms. Here, we build upon the existing literature, which includes the work of Choi and Yi (2000), Church and Gandal (2000), and OSS (1992), who demonstrate that commitment is effective in extended versions of the OSS (1990) model. Our argument is broader in that we claim the integrated firm will strive to become the price leader, as in a model of endogenous timing (Hamilton and Slutsky, 1990; Normann, 2002). By contrast, a non-integrated firm would never want to be a price leader.

Our experimental evidence shows that price leadership indeed leads to monopolization, but it also shows that learning effects from experiences a phase of price leadership are limited. Once they are no longer the price leader, integrated firms do not charge higher prices than non-integrated firms, nor are prices higher than in simultaneous-move experiments. This supports the findings of Hart and Tirole (1990) and Reiffen (1992) that, in the absence of price leadership, the commitment problem is severe and vertical mergers do not have anticompetitive effects. The Nash equilibrium is strong – it seems that players cannot learn to achieve non-Nash outcomes in this case.

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Appendix A: Linear Model

This appendix presents the model underlying the payoff tables of the experiment. See OSS (1990) and Normann (2011) for similar linear parametrizations. As in the general model, there are two upstream firms ($U1$ and $U2$) and two downstream firms ($D1$ and $D2$).

Downstream firm Di's demand is given by the linear demand function

$$q_i\left(p_i, p_j\right) = a - bp_i + dp_j; i, j = 1, 2; i \neq j,$$

where p_i and p_j are the prices the downstream firms i and j charge ($i, j = 1, 2; i \neq j$). Assume downstream firm i purchases the input good at a linear price of c_i per unit. As the D firms incur no other costs, they produce at constant marginal costs of c_1 and c_2, respectively. It follows that the downstream level is a standard model with product differentiation and asymmetric cost. We solve for downstream Nash equilibrium prices

$$p_i^*\left(c_i, c_j\right) = \frac{(2b + d)\, a + 2b^2 c_i + bdc_j}{4b^2 - d^2},$$

outputs

$$q_i^*\left(c_i, c_j\right) = b\frac{(2b + d)\, a - \left(2b^2 - d^2\right) c_i + bdc_j}{4b^2 - d^2},$$

and profits $\pi_{Di}^* = \frac{\left(q_i^*\left(c_i, c_j\right)\right)^2}{b}$.

Upstream firms have constant marginal cost which are assumed to be zero as in the general model. The upstream firms compete for each of the two downstream markets in a Bertrand fashion. Employing slightly different notation than above, we assume upstream firm k sets two prices, c_1^{Uk} and c_2^{Uk}, for downstream firms 1 and 2, respectively. Bertrand competition implies that the downstream firm i buys from the upstream firm with the lowest price, formally $c_i = \min\left\{c_i^{U1}, c_i^{U2}\right\}, i = 1, 2$. Put it another way, an upstream firm will sell a positive amount to Di only if it charges the lowest price. Formally, when upstream firm k bids c_i^{Uk} to downstream firm i, it will make the following profit with Di

$$\pi_i^{Uk}\left(c_i^{Uk}, c_i^{Ul}\right) = \begin{cases} c_i^{Uk} \cdot q_i^*\left(c_i^{Uk}, c_i^{Uk}\right) & if\, c_i^{Uk} < c_i^{Ul} \\ c_i^{Uk} \cdot q_i^*\left(c_i^{Uk}, c_i^{Uk}\right)/2 & if\, c_i^{Uk} = c_i^{Ul} \\ 0 & if\, c_i^{Uk} > c_i^{Ul} \end{cases}$$

where $k, l = 1, 2; k \neq l; i = 1, 2$.

When neither firm is integrated, in the general model, $U1$ and $U2$ set prices $\left(c_1^{U1}, c_2^{U1}\right)$ and $\left(c_1^{U2}, c_2^{U2}\right)$, respectively. For the derivation of the payoff tables, c_1 is set equal to zero. The reason is that $c_1 = 0$ with vertical integration. Thus, in order to keep treatments comparable and avoid wealth effects, one also needs $c_1 = 0$ without integration. Essentially, this is implies that firms only compete for $D2$ also absent integration. This is without loss of generality of the qualitative features of Bertrand competition are unaffected by this. $D2$ buys at the lower of the two prices such that $c_2 = \min\left\{c_2^{U1}, c_2^{U2}\right\}$. Next, given $c_1 = 0$ and c_2, $D1$ and $D2$ set the final good prices. In equilibrium, $D1$ and $D2$ charge $p_1^*\left(0, c_2\right)$ and $p_2^*\left(c_{2,0}\right)$, respectively. Downstream profits are $\pi_{D1}^* = \frac{(q_1^*(0,c_2))^2}{b}$ and $\pi_{D2}^* = \frac{(q_2^*(c_{2,0}))^2}{b}$, and upstream profits are π_2^{U1}, π_2^{U2} and $\pi_1^{Uk} = 0$.

A vertical merger of $U1$ and $D1$ implies that the integrated firm's true input price is $U1$'s marginal cost (Bonanno and Vickers, 1988). Hence, $D1$ will be delivered internally and efficiently at $c_1 = 0$ and $U2$ cannot compete for the $D1$ business any more. For both upstream firms, only the $D2$ market remains a source for potential business. Profits are as follows. $D2$ earns $\pi_{D2}^* = \frac{(q_2^*(c_{2,0}))^2}{b}$, $U2$ earns π_2^{U2}, and the integrated firm $U1$-$D1$ makes a profit of $\pi_2^{U1} + \pi_{D1}^* = \pi_2^{U1} + \frac{(q_1^*(0,c_2))^2}{b}$.

Tables 2 and 3 can be derived from these closed-form solutions for the parameters $a = \frac{35}{2}$, $b = 4$, $d = 2$. The actual price parameters used to derive the profits in the table differ from the prices labels "1" to "9". In particular, profits around the joint-profit maximizing prices are quite flat. Hence, prices were increased in steps larger than one in this range to avoid the "flat-maximum" critique (Harrison, 1989). The actual price parameters underlying the values in the table are {1.1, 1.6, 2.2, 2.9, 3.5, 5.0, 6.5, 7.6, 8.5}. Additionally, profits were multiplied by three and rounded to yield the payoff in real currency subjects received.

Appendix B: Instructions

Below are the instructions for Sequen-Integ, phase 1. These include phase 1, phase 2 and the additional oral instructions.

*

This is an experiment on market decision-making. Funds for this experiment have been provided by an external research foundation. Take the time to read carefully the instructions. A good understanding of the instructions and well thought out decisions during the experiment can earn you a considerable amount of money. All earnings from the experiment will be paid to you in cash at the end of the experiment.

YOUR ROLE AND TASK IN THE EXPERIMENT

There are a total of 10 participants in this experiment (you and 9 others). Each participant will represent a firm. There are two types of firms, firm 1 and firm 2. The computer randomly assigns five participants the role of firm 1 and the other five participants the role of firm 2. Your role as firm 1 or firm 2 will remain fixed throughout the experiment, and you will learn whether you are firm 1 or firm 2 before we begin the experiment.

The experiment takes place over 25 rounds. In each round, a firm 1 and a firm 2 will meet in a market for a fictitious commodity, called market A. Firm 1 operates also in market B but firm 2 does not. The computer will randomly match the firm 1-firm 2 pairs in every round. The matching is completely random, meaning that there is no relation between the participant you have been matched with last round (or any other previous round) and the participant to whom you will be assigned this round.

Your task is the same in every round, no matter whether you are firm 1 or firm 2. You have to decide on a price, and this single price is valid in both markets A and B. The price can be any (whole) number from 1 to 9.

Importantly, firm 1 will have to choose its price first. Firm 2 is informed about firm 1?s choice, and then firm 2 chooses its price.

The profit you can make by charging the price is as follows.

PROFIT CALCULATION

In market A, the firm that charges the lowest price will receive the profit corresponding to this price in the following table. The firm with the higher price gets zero profit in that round, and, if both firms set the same price, they share the profit equally. Price profit in market A in pence profit in market B in pence

Price 1	2	3	4	5	6	7	8	9
Profit in Market A 39	54	69	81	90	99	90	72	51
Profit in Market B 66	74	84	96	105	132	159	180	198

Consider two examples for market A. If you charge a price of 7 and the other firm charges a price of 4, you will get zero and the other firm gets 41 pence in market A. Or, if both firms charge a price of 3, both will get 35 /2 = 17.5 pence in market A.

In market B, firm 1 only receives a profit – the profit of the "market B" column in the table. As in market A, it is the lowest of the two prices which determines the profit, no matter whether firm 1 or firm 2 (or both) charged the lowest price.

Consider an example for market B. If firm 1 charges a price of 7 and firm 2 charges a price of 4, firm 1 only gets 48 pence in market B.

Taking both markets into account, firm 1 receives the profit it made in market A plus the profit it made in market B. Firm 2 does not get any profit in market B, only in market A.

TWO PHASES

There are two phases in this experiment. The first phase lasts 10 periods, the second phase lasts 15 periods. So, in total, the experiment will go over 25 periods. After phase 1 is over, we will inform you about a change in the market relevant for the second phase.

EACH ROUND

A round ends when all firms have chosen their price. At the end of the round, each firm sees its own price, the price of the other firm and the own profit from the round.

At the completion of 25 rounds, you will be paid your earnings in pounds you have accumulated during the experiment. In addition to these earnings, each participant will receive a payment of 3£. While the earnings are being counted for distribution, you will be asked to complete a questionnaire related to the experiment.

QUESTIONS?

If you have any questions about the instructions, please raise your hand and an experimenter will come to assist you. Thank you for your participation.

*

The instructions for phase 2 merely emphasized that the same game would be played but that firm 1 would no longer move first. Instead, both firms would move simultaneously. The second phase lasted for 15 periods.

*

The following summary of the instructions was read aloud at the beginning of the treatment and after participants had finished reading the instructions.

TASK

- Your task is the same in every round: You have to decide on a price.
- The price can by any (whole) number from 1 to 9.
- You set only one price every period
- There are two phases in this experiment. The first phase lasts 10 periods, the second phase lasts 15 periods. After phase 1 is over, we will inform you about a change in the market relevant for the second phase.

PROFIT

As you read in the instructions, there are two markets, market A and market B. The profit you can make by charging the price is as follows.

- In market A, the firm which charges the lower price will receive the profit in the table.
- The firm with the higher price gets zero profit in that round
- and if both firms set the same price, they share the profit equally.
- In market B, firm 1 only receives a profit
- As in market A, it is the lowest of the two prices which determines the profit, no matter whether firm 1 or firm 2 (or both) charged the lowest price
- Again, firm 1 receives the profit it made both in market A and B.
- Firm 2 gets a profit only in market A.]

MATCHING

- There are two types of firms, firm 1 and firm 2.
- The computer will randomly match a firm 1 with a firm 2 pairs in every round.
- In the beginning, the computer randomly assigns five participants the role of firm 1 and the other five participants the role of firm 2.
- Your role as firm 1 or firm 2 will remain fixed throughout the experiment
- Firm 1 has to choose its price first. Firm 2 is informed about firm 1?s choice, and then firm 2 chooses its price.

ROUNDS

- Phase 1 takes place over 15 rounds.
- At the end of phase 2, you will be paid your earnings in pence
- In addition, you will receive a payment of 5