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Vertical Integration as a Source of Hold-up: an Experiment*

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Abstract

In a vertical chain in which two rivals invest before contracting with one of two competing suppliers, partial vertical integration may create hold-up problems for the rival. We develop an experiment to test this theoretical prediction in two setups, in which suppliers can either pre-commit *ex ante* to appropriating part of the joint profit, or degrade *ex post* the support they provide to their customer. Our experimental results confirm that vertical integration creates hold-up problems in both setups. However, we observe more departures from theory in the second one. Bounded rationality and social preferences provide a rationale for these departures.

Keywords: Vertical Integration, Hold-up, Experimental Economics, Bounded Rationality, Social Preferences.

JEL Classification: C91, D90, L13, L41, L42.

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1 Introduction

The risk of expropriation of investment benefits, known as the hold-up problem, has long been recognized as an important source of inefficient under-investment (see Williamson (1975, 1985) and Klein, Crawford and Alchian (1978)). In response, the incomplete contract literature has emphasized the role of vertical integration as a *solution* to this problem (see Grossman and Hart (1986)). In a recent paper, however, Allain, Chambolle and Rey (2016) – henceforth ACR – point out that vertical integration can also *create* hold-up concerns ... for rivals. The aim of this paper is to test this prediction.

Due to a lack of field data, there is a long tradition of using experimental methods to address competition issue. Hinlopen and Normann (2009), for instance, survey the use of experimental methods to understand firm behaviour in relation to competition policy.¹ Investigations of the hold-up problem through laboratory experiments have focused so far on bilateral settings, in which one player invests and must then share the return with the other player.² To test the predictions of ACR, we build on this experimental literature and consider an extended setting in which each player faces competition.

The earlier literature on vertical integration and foreclosure identifies two mechanisms through which vertical integration could harm independent rivals: supplier opportunism (Hart and Tirole (1990)) and raising rivals' costs (Ordover, Saloner and Salop (1990) and Salinger (1988)), both of which have been experimentally tested. The first one, which relies on secret contracting, has been experimentally validated by Martin, Normann and Snyder (2001). The second one relies in theory on a commitment to stop supplying or

¹In particular, Götte and Schmutzler (2009) present a rather large experimental literature on horizontal mergers. By contrast, the literature on vertical mergers is scarce.

²For example, Ellingsen and Johannesson (2004) analyze the impact of communication on hold-up; Sloof, Oosterbeek and Sonnemans (2007) study instead the role of investment observability, whereas Hoppe and Schmitz (2011) focus on the effect of contract renegotiation, and Dufwenberg, Smith and Van Essen (2013) consider the role of rights of control and vengeance.

limit rivals' access. Yet, Normann (2011) finds that vertical integration raises a rival's cost even without such commitment; he moreover shows that this is in line with a quantal response equilibrium, in which players do not best-respond with probability one, but choose better responses more frequently. We contribute to this literature by testing a different mechanism through which vertical integration can harm independent rivals, namely, the hold-up problem highlighted by ACR.

Before describing our experiment, it is useful to briefly present the setup and predictions of ACR. In the baseline model, two downstream competitors must decide whether to invest, and then contract with one of two upstream suppliers for support. Together with support, the investment generates a return, which is reduced if the rival also invests. Two market structures are considered: under vertical separation, the four firms are independent; under (partial) vertical integration, one upstream and one downstream firm are merged, whereas the other two firms remain independent. This baseline model predicts that vertical integration has no impact: upstream competition always leads suppliers – integrated or not – to offer support at cost and, anticipating this, downstream competitors always invest.

Two variants are then considered. The first one allows suppliers to pre-commit themselves *ex ante*, before investment decisions, to being “greedy”, that is, to asking a large share of their customers' profits. Independent suppliers never do so, as this would impede their ability to compete for customers. By contrast, when integrated, exerting this option enables the supplier to expose its downstream rival to being held up by the independent supplier; this discourages the rival from investing, to the benefit of the downstream subsidiary.

The second variant allows the supplier, if selected by a downstream firm, to degrade

ex post, at some cost, the quality of its support. An independent supplier has no incentive to incur this cost and thus never degrades its support. By contrast, when integrated, the supplier would always degrade the support supplied to its rival, so as to confer an advantage to its downstream subsidiary. This exposes again the downstream rival to being held up by the independent supplier and discourages its investment.

Reflecting these key features, our experiment includes three treatments, each played first under separation and then under integration. The *Benchmark* treatment corresponds to a simplified version of the baseline model in which the potentially integrated downstream firm is automatized. There are thus three players: an independent downstream firm, an independent supplier and a “strategic” supplier, who is either independent or integrated with the automatized firm; the downstream firm first decides whether to invest, the two suppliers then offer a profit-sharing contract, and finally the firm selects a supplier. The other two treatments provide the strategic supplier with “hold-up” options. The *Commitment* treatment allows it to pre-select the most greedy offer at the beginning of the treatment, whereas the *Sabotage* treatment allows it, if selected by the downstream firm, to degrade *ex post* its support (which harms the downstream firm but benefits its automatized rival). Compared with Martin, Normann and Snyder (2001), who consider an upstream monopoly, and Normann (2011), who focus on upstream players, our experiment involves an interaction between upstream and downstream players, and moreover allows the former ones, besides deciding over contract terms, to exert hold-up options.

In line with theoretical predictions, our experimental results show that vertical integration does not create hold-up problems in the Benchmark treatment, where most downstream players invest, but does so in the Commitment and Sabotage treatments, where downstream players invest less often in the vertical integration phase. Interest-

ingly, average investment rates suggest that the hold-up problem has a larger impact in the Commitment than in the Sabotage treatment, but a probit regression does not establish any significant difference in the marginal effect of vertical integration between these two treatments. This leads us to have a closer look at the impact of vertical integration on individual departures from theory by the three players. We find that in the Commitment treatment, vertical integration increases the likelihood of departures from theory by the strategic supplier's hold-up decision. By contrast, in the Sabotage treatment vertical integration increases departures from theory of the independent firms: the supplier is too generous and the downstream firm invests too frequently.

Finally, we exploit the difference in the timing of decisions, between the Commitment and Sabotage treatments, to relate the departures from theory observed in our experiment to behavioral approaches emphasized by the experimental literature: bounded rationality and social preferences.

Bounded rationality (namely, level- k theory)³ can explain the departures from theory in hold-up decisions. In the Commitment treatment, this decision comes first, and thus requires the strategic supplier to anticipate the other subjects' subsequent decisions, which involves higher levels of thinking. By contrast, in the Sabotage treatment this decision comes last, and thus requires no such anticipation.

The possibility of social preferences for the strategic supplier, and the associated uncertainty about its behavior,⁴ can instead explain the departures from theory by the independent firms. In the Commitment treatment, this uncertainty is resolved at the very beginning of the treatment. By contrast, in the Sabotage treatment, the other players must

³See Stahl (1993), Stahl and Wilson (1994), Nagel (1995) and Camerer, Ho and Chong (2004).

⁴For previous experiments on strategic uncertainty, see, e.g., Van Huyck, Battalio and Beil (1990) and Berg, Dickhaut and McCabe (1995). Fischbacher and Gächter (2010) find that heterogeneous social preferences can also create strategic uncertainty, through players' beliefs about other players' decisions, in public good games with simultaneous moves.

make their decisions before the resolution of this uncertainty. Interestingly, in the vertical integration phase of the Sabotage treatment we also observe a positive correlation between the departures from theory by the two independent firms, which is in line with the social preferences interpretation: a departure in the downstream firm's investment decision signals this firm's belief that the strategic supplier has social preferences, which in turn induces the independent supplier to be more generous.

This paper is organized as follows. We present the theory in Section 2, before describing the experimental design and the associated predictions in Section 3. We report and analyze the results in Section 4, and offer some concluding remarks in Section 5.

2 The model

We first present our baseline setup and briefly characterize the equilibrium outcome. We then consider the commitment and sabotage variants.

2.1 Benchmark game

2.1.1 Setup

A key assumption underlying the hold-up problem is that firms cannot contract *ex ante*, before investment decisions are made. Reflecting this, in ACR two downstream competitors, D_1 and D_2 , choose whether to invest before obtaining support from one of two upstream suppliers, U_A and U_B . Two market structures are considered: *Vertical Separation*, in which the four firms are independent, and (partial) *Vertical Integration*, in which U_A and D_1 are merged, while U_B and D_2 remain independent. In order to adapt the setup to the experimental constraints, we automatize D_1 's decisions; specifically, we assume that

D_1 : (i) always invests; and (ii) selects the same upstream supplier as D_2 under vertical separation, and the integrated supplier U_A otherwise.⁵ There are therefore three players, U_A , U_B and D_2 ,⁶ and the game is as follows:

- In stage 1, D_2 decides whether to invest, at cost k ; her decision, $I \in \{0, 1\}$, is publicly observed.
- In stage 2, U_A and U_B each offer the required support, in exchange for a share of the revenue; providing the support is costless, and we denote by $s \in [\underline{s}, \bar{s}] \subset [0, 1]$ the share left to the downstream competitors (no discrimination).
- In stage 3, D_2 chooses one supplier; each D_i (for $i = 1, 2$) then obtains $r_i(I) - c$, where c denotes the operating cost and $r_2(1) > r_2(0)$ whereas $r_1(1) < r_1(0)$: D_2 's investment increases her revenue but reduces her rival's revenue.

The parameters satisfy:

$$\underline{s} < s^* \equiv \frac{k}{r_2(1) - r_2(0)} < \bar{s}. \quad (1)$$

This ensures that D_2 invests if her share is large enough (namely, $s > s^*$), but does not if her share is too low ($s < s^*$). We describe below the Subgame Perfect Nash Equilibria under vertical separation and integration.

⁵In ACR, D_1 always invests in equilibrium, regardless of whether she is integrated. Furthermore, under vertical separation, the two downstream competitors have the same objective and thus pick the cheaper supplier when their offers differ; when instead the two suppliers offer the same terms, assuming that the two downstream firms select the same supplier does not affect the equilibrium outcomes.

⁶For the sake of exposition, we will use "he" for U_A (integrated or not) and U_B , and "she" for D_2 .

2.1.2 Vertical separation

Consider first the case of vertical separation. D_2 's net payoff depends on her investment decision and on the share s_h offered by the selected supplier, U_h (for $h = A, B$):

$$\Pi_{D_2}(s_h, I) = s_h r_2(I) - c - kI. \quad (2)$$

The selected supplier, U_h , receives a share $1 - s_h$ of both downstream firms' revenues, and thus obtains:

$$\Pi_{U_h}(s_h, I) = (1 - s_h) [r_1(I) + r_2(I)]. \quad (3)$$

In stage 2, upstream competition induces suppliers to leave the maximum share \bar{s} to the downstream firms; hence, there is no hold-up. It follows that D_2 is indifferent between the two suppliers in stage 3, and invests in stage 1 (as $\bar{s} > s^*$).

2.1.3 Vertical integration

Suppose now that U_A and D_1 are vertically integrated. Regardless of whether U_A is selected by D_2 , the integrated firm receives the profit generated by his downstream division D_1 , $r_1(I) - c - k$. D_2 's payoff remains given by (2) and the selected supplier, U_h , receives the share $(1 - s_h)$ of D_2 's revenue. Hence:

- If D_2 selects U_A , then the profit of the integrated firm is:

$$\Pi_{U_A-D_1}(s_A, I) = (1 - s_A) r_2(I) + r_1(I) - c - k. \quad (4)$$

- If instead D_2 selects U_B , then the profits of the integrated firm and of U_B are respec-

tively given by:

$$\Pi_{U_A-D_1}(s_A, I) = r_1(I) - c - k, \quad (5)$$

$$\Pi_{U_B}(s_B, I) = (1 - s_B) r_2(I). \quad (6)$$

Upstream competition eliminates again any risk of hold-up (that is, both suppliers offer to leave D_2 the maximal share \bar{s}) and D_2 thus still invests.

2.2 Commitment and Sabotage variants

We now introduce the possibility of commitment or sabotage in the above game.

2.2.1 Commitment

The Commitment game adds an *ex ante* stage 0 to the Benchmark game, in which suppliers can commit themselves to being “greedy”. Specifically, in this stage 0, which takes place before investment decisions, suppliers can commit themselves, if they wish so, to leaving no more than \underline{s} to the downstream competitors. Independent suppliers never make such a commitment, as this would put them at a disadvantage in the competition stage. Therefore, under vertical separation, the outcome remains as before: the suppliers offer the maximal share \bar{s} to D_2 , who thus invests.

Under vertical integration, however, it is optimal for the integrated U_A to commit himself in stage 0 to leaving \underline{s} : this confers market power to U_B who, in stage 2, offers D_2 a share only slightly higher than \underline{s} . Anticipating this, D_2 does not invest in stage 1, which benefits the downstream subsidiary of the integrated firm $U_A - D_1$. Hence, in this Commitment variant, vertical integration creates hold-up problems for the independent

rival, D_2 , who does not invest.

2.2.2 Sabotage

The Sabotage game adds instead an *ex post* stage 4 to the Benchmark game, in which, if selected by D_2 , U_A can “degrade” his support, which harms D_2 but benefits D_1 . Specifically, if selected by D_2 in stage 3, then in this stage 4 U_A can engage in sabotage; exerting this option costs $C > 0$ to U_A and reduces D_2 's revenue (regardless of U_A 's initial offer) to $\hat{s}r_2(I)$, where $\hat{s} < s^*$, but gives D_1 an extra benefit $B > C$.

As sabotage is costly and brings no direct benefit, U_A never degrades his support when independent. Therefore, under vertical separation, the outcome still remains as in the Benchmark game: the suppliers offer the maximal share \bar{s} to D_2 , who invests.

By contrast, a vertically integrated U_A has an incentive to sabotage the downstream rival D_2 , as this brings a benefit $B > C$ to his downstream subsidiary D_1 . As a result, regardless of the offer made by U_A , U_B wins the competition by offering a share only slightly higher than \hat{s} , and thus smaller than s^* ; anticipating this, D_2 does not invest in stage 1, which benefits the downstream subsidiary of the integrated firm $U_A - D_1$. Hence, in this Sabotage variant, vertical integration creates again hold-up problems for the independent rival, D_2 , who does not invest. Note that, formally, there are multiple equilibria, which only differ in the offer initially made by U_A : offering any share constitutes an equilibrium strategy.

3 Experimental design

To test the above theoretical predictions, we ran an experiment involving three players (U_A , U_B and D_2) and three treatments: *Benchmark*, *Commitment* and *Sabotage*. Each treat-

ment included a first phase with vertical separation (“VS”) and a second phase with vertical integration (“VI”) between U_A and D_1 . Each phase lasted for ten periods.

We now present in detail the parameters and payoffs used in each treatment.

3.1 Parameters

To expedite the decision process, we discretized the set of sharing rules. However, to limit the emergence of cooperative strategies, we maintained a substantial number of options (namely, nine). Furthermore, to ensure equilibrium uniqueness, we introduced a cap on the offered share.⁷ Specifically, the set of possible sharing rules is:

$$\mathcal{S} \equiv \{50\%; 55\%; 60\%; 65\%; 70\%; 75\%; 80\%; 85\%; 90\%\}.$$

Firms’ profits are based on the following underlying symmetric specification:

- D_i ’s revenue is $\hat{r}(\hat{I}_i, \hat{I}_j) = \hat{I}_i(a - b\hat{I}_i - b\hat{I}_j)$, for $i \neq j \in \{i, j\}$, with $\hat{I}_1 = \bar{I}$ and \hat{I}_2 equal to either \bar{I} (if D_2 “invests”) or \underline{I} (if D_2 “does not invest”); D_i ’s cost is $\hat{k}\hat{I}_i$.
- The parameters are $a = 140$, $b = 33$, $\hat{k} = 45$, $\underline{I} = 0.3$, and $\bar{I} = 1$;⁸ it can be checked that D_2 is indifferent between investing or not for $s^* \simeq 70\%$.
- Sabotage costs and benefits are $C = 5$ and $B = 10$.

To avoid biases against actions that may generate negative profits (see Dufwenberg *et al.*, 2007), we added fixed payments to these payoffs. Specifically: (i) D_2 obtains a

⁷If suppliers can offer a share of 100%, two equilibria exist under vertical separation: one in which suppliers offer 100% and obtain zero profit, and another one in which they offer the next-best share and receive a positive expected profit.

⁸The operating cost thus corresponds to $c = \hat{k}\underline{I} = 13.5$, whereas $k = \hat{k}(\bar{I} - \underline{I}) = 31.5$, $r_1(1) = r_2(1) = \hat{r}(\bar{I}, \bar{I}) = 74$, $r_1(0) = \hat{r}(\bar{I}, \underline{I}) = 97.1$, and $r_2(0) = \hat{r}(\underline{I}, \bar{I}) = 29.13$. The resulting payoffs have been rounded.

fixed payment $F = 9$, regardless of players' actions; and (ii) suppliers also obtain a fixed payment $f = 2$ in case they are not selected.⁹

In the experiment, players were provided with tables describing the resulting payoffs as a function of the three players' strategies. These payoff tables were common knowledge and all decisions were made public inside every three-player group. In addition, each player learnt her or his own payoff.

We now present the payoff tables.

3.2 Payoff tables

3.2.1 Benchmark treatment

Table 1 presents D_2 's payoffs (in euros) for the Benchmark treatment, as a function of D_2 's investment decision, $I \in \{0, 1\}$, and of the obtained share, s .

Table 1: Payoff of D_2 in the Benchmark treatment under VS and VI

s	50%	55%	60%	65%	70%	75%	80%	85%	90%
$I = 0$	10	12	13	14	16	17	19	20	22
$I = 1$	1	5	8	12	16	20	23	27	31

Under vertical separation, D_1 automatically selects the same supplier as D_2 . Table 2 presents the payoff of the selected supplier, as a function of the offered share, s .

Table 2: Payoff of the selected supplier in the Benchmark treatment under VS

s	50%	55%	60%	65%	70%	75%	80%	85%	90%
$I = 0$	63	57	50	44	38	32	25	19	13
$I = 1$	74	67	59	52	44	37	30	22	15

Under vertical integration, D_1 automatically selects U_A as supplier, and U_A internalizes D_1 's profit, which is presented in Table 3. In addition, the supplier selected by D_2 (U_A or U_B) obtains the payoff presented in Table 4.

⁹ Limiting the payment to these instances reduced the financial cost without affecting the equilibria.

Table 3: Payoff for U_A generated by D_1 in the Benchmark treatment under VI

$I = 0$	52
$I = 1$	29

Table 4: Payoff of the supplier selected by D_2 in the Benchmark treatment under VI

s	50%	55%	60%	65%	70%	75%	80%	85%	90%
$I = 0$	15	13	12	10	9	7	6	4	3
$I = 1$	37	33	30	26	22	19	15	11	7

Finally, under both vertical separation and vertical integration, the supplier not selected by D_2 receives the participation fee $f = 2$.

3.2.2 Commitment treatment

In the Commitment treatment, stage 0 is added in which U_A chooses whether or not to commit to leaving downstream firms the smallest possible share, $\underline{s} = 50\%$. The three stages of the benchmark game are then played, with the caveat that, in stage 2, U_A does not make any choice if he already committed himself in stage 0. The payoffs of all players are the same as in the Benchmark treatment.

3.2.3 Sabotage treatment

In the Sabotage treatment, stage 4 is added in which, whenever selected by D_2 , U_A chooses whether or not to use “option S”.¹⁰ The payoffs of D_2 are the same as in the Benchmark case, except if she selects U_A and U_A uses option S: in this case, D_2 ’s payoff only depends on her investment decision and is presented in Table 5.¹¹

Finally, the payoffs of the upstream firms are as in the Benchmark treatment, except for the cost and benefit of option S, which are added to U_A ’s payoffs.

¹⁰The word “sabotage” is never mentioned in the experiment, because its negative connotation could influence the subjects.

¹¹The “sabotage” share $\$$ has been set equal to 52.5%. Hence, if U_B anticipates that U_A engages in sabotage, his optimal strategy is to offer 55% (as in the Commitment treatment).

Table 5: Payoff of D_2 in the Sabotage treatment if she selects U_A and U_A uses option S

$I = 0$	11
$I = 1$	3

3.3 Predictions

Under vertical separation, Bertrand competition leads suppliers to offer the highest possible share, 90%, and D_2 always invests. Vertical integration does not affect this outcome in the Benchmark treatment. By contrast, in the other two treatments vertical integration discourages D_2 from investing. In the Commitment treatment, the integrated supplier U_A commits himself to leaving a 50% share. In the Sabotage treatment, if U_A were selected by D_2 , then he would choose option S. As a result, in both treatments U_B wins the competition for D_2 but leaves her a share of only 55%, and D_2 does not invest. Table 6 summarizes the equilibrium outcomes.

Table 6: Equilibrium outcomes for all treatments and phases

Treatment	Phase	Stage	Player	Action	Payoff
<i>Benchmark</i>	VS and VI	1	D_2	invests	
		2	$U_A ; U_B$	90% ; 90%	15 ; 2 ^a
		3	D_2	U_A or U_B	31
<i>Commitment</i>	VS	0	U_A	does not commit	
		1	D_2	invests	
		2	$U_A ; U_B$	90% ; 90%	15 ; 2 ^a
		3	D_2	U_A or U_B	31
	VI	0	U_A	commits to 50%	
		1	D_2	does not invest	
		2	$U_A ; U_B$	[no decision] ; 55%	54 ; 13
		3	D_2	U_B	12
<i>Sabotage</i>	VS	1	D_2	invests	
		2	$U_A ; U_B$	90% ; 90%	15 ; 2 ^a
		3	D_2	U_A or U_B	31
		4	U_A (if he were selected)	does not use S	
	VI	1	D_2	does not invest	
		2	$U_A ; U_B$	any $s \in \mathcal{S}$; 55%	54 ; 13
		3	D_2	U_B	12
		4	U_A (if he were selected)	uses S	

^a The first number is the payoff of the supplier selected by D_2 .

3.4 Procedures

We now describe the organization of the experimental sessions. Each session is dedicated to one treatment, first played for ten periods under vertical separation, followed by ten periods under vertical integration. Each subject participates in only one session (but plays both phases). Thirty subjects are active in each session: 10 for U_A , 10 for U_B , and 10 for D_2 . Each subject is randomly assigned a role (U_A , U_B or D_2) and keeps the same role for the whole session. At the beginning of each period, groups of 3 subjects are constituted; these three subjects interact during that period and no communication is allowed between them. In order to limit the scope for repeated interaction, we use a perfect stranger matching protocol between U_A and U_B , ensuring that these subjects meet only once within each phase; in each period, D_2 subjects are then randomly matched with the couples of U_A and U_B subjects. At the end of each period, each subject learns his or her own payoff for that period, as well as all decisions made by the three subjects in the group during that period. The instructions for each treatment are presented in Online appendix A.

At the end of the twenty periods, one period is randomly chosen, and each subject earns the payoff obtained in that period. Subjects are then asked to answer a series of questions about their age, sex and occupation; they are also asked to situate themselves on a 0 to 10 risk-aversion scale ranging from “ready to take risks” to “not ready to take risks at all” (Dohmen et al., 2005). Finally, they are asked to answer three standard questions, and we used the number of correct answers as an IQ score (from 0 to 3).¹²

We conducted nine sessions (three per treatment) at Ecole Polytechnique in Paris, from April 2015 to April 2017. In total, 270 subjects participated. The sessions lasted between

¹²See Appendix A for more details on the IQ questionnaire.

90 and 120 minutes, including time for instructions. On average, subjects earned 25.18 euros (including a show-up fee of 5 euros). The experiments were programmed using the software *z-tree* (Fischbacher, 2007). The subjects included both Polytechnique students (undergraduate and graduate students in engineering), and employees of the Ecole Polytechnique.¹³ 32% were female (41% in the Benchmark treatment, 30% in the Commitment treatment and 26% in the Sabotage treatment) and 32% were employees (40% in the Benchmark treatment, 28% in the Commitment treatment and 29% in the Sabotage treatment). The average answer to the question on risk-aversion is 5.75 (5.58 in the Benchmark treatment, 5.96 in the Commitment treatment, and 5.72 in the Sabotage treatment). Finally, the average IQ is 1.94 (1.65 in the Benchmark treatment, 2.13 in the Commitment treatment, and 2.04 in the Sabotage treatment).

Most of the students at Ecole Polytechnique are male (in our sample, 21% of students are female, whereas 56% of employees are female); hence, gender and occupation (student or employee) are highly correlated (and occupation is itself highly correlated with age).¹⁴ We also observe that IQ is highly correlated with these two variables (Pearson correlation tests are presented in appendix B). In our analysis, we have chosen to control for the individuals' IQ level (which has a broader range than the binary variables). When using a Mann-Whitney ranksum test, we observe significant differences between the Benchmark treatment and each of the Commitment and Sabotage treatments ($p < 0.05$), but no difference between the Commitment and Sabotage treatments ($p = 0.5691$). However, when using a Kolmogorov-Smirnov test, the IQ is not significantly different across the three

¹³An additional session has been conducted for each of the Commitment and Sabotage treatments. However, due to schedule constraints, these two sessions differed from the others in terms of percentage of students and IQ level. For reliability purposes, we dropped the session with an average IQ of 2.57 for the Commitment treatment and of 1.20 for the Sabotage treatment, which correspond to the two extreme values among all sessions. Including these two sessions does not affect the qualitative results.

¹⁴Students are aged between 18 and 27.

treatments. Finally, no significant difference in risk-aversion is observed across the three treatments (using both a Mann-Whitney ranksum test and a Kolmogorov-Smirnov test).

4 Results and insights

We now study the impact of vertical integration on subjects' decisions. We first observe in Section 4.1 that, as predicted by the theory, vertical integration creates hold-up problems in the Commitment and Sabotage treatments. There are some departures from theory, however, which we investigate in Section 4.2; we find that vertical integration increases these departures for U_A subjects in the Commitment treatment and for U_B and D_2 subjects in the Sabotage treatment. Finally, Section 4.3 explores possible rationales for these departures.

For each variable of interest, we first present the evolution of the mean value within each treatment. To study further the impact of vertical integration, we then report its marginal effect, using probit regressions for the binary variables¹⁵ and OLS regressions for the shares offered and accepted. In a first step, we control for session fixed effects and, as subjects make repeated decisions during a session, we evaluate standard errors using clusters at the individual level (see model I in the tables).¹⁶ In a second step, we also control for decision makers' IQ and risk-aversion (model II in the tables).¹⁷ The results show that this does not materially affect the impact of vertical integration. We also check for learning effects by ignoring the first two periods of each phase, and find that they do

¹⁵For probit regressions, we compute average marginal effects: we first compute the marginal effect for each subject, before aggregating across subjects; see Williams (2012) for details of the method.

¹⁶Because some D_2 subjects may interact more than once with U_A or U_B subjects during a session, we provide in Online Appendix C a robustness check using clusters at the session level; the results are qualitatively the same.

¹⁷Controlling for the IQ and risk aversion of all subjects in the group yields the same results; see model III in Online Appendix C.

not qualitatively affect the results in any of the three treatments.¹⁸

4.1 Hold-up

4.1.1 Investment decisions

Figure 1 displays the evolution of the proportion of D_2 subjects who invest. In the vertical separation phase (VS hereafter, corresponding to the first ten periods), the three treatments generate similar investments: about 82% of D_2 subjects invest in the Benchmark treatment and Commitment treatments, and 92% in the Sabotage treatment. In the vertical integration phase (VI hereafter, last ten periods), this proportion remains about the same in the Benchmark treatment (90%), but becomes much lower in the Commitment (32%) and Sabotage (52%) treatments.

Figure 1: Evolution of investment

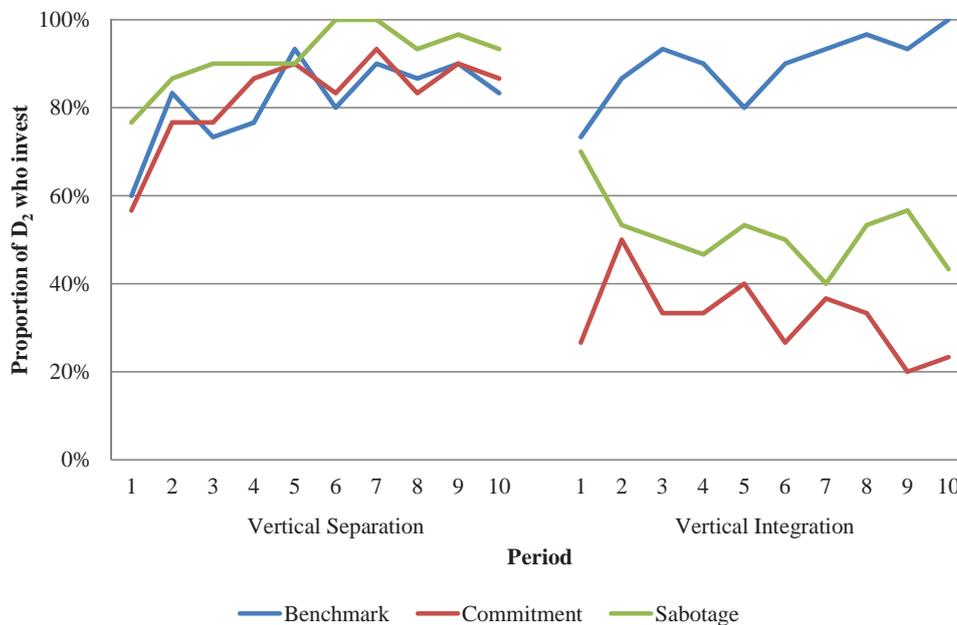


Table 7 reports the marginal effect of vertical integration on D_2 subjects' investment decisions, based on a probit regression for each treatment. The results are in accordance

¹⁸See Online Appendix C.

with theory. In the Benchmark treatment, vertical integration does not reduce investment; it actually appears to become slightly higher, which may reflect a learning effect, as the observed behavior gets closer to the prediction. By contrast, vertical integration reduces the probability of investment in the other two treatments, by 43% in the Commitment treatment and 37% in the Sabotage treatment – given the standard errors, this reduction is not significantly different between the two treatments.

Table 7: Marginal effect of vertical integration on investment (Probit model)

	Model I	Model II
Benchmark	0.080*** (0.028)	0.082*** (0.028)
Commitment	-0.428*** (0.031)	-0.428*** (0.030)
Sabotage	-0.367*** (0.055)	-0.364*** (0.052)
IQ and risk-aversion	No	Yes

Notes: Standard errors are reported in parentheses.
*** represents significance at 1% level.

These findings can be summarized as:

Result 1 (investment decisions). *In line with theoretical predictions, vertical integration does not affect investment decisions in the Benchmark treatment but makes D_2 subjects less likely to invest in the Commitment and Sabotage treatments.*

4.1.2 Revenue sharing

Figure 2 displays the evolution of D_2 's share. Under VS, the three treatments yield similar shares: about 85% in the Benchmark treatment, 84% in the Commitment treatment, and 86% in the Sabotage treatment. Under VI, the share remains about the same in the Benchmark treatment (86%) but becomes much lower in the Sabotage treatment (75%) and even

more so in the Commitment treatment (64%).

Figure 2: Evolution of the share accepted by D_2

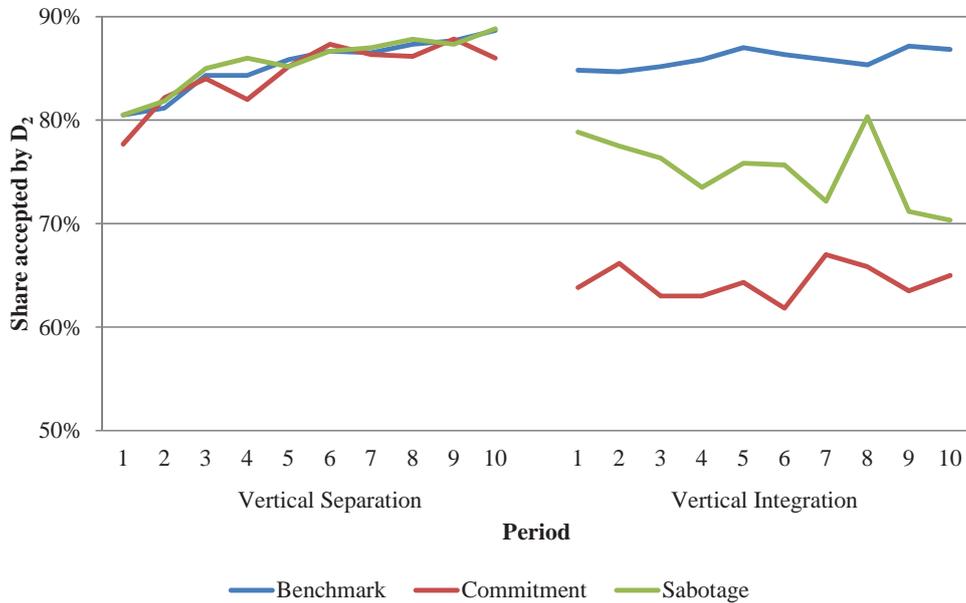


Table 8 reports the marginal effect of vertical integration on the share obtained by D_2 , based on an OLS regression for each treatment. The results are again in accordance with theory: vertical integration has no significant effect on D_2 's share in the Benchmark treatment, but reduces it in the Sabotage treatment (by 10 percentage points) and even more so in the Commitment treatment (by 20 percentage points).

Table 8: Marginal effect of vertical integration on the share accepted by D_2 (OLS model)

	Model I	Model II
Benchmark	0.600 (0.553)	0.600 (0.554)
Commitment	-20.12*** (1.282)	-20.12*** (1.284)
Sabotage	-10.45*** (1.181)	-10.45*** (1.183)
IQ and risk-aversion	No	Yes

Notes: standard errors are reported in parentheses;
*** represents significance at 1% level.

These findings can be summarized as:

Result 2 (revenue sharing). *In line with theoretical predictions, vertical integration has no effect on the share obtained by D_2 subjects in the Benchmark treatment, but reduces it in the Commitment and Sabotage treatments; this decrease is however more pronounced in the Commitment than in the Sabotage treatment.*

4.1.3 Suppliers' behavior

Figure 3 depicts the evolution of the shares offered by U_A and U_B . Under VS, the three treatments yield similar shares for both suppliers: their average shares range from 80% to 84% in the three treatments. Under VI, these shares remain similar in the Benchmark treatment (82% for U_A and 81% for U_B). By contrast, they decrease in the Commitment treatment (58% and 62%, respectively) and the share offered by U_B also decreases in the Sabotage treatment (68%).¹⁹

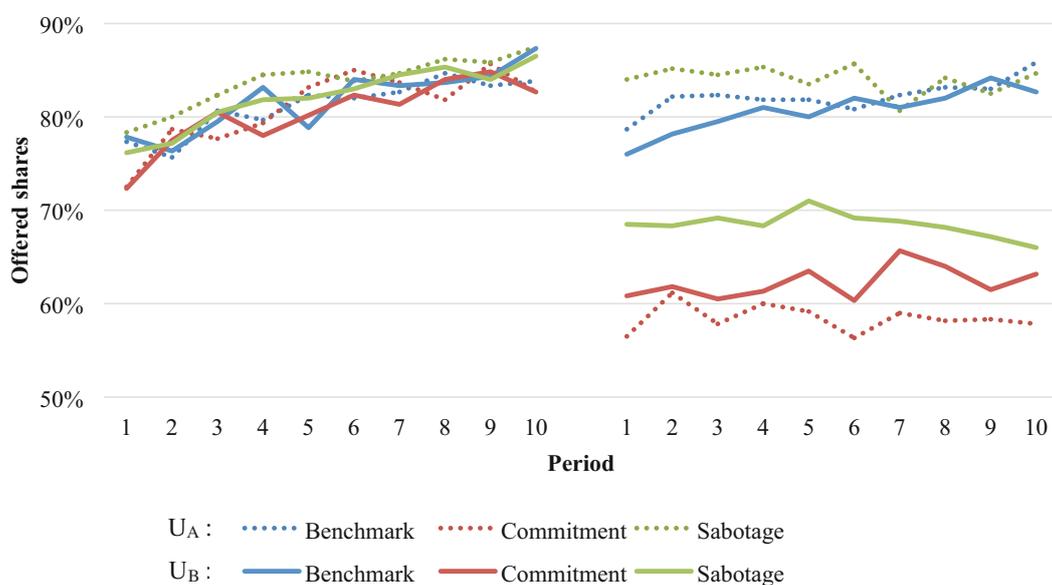
Table 9 reports the marginal effect of vertical integration on the shares offered by the two suppliers, based on an OLS regression. The results are still in line with theory. There is no significant effect in the Benchmark treatment; by contrast, vertical integration reduces the share offered by both suppliers in the Commitment treatment, and the share offered by U_B in the Sabotage treatment. In the Commitment treatment, the evolution is primarily driven by the proportion of U_A subjects who choose to commit to a 50% share, which increases from 8% under VS to 72% under VI. Vertical integration thus reduces the share offered by U_A ,²⁰ and in response U_B also offers a lower share.²¹ In the Sabotage

¹⁹Recall that, in the Sabotage treatment, there is no theoretical prediction about the share offered by U_A – any share can be offered in equilibrium; the observed shares (84%) are similar to those under VS.

²⁰We present in appendix C the results of a probit regression for U_A subjects' commitment decisions, finding a marginal effect of vertical integration of 48% (see table 23). We also ran an OLS regression for the shares offered by those U_A subjects who did not commit to offering a 50% share, and find that vertical integration generates a significant but small decrease of 3% (see table 24).

²¹The average share offered by U_B drops from 75% in the absence of commitment by U_A to 57% in case

Figure 3: Effect of vertical integration on offered shares



treatment, the evolution is primarily driven by the threat of sabotage. Indeed, the proportion of U_A subjects who choose the sabotage option when selected increases from 10% under VS to 78% under VI.²² Anticipating this threat of sabotage by U_A , U_B offers a lower share.

Table 9: Marginal effect of vertical integration on offered shares (OLS model)

	U_A		U_B	
	Model I	Model II	Model I	Model II
Benchmark	0.983 (0.993)	0.983 (0.995)	-1.183 (1.054)	-1.183 (1.056)
Commitment	-22.583*** (2.688)	-22.583*** (2.692)	-18.1*** (1.416)	-18.1*** (1.418)
Sabotage	0.217 (1.100)	0.217 (1.102)	-13.633*** (1.823)	-13.633*** (1.826)
IQ and risk-aversion	No	Yes	No	Yes

Notes: standard errors are reported in parentheses; *** represents significance at 1% level.

of commitment.

²²We present in Appendix C the results of a probit regression for U_A subjects' sabotage decisions when selected, finding a marginal effect of vertical integration of 46% (see table 25).

These findings can be summarized as:

Result 3 (suppliers' behavior). *In line with theoretical predictions, vertical integration has no effect on the shares offered by the suppliers in the Benchmark treatment, but reduces them in the Commitment treatment and reduces the shares offered by U_B in the Sabotage treatment. Furthermore:*

- *in the Commitment treatment, vertical integration increases the proportion of U_A subjects who commit themselves to offering a 50% share;*
- *in the Sabotage treatment, vertical integration increases the proportion of U_A subjects who choose the option S when selected by D_2 .*
- *the reduction in the share offered by U_B is more pronounced in the Commitment than in the Sabotage treatment.*

4.2 Individual departures from theory

The decisions observed in the experiment are thus broadly in line with theoretical predictions: vertical integration has no significant effect in the Benchmark treatment but creates hold-up problems in the Commitment and Sabotage treatments. Still, some discrepancies can be noted. Although in theory vertical integration has the same impact in the Commitment and Sabotage treatments, we observe a larger impact on the shares offered by U_B and those obtained by D_2 in the former treatment. The picture is less clear for investment. Figure 1 displays an investment rate that, under VI, remains about 10 points higher in the Sabotage than in the Commitment treatment; yet Table 7 shows that the marginal effect of vertical integration on investment is not significantly different across treatments. However, the sequence of decisions varies in the two treatments. In the Sabotage treatment,

the investment decision is made first and is thus entirely attributable to D_2 . By contrast, in the Commitment treatment, U_A moves first and can therefore influence D_2 's investment decision. This is confirmed by Table 10 which shows that, regardless of the phase, U_A 's commitment decision has a significant and substantial effect on the other subjects' decisions.

Table 10: Marginal effect of U_A 's commitment (Probit model)

	Model I	Model II
Investment	-0.500*** (0.015)	-0.494*** (0.013)
Share offered by U_B	-22.851*** (1.666)	-22.874*** (1.657)
Share accepted by D_2	-28.502*** (2.250)	-28.536*** (2.232)
IQ and risk-aversion	No	Yes

Notes: standard errors are reported in parentheses;
*** represents significance at 1% level.

This leads us to investigate the individual contributions of U_A , U_B and D_2 subjects to the observed discrepancies. To this end, for each decision of interest, we first build a binary deviation score reflecting whether this decision substantially departs from theory, and present its average value for each treatment and phase. We then compute the marginal effect of vertical integration on this deviation score.

4.2.1 U_A subjects

Hold-up decisions For U_A subjects' "hold-up" decisions over commitment or sabotage, we define the deviation score σ_A^H as follows:

- Commitment treatment: $\sigma_A^H = 1$ when U_A opts for the commitment option under VS, and does not do so under VI; $\sigma_A^H = 0$ otherwise;

- Sabotage treatment, if U_A is selected:²³ $\sigma_A^H = 1$ when U_A opts for the sabotage option under VS, and does not do so under VI; $\sigma_A^H = 0$ otherwise.

Table 11 shows that, under VS, the average value of this deviation score is less than 0.1 in both treatments; by contrast, under VI it jumps to 0.28 in the Commitment and 0.22 in the Sabotage treatments.²⁴

Table 11: Average deviation score of U_A (σ_A^H)

Treatment	Phase	P1 to P10	P3 to P10
<i>Commitment</i>	VS	0.08	0.08
	VI	0.28	0.28
<i>Sabotage</i> (for selected U_A)	VS	0.10	0.07
	VI	0.22	0.19

Table 12 reports the marginal effect of vertical integration on σ_A^H . Vertical integration increases the probability that U_A deviates by 20 percentage points in the Commitment treatment; it has instead no significant effect in the Sabotage treatment.

Table 12: Marginal effect of vertical integration on σ_A^H (Probit model)

	Model I	Model II
Commitment	0.198*** (0.074)	0.200*** (0.073)
Sabotage	0.115 (0.078)	0.108 (0.071)
IQ and Risk aversion	No	Yes

Notes: standard errors are reported in parentheses;
*** represents significance at 1% level.

Shares offered We now turn to the shares offered by U_A subjects. In the Benchmark treatment, and in the Commitment treatment for subjects that did not exert the hold-up

²³ U_A is selected by 40% of D_2 subjects under VS and by 26% under VI.

²⁴Two average values are reported: for all periods (P1 to P10) and, to account for potential learning effects, for the last eight periods of each session and phase (P3 to P10).

option,²⁵ we define the deviation score σ_A^O as follows:

- $\sigma_A^O = 1$ when U_A chooses a share in $[50\%, 75\%]$;²⁶
- $\sigma_A^O = 0$ otherwise.

Table 13 shows that the average value of this deviation score is about 0.2 in both phases of the Benchmark treatment. In the Commitment treatment, it remains about the same (0.16) under VS, whereas it almost doubles (0.28) under VI.

Table 13: Average deviation score for the shares offered by U_A (σ_A^O)

Treatment	Phase	P1 to P10	P3 to P10
<i>Benchmark</i>	VS	0.21	0.16
	VI	0.20	0.18
<i>Commitment</i> (for non-committed U_A)	VS	0.16	0.09
	VI	0.28	0.30

Table 14 shows that vertical integration has no marginal effect on σ_A^O in the Benchmark treatment, and no significant effect either in the Commitment treatment.

Table 14: Marginal effect of vertical integration on σ_A^O (Probit model)

	Model I	Model II
Benchmark	-0.007 (0.049)	-0.004 (0.049)
Commitment (for non-committed U_A)	0.096 (0.078)	0.082 (0.063)
IQ and risk-aversion	No	Yes

Note: standard errors are reported in parentheses.

We can summarize these findings as follows:

²⁵These are the only relevant cases: U_A subjects who exert the commitment option have no other decision to make and, in the Sabotage treatment, U_A can offer any share in equilibrium when integrated.

²⁶We allow for small "trembles" (namely, up to 10 percentage points) around the equilibrium share and thus only consider larger deviations as departures from theory.

Insight 1 (U_A subjects). *Vertical integration increases departures from theory in U_A subjects' hold-up decisions in the Commitment treatment, but has no such effect in the Sabotage treatment. In addition, vertical integration has no effect on departures from theory in the shares offered by U_A subjects in the relevant treatments (Commitment and Benchmark).*

4.2.2 U_B subjects

Shares offered We similarly define a deviation score, σ_B^O , for the shares offered by U_B subjects, which is equal to 1 in the following instances (and to 0 otherwise):

- Benchmark treatment: when U_B chooses a share in [50%, 75%];
- Commitment treatment: when U_B chooses a share in [70%, 90%] if U_A opted for the commitment option, and in [50%, 75%] if U_A did not do so;
- Sabotage treatment: when U_B chooses a share in [50%, 75%] under VS, and in [70%, 90%] under VI.

Table 15 shows that the average value of this deviation score ranges between 0.19 and 0.28, except in the Sabotage treatment under VI where it jumps to 0.51.

Table 15: Average deviation score for the shares offered by U_B (σ_B^O)

Treatment	Phase	P1 to P10	P3 to P10
<i>Benchmark</i>	VS	0.24	0.20
	VI	0.28	0.23
<i>Commitment</i>	VS	0.21	0.15
	VI	0.21	0.20
<i>Sabotage</i>	VS	0.19	0.12
	VI	0.51	0.53

Table 16 reports the marginal effect of vertical integration on σ_B^O . Vertical integration increases U_B subjects' deviations by 30 percentage points in the Sabotage treatment; by contrast, it has no effect in the Benchmark and Commitment treatments.

Table 16: Marginal effect of vertical integration on σ_B^O (Probit model)

	Model I	Model II
Benchmark	0.038 (0.052)	0.038 (0.051)
Commitment	0.002 (0.041)	0.004 (0.041)
Sabotage	0.301*** (0.058)	0.300*** (0.057)

Notes: standard errors are reported in parentheses;
*** represents significance at 1% level.

We can summarize these findings as follows:

Insight 2 (U_B subjects). *Vertical integration increases departures from theory in the shares offered by U_B subjects in the Sabotage treatment, but has no effect in the other two treatments.*

4.2.3 D_2 subjects

Investment decision The deviation score for D_2 subjects' investment decisions, σ_D^I , is equal to 1 in the following instances (and to 0 otherwise):

- Benchmark treatment: when D_2 does not invest;
- Commitment treatment: when D_2 invests if U_A chose to commit himself, and D_2 does not invest if U_A chose instead not to commit himself;
- Sabotage treatment: when D_2 does not invest under VS, and invests under VI.

Table 17 shows that the average value of this deviation score is low under VS (ranging from 0.08 in the Sabotage treatment to 0.18 in the Benchmark treatment). Under VI, this average score remains low in the Benchmark and the Commitment treatments, but jumps to 0.52 in the Sabotage treatment.²⁷

²⁷This average score is only slightly lower, namely 0.49, if we ignore the first two periods.

Table 17: Average deviation score for D_2 's investment decision (σ_D^I)

Treatment	Phase	P1 to P10	P3 to P10
<i>Benchmark</i>	VS	0.18	0.16
	VI	0.10	0.08
<i>Commitment</i>	VS	0.15	0.12
	VI	0.18	0.15
<i>Sabotage</i>	VS	0.08	0.06
	VI	0.52	0.49

Table 18 reports the marginal effect of vertical integration on σ_D^I . Vertical integration increases D_2 subjects' deviations in their investment decisions by 39 percentage points in the Sabotage treatment, and has no effect in the Commitment treatment.²⁸

Table 18: Marginal effect of vertical integration on σ_D^I (Probit model)

	Model I	Model II
Benchmark	-0.080*** (0.028)	-0.082*** (0.028)
Commitment	0.028 (0.036)	0.028 (0.035)
Sabotage	0.389*** (0.044)	0.391*** (0.043)
IQ and risk-aversion	No	Yes

Notes: standard errors are reported in parentheses;
*** represents significance at 1% level.

Choice of supplier We now define a deviation score, σ_D^U , for D_2 subjects' choice of supplier:

- in the Sabotage treatment, under VI, $\sigma_D^U = 1$ whenever D_2 chooses U_A even though U_B offered at least 55%, and $\sigma_D^U = 0$ otherwise;
- in the other treatments, as well as under VS in the Sabotage treatment, $\sigma_D^U = 1$ if D_2 chooses the supplier who offered the lower share, and $\sigma_D^U = 0$ otherwise.

²⁸In the Benchmark treatment, we observe a small positive effect which probably reflects a learning effect similar to that observed in Table 7.

Table 19 shows that the average value of this deviation score is always lower than 0.1 except in the Sabotage treatment under VI, where it reaches 0.24.

Table 19: Average deviation score for D_2 's choice of supplier (σ_D^U)

Treatment	Phase	P1 to P10	P3 to P10
<i>Benchmark</i>	VS	0.06	0.06
	VI	0.04	0.04
<i>Commitment</i>	VS	0.02	0.01
	VI	0.06	0.06
<i>Sabotage</i>	VS	0.10	0.10
	VI	0.24	0.20

Table 20 reports the marginal effect of vertical integration on σ_D^U . Vertical integration increases D_2 subjects' deviations in the choice of their suppliers by 14 percentage points in the Sabotage treatment; it has instead only a barely significant, small effect in the Commitment treatment. In the Benchmark treatment, there is a small negative impact, probably reflecting again a learning effect.

Table 20: Marginal effect of vertical integration on σ_D^U (Probit model)

	Model I	Model II
Benchmark	-0.024* (0.014)	-0.025* (0.014)
Commitment	0.043* (0.022)	0.044* (0.023)
Sabotage	0.143*** (0.039)	0.141*** (0.038)
IQ and risk-aversion	No	Yes

Notes: standard errors are reported in parentheses;
*** and * represent significance at 1% and 10% levels.

We can summarize these findings as follows:

Insight 3. *Vertical integration increases D_2 subjects' departures from theory (investment decisions and choices of supplier) in the Sabotage treatment, but has no substantial effect in the*

other two treatments.

4.2.4 Interplay between individual departures

The above analysis shows that vertical integration increases D_2 and U_B subjects' departures from theory in the Sabotage treatment, whereas it increases U_A subjects' departures from theory in their commitment decisions. We conclude this analysis with an exploration of the interplay between these individual departures.

Specifically, we now study the marginal effect of every $\sigma \in \Sigma \equiv \{\sigma_A^H, \sigma_B^O, \sigma_D^I\}$ ²⁹ on every subsequent $\sigma' \in \Sigma$ in the same period.³⁰ In order to identify such interplay in its purest form, we focus on pairs of decisions and restrict attention to situations in which the third decision did not depart from theory. We further focus on vertical integration because, under VS, the few statistically significant effects either do not differ between the Commitment and Sabotage treatments, or rely on too few departures for a meaningful interpretation of the results (see Appendix D).

Table 21 reports the results. σ_D^I has a highly significant impact on σ_B^O in the Sabotage treatment; conversely, σ_A^H has a highly significant impact on σ_B^O in the Commitment treatment. This leads to:

²⁹ We do not consider U_A subjects' departures in the offered shares (σ_A^O), as they cannot be defined for committed subjects in the Commitment treatment, as well as under VI in the Sabotage treatment. Similarly, we do not consider D_2 subjects' departures in the choice of supplier (σ_D^U), because they are mostly observed in the Sabotage treatment under VI (see Table 19), where they constitute a prerequisite for an error in sabotage decisions and are therefore highly correlated with σ_A^H .

³⁰ Recall that the experiment is designed to avoid dynamic effects across periods: a perfect stranger protocol ensures that each U_A and each U_B only meet once, and D_2 is randomly matched with a couple of U_A and U_B subjects. We nevertheless studied the impact of one subject's decision on another subject's subsequent decision in the following period and found that the only effects were mirror images of the interplay observed within the same period (see Online Appendix D). For instance, for D_2 and U_B subjects paired in period t , departures in the shares offered in period t , $\sigma_B^O(t)$, are correlated with subsequent departures in investment decisions (by the same D_2 subjects) in period $t + 1$, $\sigma_D^I(t + 1)$; this however reflects the correlation between the subjects' decisions in period t , $\sigma_D^I(t)$ and $\sigma_B^O(t)$, combined with an auto-correlation between D_2 subjects' decisions across periods, $\sigma_D^I(t)$ and $\sigma_D^I(t + 1)$.

Table 21: Interplay between subsequent departures under VI (Probit model)

	Commitment	Sabotage
σ_A^H on σ_B^O (if $\sigma_D^I = 0$)	0.262*** (0.040)	
σ_B^O on σ_A^H (if U_A is selected and $\sigma_D^I = 0$)		(a)
σ_A^H on σ_D^I	0.034 (0.073)	
σ_D^I on σ_A^H (if U_A is selected and $\sigma_B^O = 0$)		-0.184 (0.118)
σ_D^I on σ_B^O (if $\sigma_A^H = 0$)	-0.014 (0.026)	
σ_D^I on σ_B^O		0.175*** (0.059)

Notes: (a) There is a single occurrence in which $\sigma_D^I = 0$, $\sigma_B^O = 1$ and U_A is selected (the U_A subject then deviated).
Standard errors in parentheses; *** represents significance at 1% level.

Insight 4. *Under vertical integration:*

- (i) *In the Sabotage treatment, D_2 's decisions to invest are positively correlated with U_B subsequently offering too high shares in the same period; by contrast, in the Commitment treatment, no correlation is observed.*
- (ii) *In the Commitment treatment, U_A 's decisions not to commit themselves are positively correlated with U_B subsequently offering too low shares in the same period.*

4.3 Behavioral approaches

The above analysis shows that vertical integration has no substantial impact on individual departures from theory in the Benchmark treatment. In the other treatments, however, the analysis highlights two countervailing forces. In the Commitment treatment, vertical integration generates more departures in U_A subjects' hold-up decisions (Insight 1). In the Sabotage treatment, vertical integration triggers instead more departures in the in-

vestments made by D_2 subjects and in the shares offered by U_B subjects (Insights 2 and 3). Finally, we find a positive correlations, within periods and under VI, between U_A and U_B subjects' departures in the Commitment treatment (Insight 4 (i)), and between D_2 and U_B subjects' departures in the Sabotage treatment (Insight 4 (ii)).

In what follows we consider different behavioral approaches that may explain why vertical integration has a different impact on individual departures from theory in the Commitment and Sabotage treatments.³¹ We explore below both classic bounded rationality and social preference approaches. The level- k theory can explain the first of these results (Insight 1) but not the others. Social preferences can instead explain Insights 2 to 4 (i). Finally, Insight 4 (ii) can be derived from an alternative bounded rationality approach.

4.3.1 Level- k theory

A classic bounded rationality approach, referred to as level- k theory, consists in introducing an iterative decision process where players vary in “depth”, that is, in their levels of thinking (see for instance Stahl (1993) and Nagel (1995)).³² The iterative process begins with “level-0” types who are not strategic and pick an arbitrary decision – we will assume here that they randomly choose every action with equal probability. “Level-1” players then best respond to “level-0” players, and so on.³³ In our framework, the main

³¹Following the observations mentioned in footnote 29, for D_2 's decisions we focus on departures in investment decisions (σ_D^I) and ignore those in the choice of supplier (σ_D^U); for U_A 's decisions we focus on departures in hold-up decisions (σ_A^H) and ignore those in the offered share (σ_A^O).

³²Another classic approach that takes decision errors into account is the quantal-response equilibrium analysis (see McKelvey and Palfrey (1995) and Normann (2011)). This approach generalizes the Nash equilibrium by assuming that players do not choose the best response with probability one but still choose better choices more frequently. Unfortunately, this approach is difficult to apply to multi-stage games such as the one studied here.

³³For simplicity, we assume that each level- k player anticipates that the others are of a homogeneous level- $(k - 1)$ type. Introducing heterogeneity between players, as often done in level- k analysis, would not change the insights.

predictions are as follows.³⁴

In the Sabotage treatment, on level 1, anticipating a random supplier selection by D_2 , both suppliers offer the lowest share. However, from level 1 onward U_A , whenever selected by D_2 , always uses the S option under VI, and never uses it under VS. As a result under VI, from level 2 onward U_B offers a low share and, anticipating this, D_2 stops investing, as predicted by theory. By contrast, under VS, the shares offered by the two suppliers progressively increase from level 2 onward and coincide with theory from level 10 onward; as a result, investment occurs with certainty from level 7 onward.

In the Commitment treatment, on level 1, anticipating again a random supplier selection by D_2 , both suppliers offer the lowest share. Under VS, U_A never commits himself from level 2 onward; thus, as in the Sabotage treatment, competition drives the offered shares to increase gradually (they coincide with theory from level 9 onward) and D_2 invests from level 7 onward. Under VI, U_A does not commit himself from level 2 to 6; as a result, the offered shares evolve as under VS, and D_2 does not invest until level 6, where she invests with probability $1/2$. It is only from level 7 onward that U_A commits himself to offering a low share; this then induces U_B to offer a low share and discourages D_2 from investing, as predicted by theory.

According to this level- k analysis, an independent U_A never engages in hold-up from level 2 onward; by contrast, there is a substantial difference in an integrated U_A 's hold-up decisions across treatments: in the Sabotage treatment, predictions are in line with theory from level 1 onward, whereas in the Commitment treatment departures from theory keep occurring up to level 6. These patterns are in line with Insight 1.

By contrast, level- k theory predicts the same impact of vertical integration on D_2 's investment decisions in the two treatments: investment occurs from level 7 onward under

³⁴See Appendix E.

VS and, under VI, D_2 behaves as predicted by theory from level 2 onward. Level- k theory thus cannot explain Insight 3.

Finally, according to the level- k analysis, in the two treatments under VS, the share offered by U_B progressively increases and coincides with theory from level 9 onward. Under VI, in the Sabotage treatment the share offered by U_B coincides with theory from level 2 onward; by contrast, in the Commitment treatment, as U_A commits himself only from level 7 onward, level- k theory predicts more generous shares than theory from level 2 to 6. Hence, level- k theory not only cannot explain Insight 2, which finds that vertical integration triggers less generous offers in the Commitment than in the Sabotage treatment, but actually goes in the opposite direction.³⁵

Overall, the level- k analysis can explain Insight 1 about hold-up decisions but cannot explain Insight 3 about D_2 's investment behavior and actually contradicts Insight 2 about U_B 's offers. By the same token, this approach cannot explain Insight 4 either.

4.3.2 Social preferences

Insights 2 and 3 highlight that vertical integration triggers more departures from theory for U_B and D_2 in the Sabotage treatment; by contrast, no such effect is observed in the Commitment treatment. One major difference between the two treatments is that U_B and D_2 face more strategic uncertainty³⁶ about U_A 's actions in the Sabotage treatment, where U_A 's hold-up decision occurs in the very last stage, than in the Commitment treatment, where it occurs in the very first stage. This difference in the timing of the decisions can play a role when there is uncertainty about U_A 's behavior. Indeed, in the Sabotage treatment, D_2 invests more often and U_B offers more generous shares than predicted; they

³⁵Note that it is precisely for the levels (2 to 6) where level- k theory is in line with Insight 1 that it contradicts Insight 3.

³⁶See, e.g., Van Huyck *et al.* (1990) and Heinemann *et al.* (2009).

thus behave as if they did not expect U_A to systematically exert his hold-up option. A natural interpretation is that they believe U_A to have social preferences preventing him from harming others.

The literature has indeed long recognized that individuals can be sensitive to fairness and others' payoffs and intentions.³⁷ The above analysis of the departures from theory also supports the possibility that U_A subjects may exhibit such preferences. As can be seen in Table 11, U_A is much more likely not to exert his hold-up option under VI than he is to exert it under VS: vertical integration increases the average value of σ_A^H from 8% to 28% in the Commitment treatment and from 10% to 22% in the Sabotage treatment. This suggests that a fraction of U_A subjects are indeed reluctant to exert their hold-up options – in both treatments.

This possibility of social preferences can explain the observed pattern in D_2 's departures (Insight 3). Under VS, there are few departures in all treatments anyway. Under VI, there are also few departures in the Commitment treatment, as the uncertainty about U_A 's preferences, and his willingness to exert the hold-up decision, is resolved before D_2 has to make her decision; by contrast, there are substantially more departures in the Sabotage treatment, in which D_2 must decide whether to invest and choose her supplier before the resolution of the uncertainty about U_A 's preferences.

A similar logic can explain the observed pattern in U_B 's departure, with the caveat that what matters for U_B is D_2 's beliefs about U_A 's preferences, rather than U_A 's actual preferences or U_B 's own beliefs about these preferences: it is when D_2 dismisses the threat of sabotage that U_B must offer a generous share in order to be selected by D_2 . Interest-

³⁷In Fehr and Schmidt (1999) and Bolton and Ockenfels (2000), individuals can be sensitive to inequity aversion. Rabin (1993) focuses instead on reciprocity, whereas Falk and Fischbacher (2006) include both aspects. Experimental studies support the existence of social preferences among individuals. Charness and Rabin (2002) provide a direct test of the different theories on social preferences.

ingly, the positive correlation between D_2 's and U_B 's departures (insight 4 (i)) supports this interpretation: it is precisely when D_2 invests, thereby signalling her optimism about U_A 's social preferences, that U_B offers more generous shares. By contrast, in the Commitment treatment, in which the uncertainty about U_A 's preferences is resolved upfront, no such correlation is observed.

To see this formally, in online Appendix F we introduce the possibility of social preferences in a model that follows the timing of the Sabotage treatment. Specifically, U_A may have social preferences, in which case he can never exert his hold-up option, and there are two states of the world, in which U_A has social preferences with different probabilities. Finally, D_2 is either optimistic or pessimistic about U_A preferences. When making her decision, D_2 signals her belief, which in turn affects U_B 's decision. This game has a unique equilibrium, in which: (i) D_2 always invests when optimistic, and does so only with some probability when pessimistic; and (ii) U_B always offers a low share when D_2 does not invest, and a high share with positive probability otherwise. Thus, D_2 and U_B both depart from the initial theory (Insights 2 and 3), and a departure by D_2 moreover increases the likelihood of a departure by U_B (Insight 4 (i)).

The possibility of social preferences can therefore explain Insights 2 to 4 (i).³⁸ By contrast, this approach cannot explain Insights 1 and 4 (ii), which involve U_A 's own departures.³⁹

³⁸Combined with level- k theory, the two approaches can thus explain Insights 1 to 4 (i) if the impact of social preferences on U_B 's departures outweigh that of level- k theory.

³⁹The above analysis concerns U_B 's and D_2 's beliefs about U_A 's preferences, which cannot explain differences in U_A 's behavior across treatments. Introducing beliefs about U_B 's or D_2 's own preferences is unlikely to explain differences across treatments, as these subjects play similar roles in all treatments.

4.3.3 “Crazy” types

The previous approaches can explain all of our insights but Insight 4 (*ii*): in the Commitment treatment, under VI, the likelihood that U_B makes a generous offer is significantly higher when U_A does not commit himself than when he does. The expectation of persistence in U_A subjects’ errors may however explain this positive correlation.

Such expectation cannot affect U_B ’s behavior in the Sabotage treatment, where U_B ’s own decision is concomitant with U_A ’s first decision. The same applies in the Commitment treatment under VS, as U_A has not subsequent decisions to make when departing from theory on his first decision (namely, by committing himself). By contrast, under VI, if U_A departs from theory on his first decision (namely, by *not* committing himself), then U_B may expect U_A to depart again from theory in the share offered to D_2 ; as a result, U_B may offer a less generous share.

Introducing the possibility of “crazy” types⁴⁰ for U_A subjects thus provides an interpretation of Insight 4 (*ii*). By contrast, it cannot explain Insight 1, as a crazy type is expected to depart more frequently from theory regardless of the phase or treatment. It cannot explain Insights 2 and 3 either, as it generates the same effects on U_B ’s and D_2 ’s departures under VS and VI in the Sabotage treatment. Indeed, if D_2 expects U_A to be of a crazy type, she will refrain from investing under VS and will be more prone to invest under VI. And if observing that D_2 departs from theory were to signal her belief that U_A is of a crazy type, then this would induce U_B to depart as well in his own decision: he would indeed offer a less generous share when D_2 does not invest under VS, and a more generous one when D_2 invests under VI – this, in turn, is however consistent with Insight 4 (*i*).

⁴⁰See Martin *et al.* (2001).

5 Conclusion

ACR predicts that vertical integration creates hold-up problems when the integrated firm competes both upstream and downstream. To test this theoretical prediction, we have designed a laboratory experiment featuring two phases, a first one for vertical separation followed by a second one for vertical integration. We study three treatments, in which a downstream firm must invest before negotiating with two suppliers – one being always independent, and the other being either independent or integrated with a rival of the downstream firm. The Benchmark treatment does not include any hold-up option, and vertical integration should therefore have no effect. The Commitment treatment enables one supplier to engage in hold-up by pre-committing himself *ex ante* to appropriating part of his customers' profits. Finally, the Sabotage treatment enables instead the supplier to degrade *ex post* his customers' profits. Theory predicts that, in these last two treatments, vertical integration induces the supplier to exert his hold-up option.

The laboratory data support the theoretical predictions about the impact of vertical integration on hold-up. Yet, they also reveal some departures from theory. Interestingly, these are more pronounced for the hold-up decision in the Commitment treatment, whereas in the Sabotage treatment they are instead more pronounced for the investment decision and for the contract terms offered by the independent supplier, and these departures are moreover positively correlated. We consider several behavioral approaches that may explain these departures from theory. We find that bounded rationality (namely, level- k theory) can explain the first observation; this is because the hold-up decision comes earlier in the Commitment treatment, and thus involves higher levels of thinking. The introduction of social preferences for the supplier can instead explain the other observations; this is because the hold-up decision comes later in the Sabotage treatment,

and thus exposes the other players to greater strategic uncertainty.

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Appendix

A IQ Questionnaire

The following three questions were asked. Each good answer yields one point, while each wrong answer brings zero. The IQ score is the sum of the three.

1. A bat and a ball cost 1.10 in total. The bat costs \$1.00 more than the ball. How much does the ball cost? ... cents
2. If it takes 5 machines 5 minutes to make 5 widgets, how long would it take 100 machines to make 100 widgets? ... minutes
3. In a lake, there is a patch of lily pads. Every day, the patch doubles in size. If it takes 48 days for the patch to cover the entire lake, how long would it take for the patch to cover half of the lake? ... days

B Pearson correlation tests

Table 22: Pearson correlation coefficients

Female and Employee	0.382***
Female and IQ	-0.446***
Employee and IQ	-0.620***

Note: *** represents significance at 1% level.

C Marginal effect of vertical integration on U_A 's decisions

Table 23: Marginal effect of vertical integration on U_A 's commitment (Probit model)

	Model I	Model II
Commitment	0.481*** (0.013)	0.481*** (0.013)
IQ and risk-aversion	No	Yes

Notes: standard errors are reported in parentheses;
*** represents significance at 1% level.

Table 24: Marginal effect of VI on U_A 's offered share when not committed (OLS model)

	Model I	Model II
Commitment	-3.748** (1.734)	-3.540*** (1.271)
IQ and risk-aversion	No	Yes

Notes: standard errors are reported in parentheses;
*** represents significance at 1% level.

Table 25: Marginal effect of VI on U_A 's sabotage decision (Probit model)

	Model I	Model II
Sabotage	0.458*** (0.021)	0.458*** (0.018)
IQ and risk-aversion	No	Yes

Notes: standard errors are reported in parentheses;
*** represents significance at 1% level.

D Interplay between σ_D^I , σ_B^O and σ_A^H under VS

Table 26 presents the interplays between σ_D^I , σ_B^O and σ_A^H under VS in t in the Commitment and Sabotage treatments.

Table 26: Interplay between subsequent departures under VS (Probit model)

	Commitment	Sabotage
σ_D^I on σ_B^O	0.129* (0.067)	
σ_D^I on σ_B^O		0.145* (0.078)
σ_A^H on σ_D^I	0.199*** (0.066)	
σ_D^I on σ_A^H (if U_A selected and $\sigma_B^O = 0$)		a
σ_A^H on σ_B^O (if $\sigma_D^I = 0$)	0.093 (0.082)	
σ_B^O on σ_A^H (if U_A selected and $\sigma_D^I = 0$)		-0.009 (0.065)

Notes: a : $\sigma_D^I = 1$ predicts $\sigma_A^H = 0$ perfectly.
Standard errors in parentheses; *** and * represent significance at 1% and 10% levels.

E Level- k theory

For simplicity we assume that, for $k \geq 1$, each level- k player believes that all the other players are of level- $(k - 1)$. We also assume that when indifferent between several actions, players randomly choose every action with equal probability. A more detailed, step-by-step analysis is provided in Online Appendix B.

E.1 The Sabotage game

In the sabotage game, level-0 players play randomly under both VS and VI. In stage 1, D_2 invests with probability $1/2$; in stage 2, both U_A and U_B select each of the 9 possible sharing-rules with equal probability; in stage 3, D_2 selects each supplier with equal probability, regardless of the shares offered; and whenever he is selected, in stage 4 U_A uses the sabotage option with probability $1/2$.

From level-1 on, U_A always uses the sabotage option when selected under VI, and never uses it under VS.

On level-1, anticipating a random selection by D_2 , both suppliers offer the lowest share (50%). Anticipating random offers and random use of the sabotage option by U_A , D_2 invests.⁴¹ In stage 3, D_2 selects the offer from U_A only if the expected profit she receives from this offer with a probability $1/2$ of sabotage is higher than the profit she receives from the offer of U_B .

From level-2 on, under VI, anticipating that U_A will use the sabotage option whenever selected, U_B always offers 55% and D_2 never invests. By contrast, under VS, the two suppliers compete to supply D_2 , and the offered shares increase gradually: the better offer reaches 70% on level-5 and 90% from level-9 on. D_2 thus never invests before level-6, and always invest from level-7 on.

E.2 The Commitment game

In the commitment game, level-0 players play again randomly under both VS and VI. Hence, U_A commits himself with probability $1/2$ in stage 0 and D_2 invests with probability $1/2$ in stage 1; in stage 2, both U_A (if not committed) and U_B select each of the 9 possible sharing-rules with equal probability, and in stage 3, D_2 selects each supplier with equal probability, regardless of the shares offered.

On level 1, suppliers anticipate again a random selection by a level-0 D_2 . Hence, U_B offers the lowest (50%) whereas U_A makes the commitment decision randomly and, if not committed, offers 50% as well. Consider now by D_2 's investment decision. If U_A has not committed himself in stage 0, D_2 anticipates that both U_A and U_B will offer a randomly chosen sharing rule. The probabilities that the best offer is a given sharing rule are presented in Table 27. Given these probabilities, D_2 invests (her expected profit is then 21.4 instead of 18 when she does not invest). By contrast, if U_A has committed himself in

⁴¹ D_2 's expected profit is 16.64 if she does not invest, and 17.81 if she does.

stage 0, then D_2 anticipates that the best offer she will receive will be U_B 's, which can be any share with probability $1/9$. Her expected profit is then $143/9$ whether she invests or not; D_2 thus invests randomly and, in stage 3, selects the supplier who offered the higher share.

Table 27: Level-1, probability of best offer being s

s	50%	55%	60%	65%	70%	75%	80%	85%	90%
Probability	$\frac{1}{81}$	$\frac{3}{81}$	$\frac{5}{81}$	$\frac{7}{81}$	$\frac{9}{81}$	$\frac{11}{81}$	$\frac{13}{81}$	$\frac{15}{81}$	$\frac{17}{81}$

On level-2, under both VS and VI, and regardless of U_A 's commitment decision, D_2 expects 50% shares from the level-1 suppliers, and does not invest. Similarly, U_B expects the level-1 U_A to offer 50% and thus offers the next best share (55%) – offering 50% is less profitable, as it reduces by half the selection probability. Likewise, U_A chooses to not commit himself, and offers a 55% share – committing himself would furthermore reduce the probability of investment by the level-1 D_2 .

From level-3 on, under both VS and VI, commitment by U_A discourages investment by D_2 : U_B 's best response to level- $(k - 1)$ players' strategies is then to offer a 55% share, and D_2 's is not to invest. However, an independent U_A never commits himself: this would yield the lowest possible payoff (2), whereas not committing and matching U_B 's offer, for example, would yield a higher payoff with positive probability. Furthermore, absent commitment, each supplier seeks to outbid his level- $(k-1)$ rival; hence both suppliers' offers increase gradually with k , reach 70% (the share that leaves D_2 indifferent between investing or not) when $k = 5$, and is maximal (90%) from level-10 on.

It follows that U_A never commits before $k = 7$ (expecting no influence on investment, this would only limit his ability to compete) and D_2 never invests before before $k = 6$, where it does so with probability $1/2$. Differences between VS and VI appear from level-7 on. Under VS, U_A never commits himself, the suppliers compete and, anticipating high enough offers from level- $(k - 1)$ suppliers, D_2 invests. Under VI, by contrast, U_A commits himself to prevent D_2 from investing, as this strategy becomes more profitable than competing to supply D_2 .⁴²

F Social preferences

We propose here a stylized model showing that the introduction of (uncertain) social preferences for U_A can explain why, in the Sabotage treatment (but not in the Commitment treatment), D_2 's investing may induce U_B to be generous. The intuition is that D_2 's investment decision may convey some information about D_2 's beliefs about U_A 's preferences, which induces U_B to adjust his offer accordingly. For simplicity, U_A is replaced by an automatized robot, and U_B has only two offers to choose from.

⁴²For example, by committing himself on level-7 under VI, U_A prevents D_2 from investing and obtains a profit of 54; he expects that not committing himself (and offering a 80% share) would instead induce the level-6 D_2 to invest with probability $1/2$, giving him an expected profit of 51.

F.1 Setting

• *Players.* There are two strategic players: U_B and D_2 . In addition, D_2 has access to an outside option (standing for U_A) which is “good” ($\theta = G$) with probability x and “bad” ($\theta = B$) otherwise; a good outside option enables D_2 to obtain a share $\hat{s} \in (0, 1)$ of her profit, whereas a bad outside option gives her zero profit.

• *Information.* At the beginning of the game, U_B and D_2 believe that the outside option is good with probability \hat{x} . D_2 then observes a binary signal $\sigma \in \{g, b\}$, distributed in such a way that:⁴³

- with probability $\lambda \in (0, 1)$, D_2 observes $\sigma = g$; it then becomes “optimistic” and believes that the outside option is good with probability $x_H \in (0, 1)$;
- with probability $1 - \lambda$, D_2 observes $\sigma = b$; it then becomes “pessimistic” and believes that the outside option is good with lower probability $x_L \in (0, x_H)$.

By construction, $\hat{x} = \lambda x_H + (1 - \lambda) x_L$. We moreover assume that D_2 is likely to be pessimistic:⁴⁴

$$\lambda < \bar{\lambda} \equiv \frac{s_H - s_L}{1 - s_L}. \quad (7)$$

• *Decisions.* D_2 chooses whether or not to invest (at cost $I > 0$); she generates a profit $\Pi > 0$ if she does not invest and $\Pi + \Delta > \Pi$ if she invests. U_B chooses whether to offer D_2 a share $s_H \in (0, 1)$ or a lower share $s_L \in (0, x_L)$.

• *Payoffs.* Let $\delta \in \{0, 1\}$ denote D_2 's investment decision (where $\delta = 1$ if D_2 invests, and $\delta = 0$ otherwise), and $s \in \{s_L, s_H\}$ denote the share offered by U_B . The payoffs are as follows:

- If D_2 opts for the outside option, then D_2 obtains $\hat{s}(\Pi + \delta\Delta) - \delta I$ if the outside option is of good quality and $-\delta I$ otherwise; U_B obtains 0.
- If instead D_2 accepts U_B 's offered share s , then D_2 obtains $s(\Pi + \delta\Delta) - \delta I$ and U_B obtains $(1 - s)(\Pi + \delta\Delta)$.

We assume that the ratio I/Δ and the share \hat{s} satisfy:

$$s_H > x_H \hat{s} > \frac{I}{\Delta} > s_L > x_L \hat{s}. \quad (8)$$

This assumption asserts that investing is profitable for D_2 if she obtains s_H from U_B , or if she opts for the outside option and is optimistic, but is unprofitable otherwise; in

⁴³That is, the joint distribution of θ and σ is given by $\Pr(G, g) = \lambda x_H$, $\Pr(B, g) = \lambda(1 - x_H)$, $\Pr(G, b) = (1 - \lambda)x_L$ and $\Pr(B, b) = (1 - \lambda)(1 - x_L)$.

⁴⁴This assumption rules out trivial situations in which U_B would always offer s_H and D_2 would therefore always invest.

addition, it asserts that U_B can win D_2 's business with the lower share s_L when she is pessimistic, but needs instead to offer her the higher share s_H if she is optimistic.

• *Timing.* There are three stages:

- Stage 0: Nature randomly draws the quality $\theta \in \{G, B\}$ of the outside option and the signal $\sigma \in \{g, b\}$; the former is not observed, whereas the latter is privately observed by D_2 .
- Stage 1: D_2 chooses whether or not to invest; this decision is observed by U_B .
- Stage 2: U_B chooses whether to offer s_L or s_H ; having observed the offer, D_2 chooses whether to accept it, or to opt for the outside option.

F.2 Equilibrium analysis

We now show that there exists a unique equilibrium, which we characterize:

Proposition 1 *There exists a semi-separating equilibrium in which:*

- D_2 invests with probability 1 when she is optimistic, and with probability

$$y^* \equiv \frac{\lambda(1 - s_H)}{(1 - \lambda)(s_H - s_L)} \in (0, 1) \quad (9)$$

otherwise.

- U_B offers s_L with probability 1 when D_2 does not invest, and offers s_H with probability

$$z^* \equiv \frac{I - s_L \Delta}{(s_H - s_L)(\Delta + \Pi)} \in (0, 1) \quad (10)$$

otherwise.

The proof of this proposition consists of four lemmas. We first show that there is no separating equilibrium.

Lemma 1 *There is no separating equilibrium.*

Proof. Suppose that D_2 's investment decision reveals her type, that is, whether she is optimistic or pessimistic; upon observing D_2 's investment decision, U_B then updates and shares D_2 's beliefs. Two cases can be distinguished, depending on which type chooses to invest.

- Case a. Suppose that D_2 invests only when being optimistic. Along the equilibrium path, U_B then offers s_H if D_2 invests (as an optimistic D_2 is unwilling to accept s_L), and s_L if D_2 does not invest (as a pessimistic D_2 is willing to accept it). A pessimistic D_2 would therefore gain from deviating and investing, a contradiction.

- Case b. Suppose now that D_2 invests only when being pessimistic, in which case U_B offers s_L . A pessimistic D_2 would therefore gain from deviating and not investing, a contradiction. ■

Next, we show that there is no pooling equilibrium either:

Lemma 2 *There is no pooling equilibrium.*

Proof. Suppose that D_2 makes the same investment decision, regardless of her type. In the continuation equilibrium, U_B expects D_2 to be optimistic with probability λ and pessimistic with probability $1 - \lambda$. If U_B offers s_H , then D_2 accepts the offer regardless of her type, and U_B thus obtains a share $1 - s_H$ of the profit. If instead U_B offers s_L , D_2 accepts the offer when she is pessimistic and rejects it otherwise; U_B thus obtains an expected share of the profit equal to $(1 - \lambda)(1 - s_L)$, which exceeds $1 - s_H$ under (7). It follows that U_B offers s_L with probability 1. But then, an optimistic D_2 finds it optimal to invest (and opt for the outside option), whereas a pessimistic D_2 prefers not to invest, a contradiction. ■

We now establish the existence of the candidate equilibrium:

Lemma 3 *There exists a semi-separating equilibrium in which:*

- D_2 invests with probability 1 when she is optimistic, and with probability $y^* \in (0, 1)$ otherwise.
- U_B offers s_L with probability 1 when D_2 does not invest, and offers s_H with probability $z^* \in (0, 1)$ otherwise.

Proof. Suppose that D_2 invests with probability 1 when she is optimistic, and with probability $y \in (0, 1)$ otherwise. If U_B observes that D_2 did not invest, he revises his belief about D_2 and expects her to be pessimistic; it is therefore optimal for U_B to offer s_L . If U_B observes instead that D_2 invested, he expects D_2 to be optimistic with probability

$$\hat{\lambda}(y) = \frac{\lambda}{\lambda + (1 - \lambda)y}.$$

If U_B offers s_H , then D_2 accepts the offer regardless of her type, and U_B thus obtains a share $1 - s_H$ of the profit. If instead U_B offers s_L , then D_2 accepts the offer when she is pessimistic and rejects it otherwise, and U_B thus obtains an expected share of the profit equal to $[1 - \hat{\lambda}(y)](1 - s_L)$. Hence, for U_B to be indifferent between making either offer, the probability y must be equal to y^* , given by (9). It is straightforward to check that y^* is positive and increases with λ , and that (7) implies $y^* < 1$.

Conversely, suppose that U_B offers s_L with probability 1 when D_2 does not invest, and s_H with probability $z \in (0, 1)$ otherwise. Consider first the investment decision of a pessimistic D_2 . As D_2 then always accepts U_B 's offer, not investing yields a profit equal to

$s_L\Pi$, whereas investing yields an expected profit given by $[zs_H + (1 - z)s_L](\Pi + \Delta) - I$. Hence for a pessimistic D_2 to be indifferent between investing or not, the probability z must satisfy:

$$s_L\Pi = [zs_H + (1 - z)s_L](\Pi + \Delta) - I,$$

which amounts to $z = z^*$, given by (10). It is straightforward to check that z^* is positive (from (8)) and strictly lower than 1.⁴⁵

Finally, if D_2 is indifferent between investing or not when she is pessimistic, then she strictly prefers to invest when she is optimistic. ■

Finally, we check that there is no other equilibrium:

Lemma 4 *The equilibrium characterized in lemma 3 is the unique equilibrium.*

Proof. Consider a candidate equilibrium in which D_2 invests with probability y_H when she is optimistic, and with probability y_L otherwise. lemma 3 identified a unique equilibrium among the candidates where $y_H = 1$ and $y_L \in (0, 1)$; furthermore, the case $\{y_H = 1, y_L = 0\}$ is discarded by lemma 1 and the case where $y_H = y_L = 1$ is discarded by lemma 2. Hence, without loss of generality, we can now focus on candidate equilibria in which $y_H < 1$, which in turn requires $z < z^*$ (otherwise, as seen above, an optimistic D_2 strictly prefers investing). It follows that $y_L = 0$ and thus, from lemma 2, $y_H > 0$. But then, when observing that D_2 invested, U_B revises his beliefs and expects D_2 to be optimistic; it is therefore strictly optimal for U_B to offer s_H , contradicting the working assumption $z < z^*$. ■

F.3 Conclusion

The above analysis shows that there exists a unique equilibrium, in which not only D_2 and U_B depart from the initial theoretical predictions, but D_2 's investment decision moreover influences U_B 's behavior: D_2 invests with positive probability, in which case U_B responds by offering the higher share s_H with positive probability. It can moreover be noted that the introduction of uncertain social preferences for U_A has no impact under vertical separation, as U_A never engages in sabotage anyway. Likewise, in the Commitment treatment, introducing the possibility that social preferences may prevent U_A from committing himself to offering the lowest share would have no impact, both in vertical separation and vertical integration, as the associated uncertainty would be resolved before the stages where the other players have to make their decisions.

⁴⁵To see this, note that z^* decreases as Π increases, and is therefore lower than

$$\frac{I - s_L\Delta}{(s_H - s_L)(\Delta + \Pi)} \Big|_{\Pi=0} = \frac{\frac{I}{\Delta} - s_L}{s_H - s_L} < 1,$$

where the inequality follows from (8).

Online appendix for
Vertical Integration as a Source of Hold-up: an Experiment
Not for publication

A Instructions

A.1 Instructions for the Benchmark treatment

The following displays the english translation of the instructions handed out and read to the subjects participating in the Benchmark treatment.

Instructions Benchmark (english translation)

You are about to participate to an experiment on decision-making. This experiment is realized jointly by the Econometrics Laboratory at Ecole Polytechnique, Toulouse School of Economics, and the INRA-ALISS Laboratory. During this session, you will be able to earn money. How much you will earn will depend on your decisions and also on the decisions taken by other participants with whom you will be interacting. In addition to this amount you will also receive a participation fee of 5 Euros. Your earnings will be paid cash at the end of the experiment, in a separate room for confidentiality reasons.

During the experiment, you have been randomly assigned to two separate rooms. Because there are many of you, in total 30 participants, we had to allocate you into two rooms. This allocation is purely random and has no relation to the decisions you have to make during the experiment. During the experiment you will have to interact with other participants in the same room as well as participants in the other room.

These instructions explain in detail what are the decision-making tasks you will have to make during the experiment, and how your payment is going to be computed. All the participants receive the same instructions, irrespective of the room they are allocated to.

The decisions you make during the experiment are anonymous.

If you have questions about the instructions, please raise your hand. We will answer your questions privately. Along the session, it is prohibited to communicate with each other, subject to being excluded from the session and not receiving any payment. We also require that you do not use your mobile phones.

Proceedings of the experiment

At the beginning of this experiment, you will be attributed a role that you will keep throughout the experiment. The computer program assigns these roles randomly. 10 participants will be assigned the role A, 10 the role B and 10 the role C. You will participate to two phases of 10 periods each. You will keep the same role for all the periods of the experiment. You will thus keep the same role for these two phases.

We present first the proceedings of the first phase. Once the first phase will be over, we will give you the instructions for the second phase. The two phases are independent from each other. At the end of the experiment, one period among the twenty periods will be randomly drawn by the computer; this will determine your payments for the experiment.

Phase 1

This phase consists in ten periods. All your decisions are anonymous. We describe below the proceedings of phase 1.

Description of each period At the beginning of each period, groups of three players are composed with one player A, one B and one C. These three players will interact throughout the period. The interactions of these three players create revenues. All the groups are anonymous: you will not know with whom you are playing.

During the ten periods of phase 1, players A and B interact only once: it is not possible that players A and B interact once more in phase 1. Players C are randomly affected to a player A and a player B: it is possible that a player C interacts several times with a player A or a player B but it is not automatic.

Inside each group of three participants, each period is composed of three stages:

- In stage 1, player C makes a first decision. He must choose between two options:
 - “Invest” or
 - “Not invest”.
- In stage 2, the choice of player C in stage 1 is revealed to players A and B. Players A and B make their decisions, simultaneously and without consulting each other. Each of them must choose one among the following nine options, which correspond to a percentage of the total revenues they plan to leave to player C:
 - 50% or
 - 55% or
 - 60% or
 - 65% or
 - 70% or
 - 75% or
 - 80% or

- 85% or
- 90%.
- In stage 3, the choices of players A and B in stage 2 are revealed to player C. Player C makes a second decision. He must choose one of the two players A and B :
 - "Player A" or
 - " Player B" .

How are the gains of each player computed in each period ?

The gains of players A, B and C at each period depend on the choices of all of them. All the amounts reported in the following tables are in euros.

Gains of player C The gains of player C depend on his investment decision and on the percentage of the revenues that will be left to him subsequently. This percentage of the revenues corresponds to the percentage of the revenues offered by the player A or B selected by player C in stage 3. The gains of player C in each situation are displayed in the following table:

Percentage of revenues left to C		50%	55%	60%	65%	70%	75%	80%	85%	90%
Choice of C	Not invest	10	12	13	14	16	17	19	20	22
	Invest	1	5	8	12	16	20	23	27	31

Example: suppose that

- In stage 1, player C chooses to not invest;
- In stage 2, player A chooses to leave 85% of the revenues to player C; Player B chooses to leave 55% of the revenues to player C ;
- In stage 3, player C selects player A.

The gain of player C for this period is 20€.

Gains of players A and B The gains of players A and B depend on the percentage of the revenues that they offer to leave to player C and on the choices of player C (to invest or not, and player A or B).

- If player C chooses the offer of player A in stage 3:
 - The gains of player A in each situation are displayed in the following table;
 - The gain of player B is 2€.
- If player C chooses the offer of player B in stage 3:

- The gains of player B in each situation are displayed in the following table;
- The gain of player A is 2€.

Gains of A or B

Percentage of revenues left to C		50%	55%	60%	65%	70%	75%	80%	85%	90%
Choice of C	Not invest	63	57	50	44	38	32	25	19	13
	Invest	74	67	59	52	44	37	30	22	15

Example. Suppose that:

- In stage 1, player C chooses to not invest;
- In stage 2, player A chooses to leave 85% of the revenues to player C; Player B chooses to leave 55% of the revenues to player C;
- In stage 3, player C selects player A.

The gain of player A for this period is 19€. The gain of player B for this period is 2€.

Information received by the players at the end of each period At the end of each period, the screen displays the amount of the player's gain for this period. Each player learns only his gain for the current period; the gains of the other players are not displayed.

The screen also displays the decisions taken by all players during the period: the three players in each group are reminded of the choices of player C in stage 1 and in stage 3 and the choices of players A and B in stage 2.

Please read these instructions carefully. Before starting phase 1 of this experiment, you will answer a few questions about these instructions. As soon as you will have correctly answered these questions, we will be able to start.

Thanks for your participation

Questions about the instructions

Please answer the following questions about the instructions

- At the beginning of each period, groups of three participants consisting of one player A, one player B and one player C are constituted.
TRUE FALSE
- A player A and a player B can be part of the same group several times during a given phase.
TRUE FALSE
- A player A and a player C can be part of the same group several times during a given phase.
TRUE FALSE
- A phase consists of 10 periods.
TRUE FALSE
- At the end of the experiment, one period among the 20 periods played is randomly drawn. Each participant will receive as a payment for the experiment the amount of his gains for this period, plus the participation fee of 5€.
TRUE FALSE
- At each period, the three players of one group learn their own gains and the gains of the two other players of their group.
TRUE FALSE

Example 1. Suppose that:

- In stage 1, player C chooses to not invest;
- In stage 2, player A chooses to leave 50% of the revenues to player C; player B chooses to leave 90% of the revenues to player C;
- In stage 3, player C selects player B.

What is the gain of player A ? _____

What is the gain of player B ? _____

What is the gain of player C ? _____

Example 2. Suppose that:

- In stage 1, player C chooses to invest;
- In stage 2, player A chooses to leave 70% of the revenues to player C; player B chooses to leave 80% of the revenues to player C;
- In stage 3, player C chooses player A.

What is the gain of player A ? _____

What is the gain of player B ? _____

What is the gain of player C ? _____

Phase 2

The instructions for phase 2 are identical to the instructions for phase 1, except for the computation of the gains of players A and B. For the record, these instructions detail the proceedings of each period. As only the computation of the gains of players A and B differs from that in phase 1, we will read this part only together. It corresponds to the text written in blue.

You keep the same role than in phase 1 of the experiment. All your decisions are anonymous.

This phase is independent from phase 1. This phase consists in ten periods. We describe below the proceedings of phase 2.

Description of each period As in phase 1, at the beginning of each period, groups of three players are composed with one player A, one B and one C. These three players will interact throughout the period. The interactions of these three players create revenues. All the groups are anonymous: you will not know with whom you are playing.

During the ten periods of phase 2, players A and B interact only once: it is not possible that players A and B interact once more in phase 2. Players C are randomly affected to a player A and a player B: it is possible that a player C interacts several times with a player A or a player B but it is not automatic.

As in phase 1, inside each group of three participants, each period consists in three stages:

- In stage 1, player C makes a first decision. He must choose between two options:
 - “Invest” or
 - “Not invest”.

- In stage 2, the choice of player C in stage 1 is revealed to players A and B. Players A and B make their decisions, simultaneously and without consulting each other. Each of them must choose one among the following nine options, which correspond to a percentage of the total revenues they plan to leave to player C:
 - 50% or
 - 55% or
 - 60% or
 - 65% or
 - 70% or
 - 75% or
 - 80% or
 - 85% or
 - 90%.

- In stage 3, the choices of players A and B in stage 2 are revealed to player C. Player C makes a second decision. He must choose one of the two players A and B :
 - "Player A " or
 - " Player B" .

How are the gains of each player computed in each period ?

The gains of players A, B and C at each period depend on the choices of each of them. All the amounts reported in the following tables are in Euros.

Gains of player C

- The gain of player C is computed as in phase 1.
- The gain of player C depends on his investment decision and on the percentage of the revenues that will be left to him subsequently.
- This percentage of the revenues corresponds to the percentage of the revenues offered by the player A or B selected by player C in stage 3.

The gain of player C in each situation is displayed in the following table (this table is the same than in phase 1):

Gains of C

Percentage of revenues left to C		50%	55%	60%	65%	70%	75%	80%	85%	90%
Choice of C	Not invest	10	12	13	14	16	17	19	20	22
	Invest	1	5	8	12	16	20	23	27	31

Gains of players A and B The gains of players A and B are computed differently in phase 2 compared to phase 1. The gains of players A and B depend from the percentage of the revenues that they offer to leave to player C and from the choices of player C (to invest or not, and player A or B).

- If player C chooses the offer of player A in stage 3:
 - The gains of player A in each situation are displayed in the following table (this table is not the same than in phase 1);
 - The gain of player B is 2€.
- If player C chooses the offer of player B in stage 3:
 - The gains of player B in each situation are displayed in the following table (this table is not the same than in phase 1);

- The gain of player A is 2€.

Gains of A and B

Percentage of revenues left to C		50%	55%	60%	65%	70%	75%	80%	85%	90%
Choice of C	Not invest	15	13	12	10	9	7	6	4	3
	Invest	37	33	30	26	22	19	15	11	7

In addition to the amount displayed above, player A also receives a guaranteed amount that depends on the investment choice made by C. Whether player C selects A or B in stage 3, player A is certain to receive this guaranteed amount. This guaranteed amount is displayed in the following Table:

Additional payoff for A

		Guaranteed amount
Choice of C	Not invest	52
	Invest	29

Example. Suppose that:

- In stage 1, player C chooses to not invest;
- In stage 2, player A chooses to leave 85% of the revenues to player C; player B chooses to leave 55% of the revenues to player C;
- In stage 3, player C selects player A.

The gain of player A for this period is $4€ + 52€ = 56€$. The gain of player B for this period is 2€.

Information received by the players at the end of each period As in phase 1, at the end of each period, the screen displays the amount of the player's gain for this period. Each player learns only his gain for the current period; the gains of the other players are not displayed.

The screen also displays the decisions taken by all players during the period: the three players in each group are reminded of the choices of player C in stage 1 and in stage 3 and the choices of players A and B in stage 2.

Please read these instructions carefully. Before starting phase 2 of this experiment, you will answer a few questions about these instructions. As soon as you will have correctly answered these questions, we will be able to start.

Questions about the instructions

Please answer the following questions about the instructions

- The table of the gains of player A, apart from the guaranteed amount, is the same as in phase 1.
TRUE FALSE
- The table of the gains of player B is the same as in phase 1.
TRUE FALSE
- The table of the gains of player C is the same as in phase 1.
TRUE FALSE
- The guaranteed amount is received by player A and player B.
TRUE FALSE
- Player A receives a guaranteed amount only if he is chosen by C in stage 3.
TRUE FALSE
- The guaranteed amount received by player A depends on the investment choice by player C in stage 1.
TRUE FALSE

Example 1. suppose that:

- *In stage 1, player C chooses to not invest;*
- *In stage 2, player A chooses to leave 50% of the revenues to player C; player B chooses to leave 90% of the revenues to player C;*
- *In stage 3, player C selects player B.*

What is the gain of player A ? _____

What is the gain of player B ? _____

What is the gain of player C ? _____

Example 2. Suppose that:

- *In stage 1, player C chooses to invest;*
- *In stage 2, player A chooses to leave 70% of the revenues to player C; player B chooses to leave 80% of the revenues to player C;*
- *In stage 3, player C chooses player A.*

What is the gain of player A ? _____

What is the gain of player B ? _____

What is the gain of player C ? _____

A.2 Instructions for the Commitment treatment

The following displays the english translation of the instructions handed out and read to the subjects participating in the Commitment treatment.

Instructions Commitment (english translation)

You are about to participate to an experiment on decision-making. This experiment is realized jointly by the Econometrics Laboratory at Ecole Polytechnique, Toulouse School of Economics, and the INRA-ALISS Laboratory. During this session, you will be able to earn money. How much you will earn will depend on your decisions and also on the decisions taken by other participants with whom you will be interacting. In addition to this amount you will also receive a participation fee of 5 Euros. Your earnings will be paid cash at the end of the experiment, in a separate room for confidentiality reasons.

During the experiment, you have been randomly assigned to two separate rooms. Because there are many of you, in total 30 participants, we had to allocate you into two rooms. This allocation is purely random and has no relation to the decisions you have to make during the experiment. During the experiment you will have to interact with other participants in the same room as well as participants in the other room.

These instructions explain in detail what are the decision-making tasks you will have to make during the experiment, and how your payment is going to be computed. All the participants receive the same instructions, irrespective of the room they are allocated to.

The decisions you make during the experiment are anonymous.

If you have questions about the instructions, please raise your hand. We will answer your questions privately. Along the session, it is prohibited to communicate with each other, subject to being excluded from the session and not receiving any payment. We also require that you do not use your mobile phones.

Proceedings of the experiment

At the beginning of this experiment, you will be attributed a role that you will keep throughout the experiment. The computer program assigns these roles randomly. 10 participants will be assigned the role A, 10 the role B and 10 the role C. You will participate to two phases of 10 periods each. You will keep the same role for all the periods of the experiment. You will thus keep the same role for these two phases.

We present first the proceedings of the first phase. Once the first phase will be over, we will give you the instructions for the second phase. The two phases are independent from each other. At the end of the experiment, one period among the twenty periods will be randomly drawn by the computer; this will determine your payments for the experiment.

Phase 1

This phase consists in ten periods. All your decisions are anonymous. We describe below the proceedings of phase 1.

Description of each period At the beginning of each period, groups of three players are composed with one player A, one B and one C. These three players will interact throughout the period. The interactions of these three players create revenues. All the groups are anonymous: you will not know with whom you are playing.

During the ten periods of phase 1, players A and B interact only once: it is not possible that players A and B interact once more in phase 1. Players C are randomly affected to a player A and a player B: it is possible that a player C interacts several times with a player A or a player B but it is not automatic.

Inside each group of three participants, each period is composed of four stages:

- In stage 1, player A makes a decision. He chooses either to commit himself or to not commit himself to leaving a 50% revenue share to player C. He must choose among the following two options:
 - "I commit myself to leaving a 50% revenue share" or
 - "I do not commit myself".

If player A chooses to commit himself, he has no decision to make in stage 3. If he chooses to not commit himself, he has a decision to make in stage 3.

- In stage 2, the choice of player A made in stage 1 is revealed to player C. Player C makes a first decision. He must choose between two options:
 - "Invest" or
 - "Not invest".

- In stage 3, the choices of player A in stage 1 and of player C in stage 2 are revealed to players A and B. Player A makes his decision if he chose not to commit himself in stage 1 (and has no decision to make otherwise). Player B makes his decision. When player A and B make a decision, they make it simultaneously and without consulting each other. Each of them must choose one among the following nine options, which correspond to a percentage of the total revenues they plan to leave to player C:
 - 50% or
 - 55% or
 - 60% or
 - 65% or
 - 70% or
 - 75% or
 - 80% or
 - 85% or
 - 90%.
- In stage 4, the choices of players A and B in stage 2 are revealed to player C. Player C makes his decision. He must choose one of the two players A and B :
 - "Player A " or
 - " Player B" .

How are the gains of each player computed in each period ?

The gains of players A, B and C at each period depend on the choices of all of them. All the amounts reported in the following tables are in euros.

Gains of player C The gains of player C depend on his investment decision and on the percentage of the revenues that will be left to him subsequently. This percentage of the revenues corresponds to the percentage of the revenues offered by the player A or B selected by player C in stage 4. The gains of player C in each situation are displayed in the following table:

Gains of C

Percentage of revenues left to C		50%	55%	60%	65%	70%	75%	80%	85%	90%
Choice of C	Not invest	10	12	13	14	16	17	19	20	22
	Invest	1	5	8	12	16	20	23	27	31

Example: suppose that

- In stage 1, player A chooses to not not commit himself to leaving 50% of revenues to player C ;
- In stage 2, player C chooses to not invest;

- In stage 3, player A chooses to leave 85% of the revenues to player C; Player B chooses to leave 55% of the revenues to player C ;
- In stage 4, player C selects player A.

The gain of player C for this period is 20€.

Gains of players A and B The gains of players A and B depend on the percentage of the revenues that they offer to leave to player C and on the choices of player C (to invest or not, and player A or B).

- If player C chooses the offer of player A in stage 4:
 - The gains of player A in each situation are displayed in the following table;
 - The gain of player B is 2€.
- If player C chooses the offer of player B in stage 4:
 - The gains of player B in each situation are displayed in the following table;
 - The gain of player A is 2€.

Gains of A or B

Percentage of revenues left to C		50%	55%	60%	65%	70%	75%	80%	85%	90%
Choice of C	Not invest	63	57	50	44	38	32	25	19	13
	Invest	74	67	59	52	44	37	30	22	15

Example. Suppose that:

- In stage 1, player A do not commit himself to leaving a 50% share of revenues to Player C ;
- In stage 2, player C chooses to not invest;
- In stage 3, player A chooses to leave 85% of the revenues to player C; Player B chooses to leave 55% of the revenues to player C;
- In stage 4, player C selects player A.

The gain of player A for this period is 19€. The gain of player B for this period is 2€.

Information received by the players at the end of each period At the end of each period, the screen displays the amount of the player's gain for this period. Each player learns only his gain for the current period; the gains of the other players are not displayed.

The screen also displays the decisions taken by all players during the period: the three players in each group are reminded of the choices of player C in stage 2 and in stage 4, the choice of player A in stage 1 and in stage 3 and the choice of player B in stage 3.

Please read these instructions carefully. Before starting phase 1 of this experiment, you will answer a few questions about these instructions. As soon as you will have correctly answered these questions, we will be able to start.

Thanks for your participation!

Questions about the instructions

Please answer the following questions about the instructions

- At the beginning of each period, groups of three participants consisting of one player A, one player B and one player C are constituted.
TRUE FALSE
- A player A and a player B can be part of the same group several times during a given phase.
TRUE FALSE
- A player A and a player C can be part of the same group several times during a given phase.
TRUE FALSE
- A phase consists of 10 periods.
TRUE FALSE
- At the end of the experiment, one period among the 20 periods played is randomly drawn. Each participant will receive as a payment for the experiment the amount of his gains for this period, plus the participation fee of 5€.
TRUE FALSE
- At each period, the three players of one group learn their own gains and the gains of the two other players of their group.
TRUE FALSE
- If player A chose to commit himself to leaving player C a 50% revenue share in stage 1, he may change this decision in stage 3.
TRUE FALSE

Example 1. Suppose that:

- *In stage 1, player A chooses to commit himself to leaving a 50% share of revenues to player C.*
- *In stage 2, player C chooses to not invest;*
- *In stage 3, player A has no decision to make because he committed himself in stage 1 to leaving a 50% share of revenues to player C ; player B chooses to leave 90% of the revenues to player C;*
- *In stage 4, player C selects player B.*

What is the gain of player A ? _____

What is the gain of player B ? _____

What is the gain of player C ? _____

Example 2. Suppose that:

- *In stage 1, player A choose to not commit himself to leaving a 50% share of revenues to player C.*
- *In stage 2, player C chooses to invest;*

- In stage 3, player A chooses to leave 70% of the revenues to player C; player B chooses to leave 80% of the revenues to player C;
- In stage 4, player C selects player A.

What is the gain of player A ? _____

What is the gain of player B ? _____

What is the gain of player C ? _____

Phase 2

The instructions for phase 2 are identical to the instructions for phase 1, except for the computation of the gains of players A and B. For the record, these instructions detail the proceedings of each period. As only the computation of the gains of players A and B differs from that in phase 1, we will read this part only together. It corresponds to the text written in blue.

You keep the same role than in phase 1 of the experiment. All your decisions are anonymous.

This phase is independent from phase 1. This phase consists in ten periods. We describe below the proceedings of phase 2.

Description of each period As in phase 1, at the beginning of each period, groups of three players are composed with one player A, one B and one C. These three players will interact throughout the period. The interactions of these three players create revenues. All the groups are anonymous: you will not know with whom you are playing.

During the ten periods of phase 2, players A and B interact only once: it is not possible that players A and B interact once more in phase 2. Players C are randomly affected to a player A and a player B: it is possible that a player C interacts several times with a player A or a player B but it is not automatic.

As in phase 1, inside each group of three participants, each period consists in four stages:

- In stage 1, player A makes a decision. He chooses either to commit himself or to not commit himself to leaving a 50% revenue share to player C. He must choose among the following two options:
 - "I commit myself to leaving a 50% revenue share" or
 - "I do not commit myself".

If player A chooses to commit himself, he has no decision to make in stage 3. If he chooses to not commit himself, he has a decision to make in stage 3.

- In stage 2, the choice of player A made in stage 1 is revealed to player C. Player C makes a first decision. He must choose between two options:
 - "Invest" or
 - "Not invest".
- In stage 3, the choices of player A in stage 1 and of player C in stage 2 are revealed to players A and B. Player A makes his decision if he chose not to commit himself in stage 1 (and has no decision to make otherwise). Player B makes his decision. When player A and B make a decision, they make it simultaneously and without

consulting each other. Each of them must choose one among the following nine options, which correspond to a percentage of the total revenues they plan to leave to player C:

- 50% or
- 55% or
- 60% or
- 65% or
- 70% or
- 75% or
- 80% or
- 85% or
- 90%.

- In stage 4, the choices of players A and B in stage 2 are revealed to player C. Player C makes his decision. He must choose one of the two players A and B :

- "Player A " or
- " Player B" .

How are the gains of each player computed in each period ?

The gains of players A, B and C at each period depend on the choices of each of them. All the amounts reported in the following tables are in Euros.

Gains of player C

- The gain of player C is computed as in phase 1.
- The gain of player C depends on his investment decision and on the percentage of the revenues that will be left to him subsequently.
- This percentage of the revenues corresponds to the percentage of the revenues offered by the player A or B selected by player C in stage 4.

The gain of player C in each situation is displayed in the following table (this table is the same than in phase 1):

Gains of C

Percentage of revenues left to C		50%	55%	60%	65%	70%	75%	80%	85%	90%
Choice of C	Not invest	10	12	13	14	16	17	19	20	22
	Invest	1	5	8	12	16	20	23	27	31

Gains of players A and B The gains of players A and B are computed differently in phase 2 compared to phase 1. The gains of players A and B depend from the percentage of the revenues that they offer to leave to player C and from the choices of player C (to invest or not, and player A or B).

- If player C chooses the offer of player A in stage 4:
 - The gains of player A in each situation are displayed in the following table (this table is not the same than in phase 1);
 - The gain of player B is 2€.
- If player C chooses the offer of player B in stage 4:
 - The gains of player B in each situation are displayed in the following table (this table is not the same than in phase 1);
 - The gain of player A is 2€.

Gains of A and B

Percentage of revenues left to C		50%	55%	60%	65%	70%	75%	80%	85%	90%
Choice of C	Not invest	15	13	12	10	9	7	6	4	3
	Invest	37	33	30	26	22	19	15	11	7

In addition to the amount displayed above, player A also receives a guaranteed amount that depends on the investment choice made by C. Whether player C selects A or B in stage 4, player A is certain to receive this guaranteed amount. This guaranteed amount is displayed in the following table:

Additional payoff for A

		Guaranteed amount
Choice of C	Not invest	52
	Invest	29

Example. Suppose that:

- In stage 1, player A chooses to not commit himself to leaving a 50% revenue share to player C;
- In stage 2, player C chooses to not invest;
- In stage 3, player A chooses to let a 85% share of revenue to player C; player B chooses to leave 55% share of the revenues to player C;
- In stage 4, player C selects player A.

The gain of player A is 4€+ 52€= 56€. The gain of player B is 2€.

Information received by the players at the end of each period As in phase 1, at the end of each period, the screen displays the amount of the player's gain for this period. Each player learns only his gain for the current period; the gains of the other players are not displayed.

The screen also displays the decisions taken by all players during the period: the three players in each group are reminded of the choices of player C in stage 2 and in stage 4, the choice of player A in stage 1 and in stage 3 and the choice of player B in stage 3.

Please read these instructions carefully. Before starting phase 2 of this experiment, you will answer a few questions about these instructions. As soon as you will have correctly answered these questions, we will be able to start.

Questions about the instructions

Please answer the following questions about the instructions

- The table of the gains of player A, apart from the guaranteed amount, is the same as in phase 1.
TRUE FALSE
- The table of the gains of player B is the same as in phase 1.
TRUE FALSE
- The table of the gains of player C is the same as in phase 1.
TRUE FALSE
- The guaranteed amount is received by player A and player B.
TRUE FALSE
- Player A receives a guaranteed amount only if he is chosen by C in stage 4.
TRUE FALSE
- The guaranteed amount received by player A depends on the investment choice by player C in stage 2.
TRUE FALSE
- If player A chose to commit himself to leaving player C a 50% revenue share in stage 1, he may change this decision in stage 3.
TRUE FALSE

Example. Suppose that:

- *In stage 1, player A chooses to commit himself to leaving a 50% revenue share to player C;*
- *In stage 2, player C chooses to not invest;*
- *In stage 3, player A has no decision to make because he committed himself to let a 50% share of revenue to player C; player B chooses to leave 90% share of the revenues to player C;*
- *In stage 4, player C selects player B.*

What is the gain of player A ? _____

What is the gain of player B ? _____

What is the gain of player C ? _____

Example 2. Suppose that:

- *In stage 1, player A choose to not commit himself to leaving a 50% share of revenues to player C.*
- *In stage 2, player C chooses to invest;*
- *In stage 3, player A chooses to leave 70% of the revenues to player C; player B chooses to leave 80% of the revenues to player C;*
- *In stage 4, player C selects player A.*

What is the gain of player A ? _____

What is the gain of player B ? _____

What is the gain of player C ? _____

A.3 Instructions for the Sabotage treatment

The following displays the english translation of the instructions handed out and read to the subjects participating in the Sabotage treatment.

Instructions Sabotage (english translation)

You are about to participate to an experiment on decision-making. This experiment is realized jointly by the Econometrics Laboratory at Ecole Polytechnique, Toulouse School of Economics, and the INRA-ALISS Laboratory. During this session, you will be able to earn money. How much you will earn will depend on your decisions and also on the decisions taken by other participants with whom you will be interacting. In addition to this amount you will also receive a participation fee of 5 Euros. Your earnings will be paid cash at the end of the experiment, in a separate room for confidentiality reasons.

During the experiment, you have been randomly assigned to two separate rooms. Because there are many of you, in total 30 participants, we had to allocate you into two rooms. This allocation is purely random and has no relation to the decisions you have to make during the experiment. During the experiment you will have to interact with other participants in the same room as well as participants in the other room.

These instructions explain in detail what are the decision-making tasks you will have to make during the experiment, and how your payment is going to be computed. All the participants receive the same instructions, irrespective of the room they are allocated to.

The decisions you make during the experiment are anonymous.

If you have questions about the instructions, please raise your hand. We will answer your questions privately. Along the session, it is prohibited to communicate with each other, subject to being excluded from the session and not receiving any payment. We also require that you do not use your mobile phones.

Proceedings of the experiment

At the beginning of this experiment, you will be attributed a role that you will keep throughout the experiment. The computer program assigns these roles randomly. 10 participants will be assigned the role A, 10 the role B and 10 the role C. You will participate to two phases of 10 periods each. You will keep the same role for all the periods of the experiment. You will thus keep the same role for these two phases.

We present first the proceedings of the first phase. Once the first phase will be over, we will give you the instructions for the second phase. The two phases are independent from each other. At the end of the experiment, one period among the twenty periods will be randomly drawn by the computer; this will determine your payments for the experiment.

Phase 1

This phase consists in ten periods. All your decisions are anonymous. We describe below the proceedings of phase 1.

Description of each period At the beginning of each period, groups of three players are composed with one player A, one B and one C. These three players will interact throughout the period. The interactions of these three players create revenues. All the groups are anonymous: you will not know with whom you are playing.

During the ten periods of phase 1, players A and B interact only once: it is not possible that players A and B interact once more in phase 1. Players C are randomly affected to a player A and a player B: it is possible that a player C interacts several times with a player A or a player B but it is not automatic.

Inside each group of three participants, each period is composed of four stages:

- In stage 1, player C makes a first decision. He must choose between two options:
 - “Invest” or
 - “Not invest”.
- In stage 2, the choice of player C in stage 1 is revealed to players A and B. Players A and B make their decisions, simultaneously and without consulting each other. Each of them must choose one among the following nine options, which correspond to a percentage of the total revenues they plan to leave to player C:
 - 50% or
 - 55% or
 - 60% or
 - 65% or
 - 70% or
 - 75% or
 - 80% or

- 85% or
- 90%.
- In stage 3, the choices of players A and B in stage 2 are revealed to player C. Player C makes a second decision. He must choose one of the two players A and B :
 - "Player A " or
 - " Player B" .
- In stage 4, the choice made by player C in stage 3 is revealed to players A and B. If player C has chosen player B in stage 3, no player makes any decision in stage 4. If player C has chosen player A in stage 3, player A has to make a decision. He must choose between two options:
 - "Use the option S " or
 - "Not use the option S "

How are the gains of each player computed in each period ?

The gains of players A, B and C at each period depend on the choices of all of them. All the amounts reported in the following tables are in euros.

Gains of player C The gains of player C depend on his investment decision and on the percentage of the revenues that will be left to him subsequently. This percentage of the revenues corresponds to the percentage of the revenues offered by the player A or B selected by player C in stage 3. If player C has chosen player A, his gains also depend from the choice made by player A in stage 4 to adopt or not the option S .

- If player C chooses player B in stage 3, the gains of player C in each situation are displayed in the following table:

Gains of C

Percentage of revenues left to C		50%	55%	60%	65%	70%	75%	80%	85%	90%
Choice of C	Not invest	10	12	13	14	16	17	19	20	22
	Invest	1	5	8	12	16	20	23	27	31

- If player C chooses player A in stage 3 :
 - The gains of player C in each situation are also displayed in the above table whenever player A chooses not to use the option S ;
 - The gains of player C are displayed in the following table whenever player A chooses to use the option S .

Gains of player C

		If A chooses the option \mathcal{S}	
Choice of C	Not invest		11
	Invest		3

Example: suppose that

- In stage 1, player C chooses to not invest;
- In stage 2, player A chooses to leave 85% of the revenues to player C; Player B chooses to leave 55% of the revenues to player C ;
- In stage 3, player C selects player A.
- In stage 4, player A chooses not to use the option \mathcal{S} .

The gain of player C for this period is 20€.

Gains of players A and B The gains of players A and B depend on the percentage of the revenues that they offer to leave to player C and on the choices of player C (to invest or not, and player A or B).

- If player C chooses the offer of player A in stage 3,
 - The gains of player A depend on his choice to use or not the option \mathcal{S} in stage 4 :
 - * If player A chooses not to use the option \mathcal{S} , his gains in each situation are displayed in the following table;
 - * If player A chooses to use the option \mathcal{S} , it costs him 5€. His gains in each situation are the ones displayed in the following table minus 5€.
 - The gain of player B is 2€.
- If player C chooses the offer of player B in stage 3:
 - The gains of player B in each situation are displayed in the following table;
 - The gain of player A is 2€.

Gains of A or B

Percentage of revenues left to C		50%	55%	60%	65%	70%	75%	80%	85%	90%
Choice of C	Not invest	63	57	50	44	38	32	25	19	13
	Invest	74	67	59	52	44	37	30	22	15

Example. Suppose that:

- In stage 1, player C chooses to not invest;
- In stage 2, player A chooses to leave 85% of the revenues to player C; Player B chooses to leave 55% of the revenues to player C;
- In stage 3, player C selects player A.
- In stage 4, player A chooses not to use the option S .

The gain of player A for this period is 19€. The gain of player B for this period is 2€.

Information received by the players at the end of each period At the end of each period, the screen displays the amount of the player's gain for this period. Each player learns only his gain for the current period; the gains of the other players are not displayed.

The screen also displays the decisions taken by all players during the period: the three players in each group are reminded the choices of player C in stage 1 and in stage 3, the choices of players A and B in stage 2 and the choice of player A in stage 4 whenever player A has been selected by player C in stage 3.

Please read these instructions carefully. Before starting phase 1 of this experiment, you will answer a few questions about these instructions. As soon as you will have correctly answered these questions, we will be able to start.

Thanks for your participation!

Questions about the instructions

Please answer the following questions about the instructions

- At the beginning of each period, groups of three participants consisting of one player A, one player B and one player C are constituted.
TRUE FALSE
- A player A and a player B can be part of the same group several times during a given phase.
TRUE FALSE
- A player A and a player C can be part of the same group several times during a given phase.
TRUE FALSE
- A phase consists of 10 periods.
TRUE FALSE
- At the end of the experiment, one period among the 20 periods played is randomly drawn. Each participant will receive as a payment for the experiment the amount of his gains for this period, plus the participation fee of 5€.
TRUE FALSE
- At each period, the three players of one group learn their own gains and the gains of the two other players of their group.
TRUE FALSE
- The gains of player A are reduced by 5€ if he chooses to use the option S .
TRUE FALSE

Example 1. Suppose that:

- In stage 1, player C chooses to not invest;
- In stage 2, player A chooses to leave 50% of the revenues to player C; player B chooses to leave 90% of the revenues to player C;
- In stage 3, player C selects player B.
- In stage 4, no player makes a decision because player C has chosen player B in stage 3.

What is the gain of player A ? _____

What is the gain of player B ? _____

What is the gain of player C ? _____

Example 2. Suppose that:

- In stage 1, player C chooses to invest;
- In stage 2, player A chooses to leave 70% of the revenues to player C; player B chooses to leave 80% of the revenues to player C;
- In stage 3, player C chooses player A.
- In stage 4, player A chooses to use the option S .

What is the gain of player A ? _____

What is the gain of player B ? _____

What is the gain of player C ? _____

Phase 2

The instructions for phase 2 are identical to the instructions for phase 1, except for the computation of the gains of players A and B. For the record, these instructions detail the proceedings of each period. As only the computation of the gains of players A and B differs from that in phase 1, we will read this part only together. It corresponds to the text written in blue.

You keep the same role than in phase 1 of the experiment. All your decisions are anonymous.

This phase is independent from phase 1. This phase consists in ten periods. We describe below the proceedings of phase 2.

Description of each period As in phase 1, at the beginning of each period, groups of three players are composed with one player A, one B and one C. These three players will interact throughout the period. The interactions of these three players create revenues. All the groups are anonymous: you will not know with whom you are playing.

During the ten periods of phase 2, players A and B interact only once: it is not possible that players A and B interact once more in phase 2. Players C are randomly affected to a player A and a player B: it is possible that a player C interacts several times with a player A or a player B but it is not automatic.

As in phase 1, inside each group of three participants, each period consists in four stages:

- In stage 1, player C makes a first decision. He must choose between two options:
 - "Invest" or
 - "Not invest".

- In stage 2, the choice of player C in stage 1 is revealed to players A and B. Players A and B make their decisions, simultaneously and without consulting each other. Each of them must choose one among the following nine options, which correspond to a percentage of the total revenues they plan to leave to player C:
 - 50% or
 - 55% or
 - 60% or
 - 65% or
 - 70% or
 - 75% or
 - 80% or
 - 85% or
 - 90%.

- In stage 3, the choices of players A and B in stage 2 are revealed to player C. Player C makes a second decision. He must choose one of the two players A and B :
 - "Player A " or
 - " Player B" .
- In stage 4, the choice made by player C in stage 3 is revealed to players A and B. If player C has chosen player B in stage 3, no player makes any decision in stage 4. If player C has chosen player A in stage 3, player A has to make a decision. He must choose between two options:
 - " Use the option S " or
 - " Not use the option S "

How are the gains of each player computed in each period ?

The gains of players A, B and C at each period depend on the choices of each of them. All the amounts reported in the following tables are in Euros.

Gains of player C

- The gain of player C is computed as in phase 1.
- The gain of player C depends on his investment decision and on the percentage of the revenues that will be left to him subsequently.
- This percentage of the revenues corresponds to the percentage of the revenues offered by the player A or B selected by player C in stage 3.
- If player C has chosen player A, his gains also depend from the choice made by player A in stage 4 to adopt or not the option S .

If player C chooses player B in stage 3, the gain of player C in each situation is displayed in the following table (this table is the same than in phase 1):

Gains of C

Percentage of revenues left to C		50%	55%	60%	65%	70%	75%	80%	85%	90%
Choice of C	Not invest	10	12	13	14	16	17	19	20	22
	Invest	1	5	8	12	16	20	23	27	31

If player C chooses player A in stage 3 :

- The gains of player C in each situation are also displayed in the above table whenever player A chooses not to use the option S ;
- The gains of player C are displayed in the following table whenever player A chooses to use the option S .

Gains of player C

If A chooses the option \mathcal{S}		
Choice of C	Not invest	11
	Invest	3

Gains of players A and B The gains of players A and B are computed differently in phase 2 compared to phase 1. The gains of players A and B depend from the percentage of the revenues that they offer to leave to player C and from the choices of player C (to invest or not, and player A or B).

- If player C chooses the offer of player A in stage 3:
 - The gain of player A depend on his choice to use or not the option \mathcal{S} in stage 4:
 - * If player A chooses not to use the option \mathcal{S} , his gains in each situation are displayed in the following table (this table is not the same as in phase 1) ;
 - * If player A chooses to use the option \mathcal{S} , this brings him a gain of 5€. His gains in each situation are those displayed in the following table plus 5€.
 - The gain of player B is 2€.
- If player C chooses the offer of player B in stage 3:
 - The gains of player B in each situation are displayed in the following table (this table is not the same than in phase 1);
 - The gain of player A is 2€.

Gains of A and B

Percentage of revenues left to C		50%	55%	60%	65%	70%	75%	80%	85%	90%
Choice of C	Not invest	15	13	12	10	9	7	6	4	3
	Invest	37	33	30	26	22	19	15	11	7

In addition to the amount displayed above, player A also receives a guaranteed amount that depends on the investment choice made by C. Whether player C selects A or B in stage 3, player A is certain to receive this guaranteed amount. This guaranteed amount is displayed in the following table:

Additional payoff for A

Guaranteed amount		
Choice of C	Not invest	52
	Invest	29

Example. Suppose that:

- *In stage 1, player C chooses to not invest;*
- *In stage 2, player A chooses to leave 85% of the revenues to player C; player B chooses to leave 55% of the revenues to player C;*
- *In stage 3, player C selects player A.*
- *In stage 4, player A chooses not to use the option S.*

The gain of player A for this period is $4\text{€} + 52\text{€} = 56\text{€}$. The gain of player B for this period is 2€ .

Information received by the players at the end of each period As in phase 1, at the end of each period, players learn on the screen the amount of their gain for this period. Each player learns only his gain for the current period and the gain of the other players is not displayed.

The screen also displays the decisions taken by all players during the period: the three players in each group are reminded the choices of player C in stage 1 and in stage 3, the choices of players A and B in stage 2 and the choice of player A in stage 4 whenever player A has been selected by player C in stage 3.

Please read these instructions carefully. Before starting phase 2 of this experiment, you will answer a few questions about these instructions. As soon as you will have correctly answered these questions, we will be able to start.

Questions about the instructions

Please answer the following questions about the instructions

- The table of the gains of player A, apart from the guaranteed amount, is the same as in phase 1.
TRUE FALSE
- The table of the gains of player B is the same as in phase 1.
TRUE FALSE
- The table of the gains of player C is the same as in phase 1.
TRUE FALSE
- The guaranteed amount is received by player A and player B.
TRUE FALSE
- Player A receives a guaranteed amount only if he is chosen by C in stage 3.
TRUE FALSE
- The guaranteed amount received by player A depends on the investment choice by player C in stage 1.
TRUE FALSE
- The gains of player A are reduced by 5€ if he chooses to use the option S .
TRUE FALSE

Example 1. suppose that:

- In stage 1, player C chooses to not invest;
- In stage 2, player A chooses to leave 50% of the revenues to player C; player B chooses to leave 90% of the revenues to player C;
- In stage 3, player C selects player B.
- In stage 4, no player makes any decision because player C has chosen player B in stage 3.

What is the gain of player A ? _____

What is the gain of player B ? _____

What is the gain of player C ? _____

Example 2. Suppose that:

- In stage 1, player C chooses to invest;
- In stage 2, player A chooses to leave 70% of the revenues to player C; player B chooses to leave 80% of the revenues to player C;
- In stage 3, player C chooses player A.
- In stage 4, player A chooses to use the option S .

What is the gain of player A ? _____

What is the gain of player B ? _____

What is the gain of player C ? _____

B Level- k theory

For simplicity, we assume that, for any level $k \geq 1$, every player believes that all the other players are of level $k - 1$. We also assume that, when indifferent between several actions, players randomly choose every of these actions with equal probability.

B.1 The Commitment game

B.1.1 Level-0

Players play randomly:

- In stage 0, U_A commits himself to offering the lowest share with probability $1/2$.
- In stage 1, D_2 invests with probability $1/2$.
- In stage 2, U_A (if not committed) and U_B each select any of the 9 possible sharing-rules with probability $1/9$.
- In stage 3, D_2 selects each supplier with equal probability.

B.1.2 Level-1

From level-1 on, D_2 selects in stage 3 the supplier offering the larger share. From now on, we thus focus on the first three stages.

Stage 2. Suppliers anticipate a random selection by a level-0 D_2 , and thus seek to offer the sharing rule that grants them the highest revenue; hence, U_A (even if not committed) and U_B both offer 50%.

Stage 1. If U_A has not committed himself in stage 0, D_2 anticipates that both level-0 suppliers will offer a randomly chosen sharing rule. The probabilities that the best offer is a given sharing rule are presented in Table 28.

Table 28: Level-1, probability of receiving s as best offer

s	50%	55%	60%	65%	70%	75%	80%	85%	90%
Probability	$\frac{1}{81}$	$\frac{3}{81}$	$\frac{5}{81}$	$\frac{7}{81}$	$\frac{9}{81}$	$\frac{11}{81}$	$\frac{13}{81}$	$\frac{15}{81}$	$\frac{17}{81}$

Given these probabilities, D_2 invests:

- not investing would yield an expected payoff equal to

$$\frac{10 + 3 \times 12 + 5 \times 13 + 7 \times 14 + 9 \times 16 + 11 \times 17 + 13 \times 19 + 15 \times 20 + 17 \times 22}{81} = \frac{1461}{81};$$

- by investing, she obtains instead

$$\frac{1 + 3 \times 5 + 5 \times 8 + 7 \times 12 + 9 \times 16 + 11 \times 20 + 13 \times 23 + 15 \times 27 + 17 \times 31}{81} = \frac{1735}{81} > \frac{1461}{81}.$$

If instead U_A has committed himself in stage 0, then D_2 anticipates that the best offer will be that of level-0 U_B , which can be any share with equal probability; her expected profit is then the same, whether she invests or not:

- if she does not invest, her expected payoff is given by

$$\frac{10 + 12 + 13 + 14 + 16 + 17 + 19 + 20 + 22}{9} = \frac{143}{9};$$

- if she invests, her expected payoff is equal to

$$\frac{1 + 5 + 8 + 12 + 16 + 20 + 23 + 27 + 31}{9} = \frac{143}{9}.$$

She thus invests randomly.

Stage 0. U_A anticipates a random supplier selection by a level-0 D_2 and thus wants to offer 50% but is indifferent between doing so in stage 2 or in stage 0; U_A thus commits himself to offering the lowest share with probability 1/2.

Recap. Under both VS and VI:

- Stage 0. U_A commits himself with probability 1/2.
- Stage 1. D_2 invests with probability 1 if U_A did not commit, and with probability 1/2 otherwise.
- Stage 2. Regardless of D_2 's investment, U_A (even if not already committed to doing so) and U_B (regardless of U_A 's commitment decisions) both offer 50%.

B.1.3 Level-2

From level-2 on, suppliers expect D_2 to select the larger share in stage 3.

Stage 2. Absent commitment, each supplier expects his level-1 rival to offer 50% no matter what; hence, the relevant choice is between offering 50% or 55% (which suffices to be selected for sure). Furthermore:

- Under VS, the gains from offering 55% are 67 in case of investment and 57 otherwise; the expected gains from offering 50% are instead respectively equal to:

$$\frac{1}{2} \times 74 + \frac{1}{2} \times 2 = 38 < 67 \text{ and } \frac{1}{2} \times 63 + \frac{1}{2} \times 2 = 32.5 < 57.$$

- Under VI (and ignoring the gain obtained through $D1$, which is fixed at this stage), the expected gains from offering 55% are 33 in case of investment and 13 otherwise; the expected gains from offering 50% are instead respectively equal to:

$$\frac{1}{2} \times 37 + \frac{1}{2} \times 2 = 19.5 < 33 \text{ and } \frac{1}{2} \times 15 + \frac{1}{2} \times 2 = 8.5 < 13;$$

It follows that offering 55% is the best response, under both VS and VI, and regardless of the investment decision.

Stage 1. D_2 never invests, as she anticipates that the level-1 suppliers will not offer more than 50%.

Stage 0. U_A expects the level-1 D_2 to invest with probability $1/2$ in case of commitment and with probability 1 otherwise, and the level-1 U_B to offer 50%, regardless of D_2 's investment and of his own commitment decision.

Therefore, under VS:

- In the absence of commitment, U_A expects D_2 to invest and select his offered share of 55%; the associated gain is equal to 67.
- Under commitment, U_A expects D_2 to invest with probability $1/2$ and select his offered share of 50% with probability $1/2$; the associated expected gain is equal to:

$$\frac{1}{2} \times \left(\frac{1}{2} \times 74 + \frac{1}{2} \times 2 \right) + \frac{1}{2} \times \left(\frac{1}{2} \times 63 + \frac{1}{2} \times 2 \right) = 35.25 < 67.$$

Likewise, under VI:

- In the absence of commitment, U_A expects again D_2 to invest and select his offered share of 55%; the associated gain (including that of $D1$) is now equal to $33 + 29 = 62$.
- Under commitment, U_A expects again D_2 to invest with probability $1/2$ and select his offered share of 50% with probability $1/2$; the associated expected gain is now equal to:

$$\frac{1}{2} \times \left(29 + \frac{1}{2} \times 37 + \frac{1}{2} \times 2 \right) + \frac{1}{2} \times \left(52 + \frac{1}{2} \times 15 + \frac{1}{2} \times 2 \right) = 54.5 < 62.$$

It follows that U_A never commits himself to offering 50%.

Recap. Under both VI and VS:

- In stage 0, U_A does not commit himself.
- In stage 1, D_2 never invests, regardless of U_A 's commitment decision.
- In stage 2, regardless of D_2 's investment, U_A (if not committed) and U_B (regardless of U_A 's commitment decision) always offer 55%.

B.1.4 Level-3

Stage 2. In case of commitment, the same reasoning as before (for level-2) implies that, from level-3 on, U_B always offers 55%, regardless of U_A 's commitment and D_2 's investment decisions.

Absent commitment, each supplier expects his level-2 rival to offer 55%; hence, offering more than 60% or less than 55% constitute dominated strategies. Furthermore:

- Under VS, the expected gains from offering 60% are 59 in case of investment and 50 otherwise; the expected gains from offering 55% are instead, respectively:

$$\frac{1}{2} \times 67 + \frac{1}{2} \times 2 = 34.5 < 59 \text{ and } \frac{1}{2} \times 57 + \frac{1}{2} \times 2 = 29.5 < 50.$$

- Under VI, the expected gains from offering 60% are 30 in case of investment and 12 otherwise; the expected gains from offering 55% are instead, respectively:

$$\frac{1}{2} \times 33 + \frac{1}{2} \times 2 = 17.5 < 30 \text{ and } \frac{1}{2} \times 13 + \frac{1}{2} \times 2 = 7.5 < 12.$$

It follows that offering 60% is the best response, under both VS and VI, and regardless of the investment decision.

Stage 1. D_2 does not invest: regardless of the commitment decision, D_2 anticipates that level-2 suppliers will never offer more than 55%; hence, she does not invest.

Stage 0. U_A expects the level-2 D_2 to never invest and the level-2 U_B to always offer 55%; committing to offering 50% would therefore have no impact on the investment decision but prevent U_A from competing for D_2 (and for D_1 under VS); as losing the competition for support yields the lowest possible upstream payoff (namely, 2), it follows that U_A does not commit himself.

Recap. Under both VS and VI:

- In stage 0, U_A does not commit himself.
- In stage 1, D_2 never invests, regardless of U_A 's commitment decision.
- In stage 2, regardless of D_2 's investment, U_A and U_B offer 60% in the absence of commitment, otherwise U_B offers 55%.

B.1.5 Level-4

Stage 2. U_B offers 55% in case of commitment. In the absence of commitment, each supplier expects his level-3 rival to offer 60%; offering more than 65% or less than 60% thus constitute dominated strategies. Furthermore:

- Under VS, the expected gains from offering 65% are 52 in case of investment and 44 otherwise; the expected gains from offering 60% are instead respectively equal to:

$$\frac{1}{2} \times 59 + \frac{1}{2} \times 2 = 30.5 < 52 \text{ and } \frac{1}{2} \times 50 + \frac{1}{2} \times 2 = 26 < 44.$$

- Under VI, the expected gains from offering 65% are 26 in case of investment and 10 otherwise; the expected gains from offering 60% are instead, respectively:

$$\frac{1}{2} \times 30 + \frac{1}{2} \times 2 = 16 < 26 \text{ and } \frac{1}{2} \times 12 + \frac{1}{2} \times 2 = 7 < 10.$$

It follows that offering 65% is the best response, under both VS and VI, and regardless of the investment decision.

Stage 1. D_2 never invests, regardless of the commitment decision, as she anticipates that level-3 suppliers will not offer more than 60%.

Stage 0. U_A expects the level-3 D_2 to never invest and the level-3 U_B to offer 55% in case of commitment and 60% otherwise; committing himself would therefore have no impact on the investment decision but prevent U_A from competing for D_2 (and for D_1 under VS); it follows that U_A does not commit.

Recap. Under both VS and VI:

- In stage 0, U_A does not commit himself.
- In stage 1, D_2 never invests, regardless of U_A 's commitment decision.
- In stage 2, regardless of D_2 's investment, U_A and U_B offer 65% in the absence of commitment, otherwise U_B offers 55%;

B.1.6 Level-5

Stage 2. U_B offers 55% in case of commitment. In the absence of commitment, each supplier expects his level-4 rival to offer 65%; hence, offering more than 70% or less than 65% constitute dominated strategies. Furthermore:

- Under VS, the expected gains from offering 70% are 44 in case of investment and 38 otherwise; the expected gains from offering 65% are instead respectively equal to:

$$\frac{1}{2} \times 52 + \frac{1}{2} \times 2 = 27 < 44 \text{ and } \frac{1}{2} \times 44 + \frac{1}{2} \times 2 = 23 < 38.$$

- Under VI, the expected gains from offering 70% are 22 in case of investment and 9 otherwise; the expected gains from offering 65% are instead, respectively:

$$\frac{1}{2} \times 26 + \frac{1}{2} \times 2 = 14 < 22 \text{ and } \frac{1}{2} \times 10 + \frac{1}{2} \times 2 = 6 < 9.$$

It follows that offering 70% is the best response, under both VS and VI, and regardless of the investment decision.

Stage 1. D_2 never invests, regardless of the commitment decision, as she anticipates that level-4 suppliers will not offer more than 65%.

Stage 0. U_A expects the level-4 D_2 to never invest and the level-4 U_B to offer 55% in case of commitment and 65% otherwise; committing himself would therefore have no impact on the investment decision but prevent U_A from competing; it follows that U_A does not commit.

Recap. Under both VS and VI:

- In stage 0, U_A does not commit himself.
- In stage 1, D_2 never invests, regardless of U_A 's commitment decision.
- In stage 2, regardless of D_2 's investment, U_A and U_B offer 70% in the absence of commitment, otherwise U_B offers 55%;

B.1.7 Level-6

Stage 2. U_B offers 55% in case of commitment. In the absence of commitment, each supplier expects his level-5 rival to offer 70%; hence, offering more than 75% or less than 70% constitute dominated strategies. Furthermore:

- Under VS, the expected gains from offering 75% are 37 in case of investment and 32 otherwise; the expected gains from offering 70% are instead, respectively:

$$\frac{1}{2} \times 44 + \frac{1}{2} \times 2 = 23 < 37 \text{ and } \frac{1}{2} \times 38 + \frac{1}{2} \times 2 = 20 < 32.$$

- Under VI, the expected gains from offering 75% are 19 in case of investment and 7 otherwise; the expected gains from offering 70% are instead, respectively:

$$\frac{1}{2} \times 22 + \frac{1}{2} \times 2 = 12 < 19 \text{ and } \frac{1}{2} \times 9 + \frac{1}{2} \times 2 = 5.5 < 7.$$

It follows that offering 75% is the best response, under both VS and VI, and regardless of the investment decision.

Stage 1. Absent commitment, D_2 anticipates that level-5 suppliers will offer 70%, and is thus indifferent between investing or not; hence, she invests with probability 1/2. In case of commitment, D_2 anticipates that the level-5 U_B will offer 55%, and thus does not invest.

Stage 0. U_A expects the level-5 D_2 to never invest and the level-5 U_B to offer 55% in case of commitment and 70% otherwise; committing would therefore have no impact on the investment decision but prevent U_A from competing; it follows that U_A does not commit.

Recap. Under both VS and VI:

- In stage 0, U_A does not commit himself.
- In stage 1, D_2 invests with probability $1/2$ in the absence of commitment, otherwise she does not invest.
- In stage 2, regardless of D_2 's investment, U_A and U_B offer 75% in the absence of commitment, otherwise U_B offers 55%.

B.1.8 Level-7

Stage 2. U_B offers 55% in case of commitment. In the absence of commitment, each supplier expects his level-6 rival to offer 75%; hence, offering more than 80% or less than 75% constitute dominated strategies. Furthermore:

- Under VS, the expected gains from offering 80% are 30 in case of investment and 25 otherwise; the expected gains from offering 75% are instead, respectively:

$$\frac{1}{2} \times 37 + \frac{1}{2} \times 2 = 19.5 < 30 \text{ and } \frac{1}{2} \times 32 + \frac{1}{2} \times 2 = 17 < 25.$$

- Under VI, the expected gains from offering 80% are 15 in case of investment and 6 otherwise; the expected gains from offering 75% are instead, respectively:

$$\frac{1}{2} \times 19 + \frac{1}{2} \times 2 = 10.5 < 15 \text{ and } \frac{1}{2} \times 7 + \frac{1}{2} \times 2 = 4.5 < 6.$$

It follows that offering 80% is the best response, under both VS and VI, and regardless of the investment decision.

Stage 1. In the absence of commitment, D_2 anticipates that level-6 suppliers will offer 75%, and thus invests. In case of commitment, D_2 anticipates that level-6 U_B will offer 55%, and thus does not invest.

Stage 0. U_A expects the level-6 U_B to offer 55% in case of commitment and 75% otherwise. Hence, under VS, U_A does not commit himself, as this would prevent him from competing.

Under VI, if he commits, U_A expects the level-6 D_2 not to invest, and to select U_B ; the expected gain is $52 + 2 = 54$. In the absence commitment, U_A expects the level-6 D_2 to invest with probability $1/2$ and accept his offered share of 80%; the expected gain is therefore:

$$\frac{1}{2} \times (29 + 15) + \frac{1}{2} \times (52 + 6) = 51 < 54.$$

It follows that U_A commits himself under VI.

Recap.

- In stage 0, U_A does not commit himself under VS, but does so under VI.
- In stage 1, under both VS and VI, D_2 invests in the absence of commitment, otherwise she does not invest.
- In stage 2, under both VS and VI, and regardless of D_2 's investment, U_A and U_B offer 80% in the absence of commitment, otherwise U_B offers 55%.

B.1.9 Level-8

Stage 2. U_B offers 55% in case of commitment. In the absence of commitment, each supplier expects his level-7 rival to offer 80%; hence, offering more than 85% or less than 80% constitute dominated strategies. Furthermore:

- Under VS, the expected gains from offering 85% are 22 in case of investment and 19 otherwise; the expected gains from offering 80% are instead, respectively:

$$\frac{1}{2} \times 30 + \frac{1}{2} \times 2 = 16 < 22 \text{ and } \frac{1}{2} \times 25 + \frac{1}{2} \times 2 = 13.5 < 19.$$

- Under VI, the expected gains from offering 85% are 11 in case of investment and 4 otherwise; the expected gains from offering 80% are instead, respectively:

$$\frac{1}{2} \times 15 + \frac{1}{2} \times 2 = 8.5 < 11 \text{ and } \frac{1}{2} \times 6 + \frac{1}{2} \times 2 = 4.$$

It follows that suppliers offer 85% under VS, regardless of the investment decision, and under VI, in case of investment; under VI and in the absence of investment, suppliers randomize with equal probability between offering 80% or 85%, and anticipate an expected upstream payoff of 4.

Stage 1. In the absence of commitment, D_2 anticipates that level-7 suppliers will offer 80%, and thus invests. In case of commitment, D_2 anticipates that level-7 U_B will offer 55%, and thus does not invest.

Stage 0. U_A expects the level-7 U_B to offer 55% in case of commitment and 80% otherwise. Hence, under VS, U_A does not commit himself, as this would prevent him from competing.

Under VI, if he commits, U_A expects the level-7 D_2 not to invest, and select U_B ; the expected gain is therefore $52 + 2 = 54$. In the absence of commitment, U_A expects the level-7 D_2 to invest and accept his offered share of either 80% or 85%, yielding an expected payoff $29 + 4 = 33 < 54$. It follows that U_A commits himself.

Recap.

- In stage 0, U_A does not commit himself under VS, but does so under VI.

- In stage 1, under both VS and VI, D_2 invests in the absence of commitment, otherwise she does not invest.
- In stage 2, U_B offers 55% in case of commitment; in the absence of commitment, suppliers offer 85% under VS (regardless of the investment decision) and under VI in case of investment, and randomize between 80% and 85% with equal probability under VI in the absence of investment.

B.1.10 Level-9

Stage 2. U_B offers 55% in case of commitment. In the absence of commitment:

- Regardless of the investment decision under VS, and in case of investment under VI, each supplier expects his level-8 rival to offer 85%; hence, offering less than 85% constitutes a dominated strategy. Furthermore:

- Under VS, the expected gains from offering 90% are 15 in case of investment and 13 otherwise; the expected gains from offering 85% are instead, respectively:

$$\frac{1}{2} \times 22 + \frac{1}{2} \times 2 = 12 < 15 \text{ and } \frac{1}{2} \times 19 + \frac{1}{2} \times 2 = 10.5 < 13.$$

- Under VI, in case of investment, the expected gain from offering 90% is 7, whereas the expected gain from offering 85% is:

$$\frac{1}{2} \times 11 + \frac{1}{2} \times 2 = 6.5 < 7.$$

- Under VI and in the absence of investment, both suppliers expect the other, level-8 supplier to offer 80% and 85% with equal probability; hence, offering less than 80% constitute dominated strategies. Furthermore:

- the expected gain from offering 90% is 3;
- the expected gain from offering 85% is

$$\frac{1}{2} \times 4 + \frac{1}{2} \times \left(\frac{1}{2} \times 4 + \frac{1}{2} \times 2 \right) = 3.5 > 3;$$

- the expected gain from offering 80% is

$$\frac{1}{2} \times \left(\frac{1}{2} \times 6 + \frac{1}{2} \times 2 \right) + \frac{1}{2} \times 2 = 3.$$

It follows that suppliers offer 90% under VS, regardless of the investment decision, and under VI in case of investment; by contrast, under VI and in the absence of investment, they only offer 85%.

Stage 1. In the absence of commitment, D_2 anticipates that level-8 suppliers will offer 85%, and thus invests. In case of commitment, D_2 anticipates that the level-8 U_B will offer 55%, and thus does not invest.

Stage 0. U_A expects the level-8 U_B to offer 55% in case of commitment and at least 80% otherwise. Hence, under VS, U_A does not commit himself, as this would prevent him from competing.

Under VI, in case of commitment U_A expects the level-8 D_2 not to invest, and select U_B ; the expected gain is therefore $52 + 2 = 54$. In the absence commitment, U_A expects the level-8 D_2 to invest and accept his offered share of 90%, yielding an expected payoff $29 + 7 = 36 < 54$. It follows that U_A commits himself.

Recap.

- In stage 0, U_A does not commit himself under VS, but does so under VI.
- In stage 1, under both VS and VI, D_2 invests in the absence of commitment, otherwise she does not invest.
- In stage 2, U_B offers 55% in case of commitment; in the absence of commitment, suppliers offer 90% under VS (regardless of the investment decision) and under VI in case of investment, and offer instead 85% under VI in the absence of investment.

B.1.11 Level-10

Stage 2. U_B offers 55% in case of commitment. In the absence of commitment:

- Under VS, regardless of the investment decision, and under VI, in case of investment, each supplier expects his level-9 rival to offer 90%; hence, offering less than 90% constitutes a dominated strategy.
- Under VI, in the absence of commitment and of investment, both suppliers expect the other, level-9 supplier to offer 85%; hence, offering less than 85% constitutes a dominated strategy. Furthermore, the expected gain from offering 90% is 3, which coincides with the expected gain from offering 85%, given by:

$$\frac{1}{2} \times 4 + \frac{1}{2} \times 2 = 3.$$

It follows that suppliers offer 90% under VS, regardless of the investment decision, and under VI in case of investment; by contrast, under VI and in the absence of investment, they randomize with equal probability between offering 85% or 90%.

Stage 1. In the absence of commitment, D_2 anticipates that level-9 suppliers will offer 90%, and thus invests. In case of commitment, D_2 anticipates that level-9 U_B will offer 55%, and thus does not invest.

Stage 0. From level-10 on:

- U_A expects the level-9 U_B to offer 55% in case of commitment and at least 85% otherwise. Hence, under VS, U_A does not commit himself, as this would prevent him from competing.
- Under VI, in case of commitment U_A expects the level-9 D_2 not to invest, and to select U_B ; the expected gain is $52 + 2 = 54$. In the absence of commitment, U_A expects the level-9 D_2 to invest and accept his offered share of 90% with probability $1/2$ (as the level-9 U_B is expected to offer 90% as well); the expected payoff is thus:

$$29 + \frac{1}{2} \times 7 + \frac{1}{2} \times 2 = 33.5 < 54.$$

It follows that U_A commits himself under VI and does not do so under VS.

Recap.

- In stage 0, U_A does not commit himself under VS, but does so under VI.
- In stage 1, under both VS and VI, D_2 invests in the absence of commitment, otherwise she does not invest.
- In stage 2, U_B offers 55% in case of commitment; in the absence of commitment, suppliers offer 90% under VS (regardless of the investment decision) and under VI in case of investment, and randomize instead with equal probability between offering 85% or 90% under VI in the absence of investment.

B.1.12 Level-11

As already noted, from level-10 on, in stage 0 U_A does not commit himself under VS, but does so under VI. From now on, we thus focus on stages 1 and 2.

Stage 2. U_B offers 55% in case of commitment. In the absence of commitment:

- Under VS, regardless of the investment decision, and under VI, in case of investment, each supplier expects his level-10 rival to offer 90%; hence, as in the previous round, they offer 90%.
- Under VI, in the absence of investment, both suppliers expect the other, level-10 supplier to randomize with equal probability between offering 85% or 90%; hence, offering less than 85% constitutes a dominated strategy. Furthermore, the expected gain from offering 90% is

$$\frac{1}{2} \times 3 + \frac{1}{2} \times \left(\frac{1}{2} \times 3 + \frac{1}{2} \times 2 \right) = 2.75,$$

whereas that from offering 85% is

$$\frac{1}{2} \times \left(\frac{1}{2} \times 4 + \frac{1}{2} \times 2 \right) + \frac{1}{2} \times 2 = 2.5 < 2.75.$$

It follows that suppliers offer 90% under both VS and VI, regardless of the investment decision.

Stage 1. In the absence of commitment, D_2 anticipates that level-10 suppliers will offer at least 85%, and thus invests. In case of commitment, D_2 anticipates that the level-10 U_B will offer 55%, and thus does not invest.

Recap.

- In stage 0, U_A does not commit himself under VS, but does so under VI.
- In stage 1, under both VS and VI, D_2 invests in the absence of commitment, otherwise she does not invest.
- In stage 2, under both VS and VI, and regardless of the investment decision, U_B offers 55% in case of commitment and both suppliers offer 90% in the absence of commitment.

B.1.13 Level-12 on

We have:

- In stage 0, U_A does not commit himself under VS, but does so under VI.
- In stage 1:
 - absent commitment, D_2 anticipates that level- $(k - 1)$ suppliers will offer 90%, and thus invests;
 - in case of commitment, D_2 anticipates that the level- $(k - 1)$ U_B will offer 55%, and thus does not invest.
- In stage 2:
 - absent commitment, each supplier expects his level- $(k - 1)$ rival to offer 90%, and responds by offering 90% as well;
 - in case of commitment, as before U_B offers 55%.

B.1.14 Summary

From level-1 on, D_2 selects in stage 3 the supplier offering the larger share. However, at level-1 the suppliers, anticipating a random selection from D_2 , offer the lowest share, 50%. From level-2 on:

- D_2 does not invest in case of commitment, as she expects U_B to offer no more than 55% (specifically, 50% when of level 1 and 55% otherwise).
- An independent U_A never commits himself, as this would yield for sure the lowest possible payoff (2), whereas he can obtain a higher payoff with positive probability by (not committing and) either matching or outbidding U_B .

Furthermore, in the absence of commitment by U_A :

- The suppliers offer a share that gradually increases: it reaches the investment indifference threshold (70%) on level 5, (75%) on level 6, and the maximal level (90%) on level 9 under VS and/or in case of investment, and on level-11 under VI in case of no investment;
- In response, D_2 does not invest on levels 1 to 5 (expecting to obtain less than 70% from level- $(k - 1)$ suppliers), randomizes between investing or not on level 6 (as she expects to obtain 70% from level-5 suppliers), and invests from level 7 on (as she expects to obtain more than 70% from level- $(k - 1)$ suppliers).

It follows that an integrated U_A :

- Does not commit himself on levels 1 to 6, as he expects to face a D_2 player who, being of level at most 5, will never invest anyway (and so committing himself brings no benefit for the subsidiary D_1 , and prevents U_A from competing with U_B for D_2);
- Commits himself from level 7 on, as D_2 (being of type at least 6) would otherwise invests with probability at least $1/2$, and U_B (being also of type at least 6) will make a rather generous offer; hence, the benefit for the integrated subsidiary (equal to $(52 - 29) / 2 = 11.5$ when D_2 is of level-6, and $52 - 29 = 23$ when D_2 is of a higher level), which exceeds the expected difference in the bidding payoff (equal to $(1/2) \times (15 - 2) + (1/2) \times (6 - 2) = 8.5$ when D_2 is of level-6, and to no more than $11 - 2 = 9$ when D_2 is of a higher level).

It follows that, along the equilibrium path, from level-2 on:

- Under VS:
 - U_A never commits itself to offering a low share;
 - the suppliers offer a share that gradually increases: it reaches 70% on level 5, 75% on level 6 and 90% on level 9;

- D_2 does not invest before level 6, where she invests with probability $1/2$, and always invests from level 7 on.
- Under VI:
 - before level-7, U_A never commits himself and the two suppliers offer a share that gradually increases, reaching 70% on level-5 and 75% on level-6; D_2 never invests before level-6, where it does so with probability $1/2$.
 - from level-7 on, U_A commits himself to offering a low share, D_2 never invests, and U_B offers 55%.

B.2 The Sabotage game

B.2.1 Level-0

Players play randomly:

- In stage 1, D_2 invests with probability $1/2$.
- In stage 2, U_A and U_B each select any of the 9 possible sharing-rules with probability $1/9$.
- In stage 3, D_2 selects each supplier with equal probability.
- In stage 4, U_A degrades his support with probability $1/2$ whenever he is selected by D_2 .

B.2.2 Level-1

From level-1 on, in stage 4, an integrated U_A always degrades his support when selected by D_2 , whereas an independent U_A never does so. From now on, we will focus on stages 1 to 3.

Stage 3. Under VS D_2 selects the supplier offering the larger share; under VI, she selects the supplier offering the best deal, assuming that U_A 's support will be degraded with probability $1/2$.

Stage 2. Suppliers anticipate a random selection by a level-0 D_2 , and thus seek to offer the sharing rule that grants them the highest revenue; hence, both suppliers offer 50%.

Stage 1. D_2 anticipates that the level-0 U_A , if selected, will degrade his support with probability $1/2$. Hence, if she invests, her resulting expected payoffs, as a function of the suppliers' offers, are as in Table 29:

Table 29: Level-1, Expected payoff for D_2 (investment)

U_A 's offer	50%	55%	60%	65%	70%	75%	80%	85%	90%
D_2 's expected payoff	2	4	5.5	7.5	9.5	11.5	13	15	17
U_B 's offer	50%	55%	60%	65%	70%	75%	80%	85%	90%
D_2 's payoff	1	5	8	12	16	20	23	27	31

As D_2 expects that both suppliers will randomize their offers, her expected payoff is:

$$\frac{1}{9} \times \left(\begin{array}{l} 20 + 23 + 27 + 31 \\ + \frac{8 \times 16 + 17}{9} + \frac{6 \times 12 + 13 + 15 + 17}{9} \\ + \frac{4 \times 8 + 9.5 + 11.5 + 13 + 15 + 17}{9} \\ + \frac{2 \times 5 + 5.5 + 7.5 + 9.5 + 11.5 + 13 + 15 + 17}{9} \\ + \frac{2 + 4 + 5.5 + 7.5 + 9.5 + 11.5 + 13 + 15 + 17}{9} \end{array} \right) = \frac{1443}{81}.$$

If instead D_2 does not invest, her expected payoffs are given by Table 30:

Table 30: Level-1, Expected payoff for D_2 (no investment)

U_A 's offer	50%	55%	60%	65%	70%	75%	80%	85%	90%
D_2 's expected payoff	10.5	11.5	12	12.5	13.5	14	15	15.5	16.5
U_B 's offer	50%	55%	60%	65%	70%	75%	80%	85%	90%
D_2 's payoff	10	12	13	14	16	17	19	20	22

As D_2 expects that both suppliers will randomize their offers, her expected payoff is:

$$\frac{1}{9} \times \left(\begin{array}{l} 17 + 19 + 20 + 22 \\ + \frac{8 \times 16 + 16.5}{9} + \frac{6 \times 14 + 15 + 15.5 + 16.5}{9} \\ + \frac{4 \times 13 + 13.5 + 14 + 15 + 15.5 + 16.5}{9} \\ + \frac{3 \times 12 + 12.5 + 13.5 + 14 + 15 + 15.5 + 16.5}{9} \\ + \frac{10.5 + 11.5 + 12 + 12.5 + 13.5 + 14 + 15 + 15.5 + 16.5}{9} \end{array} \right) = \frac{1348}{81} < \frac{1443}{81}.$$

It follows that D_2 invests.

Recap. Under both VS and VI:

- In stage 1, D_2 invests.
- In stage 2, regardless of D_2 's investment, U_A and U_B offer 50%.

- In stage 3, D_2 selects the supplier offering the best deal, assuming that U_A 's support will be degraded with probability $1/2$.

B.2.3 Level-2

From level-2 on, all players anticipate that in stage 4, an integrated U_A always degrades his support when selected by D_2 , whereas an independent U_A never does so.

Stage 3. It follows from the above observation that, from level-2 on:

- under VS, D_2 selects the supplier offering the higher share and randomizes when they offer the same share.
- under VI, D_2 selects U_A whenever U_B offers a 50% share and selects U_B otherwise.

From now on, we will focus on stages 1 and 2.

Stage 2. Each supplier expects his level-1 rival to offer a 50% share, and D_2 to anticipate that U_A will use the sabotage option with probability $1/2$. Hence, U_A offers a 50% share (as this suffices to win the competition for sure), whereas U_B offers a 55% share (as this suffices to win, and offering 50% would induce the level-2 D_2 to select U_A).

Stage 1. D_2 anticipates that the two level-1 suppliers will offer a 50% share (and that the level-1 U_A will choose the sabotage option when integrated). As a result, D_2 does not invest.

Recap. Under both VS and VI:

- In stage 1, D_2 does not invest.
- In stage 2, regardless D_2 's investment, U_A offers a 50% share and U_B offers a 55% share.

B.2.4 Level-3 on

Under VI, from level-3 on:

- In stage 2, both suppliers expect the level-2 D_2 to select U_A whenever U_B offers a 50% share and U_B otherwise; hence U_B offers a 55% share and U_A offers any share.
- In stage 1, anticipating that U_B will offer a 55% share and that U_A will offer a degraded support, D_2 does not invest.

We now turn to the case of vertical separation.

Stage 2. Under VS, from level-3 on both suppliers expect the level- $(k - 1)$ D_2 to select the higher offer; it follows from the analysis of the Commitment treatment that each supplier seeks to outbid his level- $(k - 1)$ rival. Hence, regardless of D_2 's investment decision, we have:

- level-3: U_A offers a 60% share and U_B offers a 55% share;
- level-4: U_A offers a 60% share and U_B offers a 65% share;
- level-5: U_A offers a 70% share and U_B offers a 65% share;
- level-6: U_A offers a 70% share and U_B offers a 75% share;
- level-7: U_A offers a 80% share and U_B offers a 75% share;
- level-8: U_A offers a 80% share and U_B offers a 85% share;
- level-9: U_A offers a 90% share and U_B offers a 85% share;
- level-10 on: both suppliers offer a 90% share.

Stage 1. Based on the above observations:

- on levels 3 to 5, D_2 expects the level- $(k - 1)$ suppliers to offer at most a 65% share; hence, she does not invest;
- on level-6, D_2 expects the level-5 U_A to offer a 70% share for a non-degraded support, and the level-5 U_A to offer 65%; she thus invests with probability $1/2$;
- from level-7 on, D_2 expects the level- $(k - 1)$ suppliers to offer at least 75% share, and she thus invests.

B.2.5 Summary

From level-1 on, in stage 4, an integrated U_A always degrades his support when selected by D_2 , whereas an independent U_A never does so. As a result, from level-2 on:

- Under VI, D_2 does not invest and U_B offers a low share of 55%, which D_2 accepts.
- Under VS, D_2 selects the supplier offering the higher share and, from level-3 on:
 - suppliers gradually increase their offered shares: the better offer reaches 70% on level 5, 75% on level 6 and 90% on level 9; both suppliers offer 90% from level 10 on;
 - D_2 does not invest before level 6, where she invests with probability $1/2$, and always invests from level 7 on.

C Robustness checks

We provide here robustness checks for the regressions presented in the paper.

Model I and Model II are the models used in the paper, with the second one controlling for risk aversion and IQ score of the decision maker (“DM” in the tables). Model III controls instead for risk aversion and IQ score of the three players in the group (“All” in the tables).

Models IV, V and VI are similar to Models I, II and III, but exclude the first two periods in each phase. For each interest variable, two tables are available: the first table presents coefficients with clusters at the individual level and controls for session dummies (Models I, II, III, IV, V and VI) and the second table uses clusters at the session level (Models I’, II’, III’, IV’, V’ and VI’).

For each table, standard errors are reported in parentheses; ***, ** and * respectively represent significance at 1%, 5% and 10% levels.

C.1 Impact of Vertical integration on subjects’ behavior

C.1.1 D_2 subjects

Investment decisions

Table 31: Marginal effect of VI on investment (Probit model) - Cluster at the individual level

	Model I	Model II	Model III	Model IV	Model V	Model VI
Benchmark	0.080*** (0.028)	0.082*** (0.028)	0.082*** (0.028)	0.080** (0.031)	0.082*** (0.031)	0.081*** (0.031)
Commitment	-0.428*** (0.031)	-0.428*** (0.030)	-0.428*** (0.030)	-0.455*** (0.025)	-0.455*** (0.025)	-0.455*** (0.025)
Sabotage	-0.367*** (0.055)	-0.364*** (0.052)	-0.364*** (0.052)	-0.406*** (0.053)	-0.402*** (0.049)	-0.403*** (0.049)
IQ and risk-aversion	No	DM	All	No	DM	All
Exclusion of P1 and P2	No	No	No	Yes	Yes	Yes

Table 32: Marginal effect of VI on investment (Probit model) - Cluster at the session level

	Model I'	Model II'	Model III'	Model IV'	Model V'	Model VI'
Benchmark	0.080*** (0.031)	0.083*** (0.024)	0.081*** (0.022)	0.080** (0.036)	0.082*** (0.031)	0.079*** (0.025)
Commitment	-0.428*** (0.060)	-0.429*** (0.063)	-0.429*** (0.063)	-0.455*** (0.047)	-0.456*** (0.049)	-0.456*** (0.049)
Sabotage	-0.370*** (0.098)	-0.366*** (0.089)	-0.366*** (0.087)	-0.410*** (0.099)	-0.404*** (0.089)	-0.404*** (0.088)
IQ and risk-aversion	No	DM	All	No	DM	All
Exclusion of P1 and P2	No	No	No	Yes	Yes	Yes

Revenue sharing

Table 33: Marginal effect of VI on the share accepted by D_2 (OLS model) - Cluster at the individual level

	Model I	Model II	Model III	Model IV	Model V	Model VI
Benchmark	0.600 (0.553)	0.600 (0.554)	0.600 (0.515)	-0.229 (0.544)	-0.229 (0.545)	-0.229 (0.514)
Commitment	-20.117*** (1.282)	-20.117*** (1.284)	-20.117*** (1.294)	-21.417*** (1.451)	-21.417*** (1.454)	-21.417*** (1.461)
Sabotage	-10.450*** (1.181)	-10.450*** (1.183)	-10.450*** (1.189)	-12.313*** (1.189)	-12.313*** (1.191)	-12.313*** (1.203)
IQ and risk-aversion	No	DM	All	No	DM	All
Exclusion of P1 and P2	No	No	No	Yes	Yes	Yes

Table 34: Marginal effect of VI the share accepted by D_2 (OLS model) - Cluster at the session level

	Model I'	Model II'	Model III'	Model IV'	Model V'	Model VI'
Benchmark	0.600 (0.681)	0.600 (0.682)	0.600 (0.685)	-0.229 (0.708)	-0.229 (0.710)	-0.229 (0.713)
Commitment	-20.117** (3.547)	-20.117** (3.553)	-20.117** (3.565)	-21.417** (4.138)	-21.417** (4.147)	-21.417** (4.164)
Sabotage	-10.450** (1.596)	-10.450** (1.599)	-10.450** (1.604)	-12.313** (2.126)	-12.313** (2.130)	-12.313** (2.139)
IQ and risk-aversion	No	DM	All	No	DM	All
Exclusion of P1 and P2	No	No	No	Yes	Yes	Yes

C.1.2 Suppliers

U_A subjects

Table 35: Marginal effect of VI on offered shares by U_A (OLS model) - Cluster at the individual level

	Model I	Model II	Model III	Model IV	Model V	Model VI
Benchmark	0.983 (0.993)	0.983 (0.995)	0.983 (1.010)	0.250 (0.995)	0.250 (0.998)	0.250 (1.004)
Commitment	-22.583*** (2.688)	-22.583*** (2.692)	-22.583*** (2.682)	-24.042*** (2.769)	-24.042*** (2.775)	-24.042*** (2.786)
Sabotage	0.217 (1.100)	0.217 (1.102)	0.217 (1.079)	-1.083 (1.047)	-1.083 (1.050)	-1.083 (1.043)
IQ and risk-aversion	No	DM	All	No	DM	All
Exclusion of P1 and P2	No	No	No	Yes	Yes	Yes

Table 36: Marginal effect of VI on offered shares by U_A (OLS model) - Cluster at the session level

	Model I'	Model II'	Model III'	Model IV'	Model V'	Model VI'
Benchmark	0.983 (1.527)	0.983 (1.529)	0.983 (1.534)	0.250 (1.666)	0.250 (1.670)	0.250 (1.677)
Commitment	-22.583** (2.449)	-22.583** (2.453)	-22.583** (2.461)	-24.042** (2.975)	-24.042** (2.981)	-24.042** (2.994)
Sabotage	0.217 (1.620)	0.217 (1.623)	0.217 (1.629)	-1.083 (1.233)	-1.083 (1.235)	-1.083 (1.240)
IQ and risk-aversion	No	DM	All	No	DM	All
Exclusion of P1 and P2	No	No	No	Yes	Yes	Yes

U_B subjects

Table 37: Marginal effect of VI on offered shares by U_B (OLS model) - Cluster at the individual level

	Model I	Model II	Model III	Model IV	Model V	Model VI
Benchmark	-1.183 (1.054)	-1.183 (1.056)	-1.183 (1.052)	-1.479 (1.102)	-1.479 (1.105)	-1.479 (1.098)
Commitment	-18.100*** (1.416)	-18.100*** (1.418)	-18.100*** (1.427)	-19.229*** (1.666)	-19.229*** (1.670)	-19.229*** (1.674)
Sabotage	-13.633*** (1.823)	-13.633*** (1.826)	-13.633*** (1.832)	-14.979*** (1.989)	-14.979*** (1.993)	-14.979*** (2.004)
IQ and risk-aversion	No	DM	All	No	DM	All
Exclusion of P1 and P2	No	No	No	Yes	Yes	Yes

Table 38: Marginal effect of VI on offered shares by U_B (OLS model) - Cluster at the session level

	Model I'	Model II'	Model III'	Model IV'	Model V'	Model VI'
Benchmark	-1.183 (1.655)	-1.183 (1.658)	-1.183 (1.663)	-1.479 (2.121)	-1.479 (2.125)	-1.479 (2.134)
Commitment	-18.100** (2.957)	-18.100** (2.962)	-18.100** (2.972)	-19.229** (3.667)	-19.229** (3.674)	-19.229** (3.690)
Sabotage	-13.633** (2.357)	-13.633** (2.361)	-13.633** (2.369)	-14.979** (2.355)	-14.979** (2.360)	-14.979** (2.370)
IQ and risk-aversion	No	DM	All	No	DM	All
Exclusion of P1 and P2	No	No	No	Yes	Yes	Yes

C.2 Effect of U_A 's commitment

Table 39: Marginal effect of U_A 's commitment (Probit and OLS models) - Cluster at the individual level

	Model I	Model II	Model III	Model IV	Model V	Model VI
Investment	-0.500*** (0.015)	-0.494*** (0.013)	-0.495*** (0.013)	-0.489*** (0.025)	-0.484*** (0.020)	-0.487*** (0.022)
Share offered by U_B	-22.851*** (1.666)	-22.874*** (1.657)	-23.057*** (1.647)	-24.200*** (1.876)	-24.240*** (1.860)	-24.442*** (1.856)
Share accepted by D_2	-28.283*** (0.951)	-28.296*** (0.945)	-28.301*** (0.991)	-29.081*** (1.074)	-29.100*** (1.065)	-29.137*** (1.086)
IQ and risk-aversion	No	DM	All	No	DM	All
Exclusion of P1 and P2	No	No	No	Yes	Yes	Yes

Table 40: Marginal effect of U_A 's commitment (Probit and OLS models) - Cluster at the session level

	Model I'	Model II'	Model III'	Model IV'	Model V'	Model VI'
Investment	-0.481*** (0.021)	-0.483*** (0.016)	-0.488*** (0.014)	-0.474*** (0.035)	-0.477*** (0.026)	-0.481*** (0.024)
Share offered by U_B	-22.947** (2.676)	-22.890** (2.720)	-23.058** (2.688)	-24.271** (3.268)	-24.196** (3.289)	-24.389** (3.297)
Share accepted by D_2	-28.502*** (2.250)	-28.537*** (2.232)	-28.515*** (2.372)	-29.340*** (2.536)	-29.347*** (2.543)	-29.339*** (2.691)
IQ and risk-aversion	No	DM	All	No	DM	All
Exclusion of P1 and P2	No	No	No	Yes	Yes	Yes

C.3 Impact of vertical integration on departures from theory

C.3.1 Hold-up decisions (σ_A^H)

Table 41: Marginal effect of VI on σ_A^H (Probit model) - Cluster at the individual level

	Model I	Model II	Model III	Model IV	Model V	Model VI
Commitment	0.198*** (0.074)	0.200*** (0.073)	0.200*** (0.073)	0.195*** (0.073)	0.197*** (0.073)	0.198*** (0.073)
Sabotage	0.115 (0.078)	0.108 (0.071)	0.095 (0.067)	0.105 (0.071)	0.103 (0.068)	0.088 (0.062)
IQ and risk-aversion	No	DM	All	No	DM	All
Exclusion of P1 and P2	No	No	No	Yes	Yes	Yes

Table 42: Marginal effect of VI on σ_A^H (Probit model) - Cluster at the session level

	Model I'	Model II'	Model III'	Model IV'	Model V'	Model VI'
Commitment	0.203** (0.101)	0.204** (0.096)	0.203** (0.088)	0.200** (0.096)	0.203** (0.090)	0.202** (0.080)
Sabotage	0.110** (0.045)	0.106** (0.048)	0.093** (0.044)	0.103* (0.054)	0.103** (0.051)	0.085*** (0.026)
IQ and risk-aversion	No	DM	All	No	DM	All
Exclusion of P1 and P2	No	No	No	Yes	Yes	Yes

C.3.2 Shared offered by U_A (σ_A^O)

Table 43: Marginal effect of VI on σ_A^O (Probit model) - Cluster at the individual level

	Model I	Model II	Model III	Model IV	Model V	Model VI
Benchmark	-0.007 (0.049)	-0.004 (0.049)	-0.004 (0.048)	0.028 (0.048)	0.032 (0.048)	0.033 (0.047)
Commitment (for non-committed U_A)	0.096 (0.078)	0.082 (0.063)	0.086 (0.063)	0.150** (0.054)	0.139*** (0.068)	0.146*** (0.054)
IQ and risk-aversion	No	DM	All	No	DM	All
Exclusion of P1 and P2	No	No	No	Yes	Yes	Yes

Table 44: Marginal effect of VI on σ_A^O (Probit model) - Cluster at the session level

	Model I'	Model II'	Model III'	Model IV'	Model V'	Model VI'
Benchmark	-0.010 (0.091)	-0.010 (0.091)	-0.008 (0.088)	0.025 (0.095)	0.027 (0.094)	0.029 (0.092)
Commitment (for non-committed U_A)	0.112*** (0.020)	0.088** (0.038)	0.084** (0.033)	0.168*** (0.010)	0.148*** (0.029)	0.146*** (0.015)
IQ and risk-aversion	No	DM	All	No	DM	All
Exclusion of P1 and P2	No	No	No	Yes	Yes	Yes

C.3.3 Shares offered by U_B (σ_B^O)

Table 45: Marginal effect of VI on σ_B^O (Probit model) - Cluster at the individual level

	Model I	Model II	Model III	Model IV	Model V	Model VI
Benchmark	0.038 (0.052)	0.038 (0.051)	0.039 (0.052)	0.022 (0.055)	0.024 (0.048)	0.024 (0.055)
Commitment	0.002 (0.041)	0.004 (0.041)	0.004 (0.041)	0.036 (0.048)	0.040 (0.047)	0.040 (0.046)
Sabotage	0.301*** (0.058)	0.300*** (0.057)	0.300*** (0.057)	0.373*** (0.052)	0.372*** (0.052)	0.372*** (0.052)
IQ and risk-aversion	No	DM	All	No	DM	All
Exclusion of P1 and P2	No	No	No	Yes	Yes	Yes

Table 46: Marginal effect of VI on σ_B^O (Probit model) - Cluster at the session level

	Model I'	Model II'	Model III'	Model IV'	Model V'	Model VI'
Benchmark	0.037 (0.078)	0.037 (0.076)	0.038 (0.076)	0.021 (0.094)	0.023 (0.091)	0.023 (0.092)
Commitment	0.007 (0.058)	0.006 (0.056)	0.007 (0.057)	0.042 (0.059)	0.042 (0.056)	0.043 (0.055)
Sabotage	0.303*** (0.050)	0.302*** (0.047)	0.302*** (0.046)	0.373*** (0.034)	0.372*** (0.027)	0.372*** (0.027)
IQ and risk-aversion	No	DM	All	No	DM	All
Exclusion of P1 and P2	No	No	No	Yes	Yes	Yes

C.3.4 Investment decisions (σ_D^I)

Table 47: Marginal effect of VI on σ_D^I (Probit model) - Cluster at the individual level

	Model I	Model II	Model III	Model IV	Model V	Model VI
Benchmark	-0.080*** (0.028)	-0.082*** (0.028)	-0.082*** (0.028)	-0.080** (0.031)	-0.082*** (0.031)	-0.081*** (0.031)
Commitment	0.028 (0.036)	0.028 (0.035)	0.029 (0.035)	0.037 (0.033)	0.039 (0.033)	0.040 (0.032)
Sabotage	0.389*** (0.044)	0.391*** (0.043)	0.391*** (0.043)	0.392*** (0.046)	0.396*** (0.045)	0.397*** (0.045)
IQ and risk-aversion	No	DM	All	No	DM	All
Exclusion of P1 and P2	No	No	No	Yes	Yes	Yes

Table 48: Marginal effect of VI on σ_D^I (Probit model) - Cluster at the session level

	Model I'	Model II'	Model III'	Model IV'	Model V'	Model VI'
Benchmark	-0.080*** (0.031)	-0.083*** (0.024)	-0.081*** (0.022)	-0.080** (0.036)	-0.082*** (0.027)	-0.079*** (0.025)
Commitment	0.030 (0.075)	0.032 (0.078)	0.036 (0.078)	0.038 (0.069)	0.044 (0.072)	0.046 (0.071)
Sabotage	0.393*** (0.080)	0.394*** (0.077)	0.393*** (0.074)	0.399*** (0.082)	0.401*** (0.079)	0.401*** (0.073)
IQ and risk-aversion	No	DM	All	No	DM	All
Exclusion of P1 and P2	No	No	No	Yes	Yes	Yes

C.3.5 Choice of supplier (σ_D^U)

Table 49: Marginal effect of VI on σ_D^U (Probit model) - Cluster at the individual level

	Model I	Model II	Model III	Model IV	Model V	Model VI
Benchmark	-0.024* (0.014)	-0.025* (0.014)	-0.024* (0.012)	-0.017 (0.016)	-0.018 (0.016)	-0.016 (0.015)
Commitment	0.043* (0.022)	0.044* (0.023)	0.044** (0.022)	0.057*** (0.022)	0.059*** (0.022)	0.056*** (0.020)
Sabotage	0.143*** (0.039)	0.141*** (0.038)	0.139*** (0.037)	0.109*** (0.038)	0.108*** (0.037)	0.106*** (0.036)
IQ and risk-aversion	No	DM	All	No	DM	All
Exclusion of P1 and P2	No	No	No	Yes	Yes	Yes

Table 50: Marginal effect of VI on σ_D^U (Probit model) - Cluster at the session level

	Model I'	Model II'	Model III'	Model IV'	Model V'	Model VI'
Benchmark	-0.024* (0.014)	-0.025 (0.016)	-0.025 (0.018)	-0.017 (0.023)	-0.018 (0.026)	-0.018 (0.027)
Commitment	0.042 (0.029)	0.045 (0.032)	0.044 (0.031)	0.057 (0.042)	0.060 (0.047)	0.058 (0.042)
Sabotage	0.143*** (0.035)	0.141*** (0.032)	0.140*** (0.038)	0.109*** (0.028)	0.107*** (0.024)	0.106*** (0.029)
IQ and risk-aversion	No	DM	All	No	DM	All
Exclusion of P1 and P2	No	No	No	Yes	Yes	Yes

D Interplay between individual departures

Table 51: Interplay between individual departures in t and $t + 1$ under VI (Probit model)

	Commitment	Sabotage
σ_B^O in t on σ_D^I in $t + 1$ (if $\sigma_A^H = 0$)	0.055 (0.054)	
σ_B^O in t on σ_D^I in $t + 1$		0.217*** (0.051)
σ_D^I in t on σ_A^H in $t + 1$	0.026 (0.068)	
σ_A^H in t on σ_D^I in $t + 1$ (if U_A selected in t)		-0.125 (0.142)
σ_B^O in t on σ_A^H in $t + 1$	0.244*** (0.074)	
σ_A^H in t on σ_B^O in $t + 1$ (if U_A selected in t)		-0.081 (0.113)