Risk aversion and equilibrium selection in sequential games: An experiment in a vertical contracting setting*

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Abstract

In sequential games with imperfect information, the selection of equilibria depends on out-of-equilibrium beliefs. In a recent paper, Eguia *et al.* (2018) propose a new selection criterion that does not impose any restriction on beliefs. In this article, we extend their criterion by generalizing it to risk-averse players, and we show that risk aversion modifies the size of the belief subsets that support each equilibrium. We conduct an experiment which revisits the one by Eguia *et al.* (2018). We design a new treatment effect on equilibrium selection, depending on the level of risk aversion and the level of a constant amount (low or high) added to the players' payoffs. We also measure for subjects' aversion towards risk and we elicit subjects' out-of-equilibrium beliefs in an incentivized manner. Experimental results confirm our treatment effect.

Keywords: Sequential games, imperfect information, secret contract, risk aversion, beliefs elicitation, experiment.

JEL classification: L14, C90

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1 Introduction

Sequential games with imperfect information often feature multiple equilibria which depend on players' out-of-equilibrium beliefs. In order to select equilibria and perform comparative statics, scholars restrict these beliefs. McAfee and Schwartz (1994) provide a seminal summary of the belief restrictions used in vertical contracting settings.[1] Belief restriction is theoretically convenient but there is no strong argument for choosing one restriction rather than another. For instance, this literature does not investigate the role of players' level of risk aversion in the selection process. This contrasts with the literature in static games, where players' level of risk aversion can be a pivotal characteristic in equilibrium selection (Harsanyi and Selten, 1988).

In this paper, we focus on a vertical contracting game with imperfect information, and theoretically characterize the effect of players' level of risk aversion on the equilibrium selection. Specifically, we consider a risk neutral supplier making secret offers to two risk averse retailers. We then select the equilibrium by generalizing a selection criterion designed for such class of games so that it considers the retailers' risk aversion. This criterion, defined by Eguia *et al.* (2018) and named the Largest Set of Beliefs (hereafter LSB) criterion, selects equilibrium without belief restriction. In an experiment, Eguia *et al.* (2018) show that their criterion outperforms the existing belief restrictions and the other selection criterion available for such classes of games: the Re-ordering Invariance equilibrium (In and Wright, 2018).

Our paper revisits the Eguia *et al.* (2018) experiment by considering the impact of a variation of risk-averse retailers' initial endowment. We use their initial endowment as a treatment variable (that can be either high or low) and thereby genuinely modify their local sensitivity towards risk between treatments. In other words, we measure the retailers' risk aversion and determine the general curvature of their utility function. On the other hand, we vary the retailers' initial endowment which modifies the locations of all the payoff values on the retailers' utility function. More specifically, the values of payoffs with a higher initial endowment lie on a flatter part of the utility function,

[1] The beliefs that are the most frequently used in the literature are passive beliefs and symmetric beliefs. Under passive beliefs, when an agent receives an out-of-equilibrium offer, it does not revise its beliefs about the offers made to others. Conversely, under symmetric beliefs, when an agent receives an out-of-equilibrium offer, it believes that all the others receive the same offer as it receives. Wary beliefs are based on the fact that each agent thinks that others receive offers that are optimal choices. Such beliefs are considered less in the literature.

making risk-averse retailers less sensitive to risk (Pratt, 1964). The Eguia *et al.* (2018) criterion without risk aversion theoretically predicts no endowment effect. We show, on the contrary, that the presence of risk aversion actually affects the size of the belief sets supporting each equilibrium. A variation of the initial endowment enables us to control this effect and thereby to control which set becomes the largest one. We predict that the variation of the initial endowment modifies the players' strategies and equilibrium actions.

Overall, our experiment confirms our treatment effect. We find that: (i) the variation of retailers' initial endowment affects the players' strategies and equilibrium actions; (ii) the effect on retailers depends on their level of risk aversion. These results show the need to include risk aversion in the LSB criterion. Finally, an in-depth analysis of the strategies and choices of the actors suggests that the suppliers can be pivotal actors in the equilibrium selection process.

Though our main contribution is to the literature on equilibrium selection in sequential games with imperfect information, our work also contributes to three strands of literature. First, it contributes to the experimental literature on secret vertical contracting. Martin *et al.* (2001) initiate the literature by assessing the impact of a vertical merger. They also show that outcomes are not consistent with subjects holding only one belief restriction type. Alternatively, Moellers *et al.* (2017) provide evidence that cheap talk communication induces more collusive outcomes, especially with multilateral communication. In a setting without belief restriction and communication, Eguia *et al.* (2018) show that the supplier can navigate between the equilibrium outcomes by modifying its initial set of prices. In this paper, we show that retailers can also navigate between the equilibrium outcomes by modifying their initial endowment.

Our research also contributes to the literature on belief elicitation in the lab. Most of this literature elicits beliefs in normal form game experiments, e.g. public goods games, prisoner's dilemma, etc., or decision tasks (see e.g. Schotter and Trevino, 2014). Our experiment is the first to report subjects' out-of-equilibrium beliefs from a sequential game using an incentivized belief elicitation task. The latter task belongs to the class of elicitation games, as named by Schlag *et al.*, 2015, in which incentives for truthful reporting are based on others' strategies. Note that we also provide the subjects' whole strategies in addition to their beliefs by using Selten's strategy method

(Selten, 1967). This enables us to offer a detailed analysis of the equilibrium selection process and in particular to suggest that suppliers' beliefs may be the key parameters of the selection process.

Last, our paper connects to the literature that investigates house money effects in the lab (see e.g. Clark, 2002, Davis *et al.*, 2010, Jing and Cheo, 2013). These effects basically mean that risk and loss attitudes may vary, following a change in perceived or known wealth and were evidenced in the lab by Thaler and Johnson (1990) in a setting based on prospect theory. Our design is closest to Ackert *et al.* (2006) which varies the level of traders' cash endowment in an asset market experiment. The latter paper shows that traders' decisions, predictions and incidentally the final outcomes change following a rise in the level of cash endowment. In contrast to these authors, we focus on risk aversion and study a vertical contracting game. We contribute to this literature by showing that the level of initial endowment affects risk-averse subjects' strategies and therefore final outcomes in a vertical contracting game.

The paper is organized as follows. Section 2 introduces the theoretical framework extending the Eguia *et al.* (2018) contracting game to risk-averse retailers. Section 3 details the experimental design. Sections 4 and 5 respectively present the characteristics of the participants and the results of the experiment, and Section 6 concludes.

2 A vertical contracting game with risk-averse retailers

2.1 Framework

In line with the Eguia *et al.* (2018) experiment, we consider a simplified framework of vertical relationships where a supplier makes secret offers to two retailers, based on the model by Rey and Tirole, 2007. However, in contrast to Eguia *et al.* (2018) we consider risk-averse retailers. The timing of the game is as follows: (1: offers) the supplier secretly and simultaneously offers a price $p_i \in \{p^H = 36, p^L = 15\}$ to each retailer $i \in \{1, 2\}$ for each unit bilaterally delivered; (2: orders and profits) each retailer i decides the quantity q_i to buy from the supplier, with $q_i \in \{0, 1, 2, 3\}$; the retailers then release the goods in the final market where the inverse demand is given by:

$$(P(1), P(2), P(3), P(4), P(5), P(6)) = (103, 100, 46, 45, 28, 18). \quad (1)$$

The retailer's profits are given by:

$$\pi_i(q_i, q_{-i}, p_i) = \begin{cases} e - c + P(q_i + q_{-i})q_i - p_i q_i, & \text{if } q_i > 0 \\ e, & \text{otherwise.} \end{cases} \quad (2)$$

We assume a contract cost $c = 33$ and an initial endowment e that captures the outside earnings obtained by each retailer, independently of the present contract.[2] We assume that both retailers have the same level of initial endowment.

The supplier earns profits given by:

$$\pi_0(q_i, q_{-i}, p_i, p_{-i}) = q_i p_i, + q_{-i} p_{-i}. \quad (3)$$

We further assume, as Eguia *et al.* (2018) do, that the supplier is risk neutral. However, in contrast to Eguia *et al.* (2018), we consider that retailers are risk averse.[3] Formally, while Eguia *et al.* (2018) assume that retailers hold linear utility functions, we instead consider that they hold concave utility functions. More precisely, we consider that retailers have preferences following the Constant Relative Risk Aversion utility function (CRRA):

$$u(\pi) = \begin{cases} \frac{\pi^{(1-r)}}{1-r}, & \text{if } r \in [0, 1[\cup]1, +\infty[\\ \ln(\pi), & \text{otherwise} \end{cases} \quad (4)$$

where π is the payoff of the retailer of interest. The higher r is, the more risk-averse the retailer will be. And the reverse is true. Note that for $r = 0$ the retailer is risk neutral. This family of utility functions has been widely used in the experimental literature since Holt and Laury (2002)

[2]We focus on e values for which the retailer's profits are positive for all values of q_i considered.

[3]This asymmetric assumption is well established in the literature on vertical relationships (see e.g. Rey and Tirole, 1986 and Ma *et al.*, 2012).

because it often offers a good fit to data (Harrison and Rutstrom, 2008).[4] The utility function also has the useful property that higher payoffs lie on a flatter part of the utility function which means that the retailers are less sensitive to risk for higher payoffs (the absolute risk aversion decreases (Pratt, 1964)).

2.2 Equilibria and associated belief sets

We focus on the symmetric equilibria in pure strategies of the above game. Lemma 1 presents these equilibria:

Lemma 1. *There are two symmetric equilibria in pure strategies:*

- *In one equilibrium, denoted L, the supplier offers $p^L = 15$ to both retailers and each retailer buys 2 units if the price offered is p^L and 0 units if the price is p^H. The equilibrium profits of supplier and retailers are respectively $\pi_o^L = 60$ and $\pi_i^L = e + 27$.*
- *In the other equilibrium, denoted H, the supplier offers $p^H = 36$ to both retailers and each retailer buys 1 unit if the price is p^H and 2 units if the price is p^L. The equilibrium profits of supplier and retailers are respectively $\pi_o^H = 72$ and $\pi_i^H = e + 31$.*

Proof. See Appendix A. □

These equilibria are the standard equilibria discussed by the literature on secret contracting. The low-price-offer equilibrium, equilibrium L, corresponds to a situation where the two downstream firms release the Cournot quantities, and the high-price-offer equilibrium, equilibrium H, corresponds to a situation where the two downstream firms release the Monopoly quantity (see Rey and Tirole, 2007). Each of these equilibria is supported by a belief set that we detail below.

Note that the sustainability of each equilibrium depends on the retailers' reactions following an unexpected, or equivalently an out-of-equilibrium, price offer. Upon such offer, a retailer must infer the suppliers' action towards the other retailer in order to set its strategy. Each retailer's out-of-equilibrium strategy thus actually critically depends on their out-of-equilibrium beliefs upon

[4] Refer to Wakker (2008) and Moffatt (2015) for a detailed discussion of other utility functions.

out-of-equilibrium offers. For clarification, let $w(p^H_{-i}|\bar{p}_i) \in [0,1]$ be the belief of retailer i that its rival (retailer $-i$) gets the high price p^H when it (retailer i) is offered an out-of-equilibrium price $\bar{p}$. Due to additivity, once $w(p^H_{-i}|\bar{p}_i)$ is set we easily get $w(p^L_{-i}|\bar{p}_i)$.

Consider equilibrium L, this equilibrium is supported by beliefs such that, after observing the out-of-equilibrium price $\bar{p}_i = p^H$, retailer i buys 0 units, $q_i = 0$, rather than 1, 2 or 3 units. This occurs as long as upon receiving out-of-equilibrium price p^H, retailer i thinks that its is sufficiently unlikely that its rival gets price p^H. In other words, the retailer i's out-of-equilibrium belief, $w(p^H_{-i}|\bar{p}_i)$, has to lie below a certain threshold that we denote w_L. The following lemma more formally presents this idea through the concept of the subset of out-of-equilibrium beliefs supporting equilibrium L:

Lemma 2. *There exists a subset of retailer i's out-of-equilibrium beliefs, denoted by* $\Delta_L = \{w(p^H_{-i}|\bar{p}_i) \in [0,1] \ \mid w(p^H_{-i}|\bar{p}_i) \in [0, w_L]\}$*, which supports equilibrium* L*. The parameter* w_L *bounds this set and is such that* $w_L = \min\{w_{L_{1/0}} \equiv \frac{u(e)-u(e-23)}{u(e+34)-u(e-23)},\ w_{L_{2/0}} \equiv \frac{u(e)-u(e-15)}{u(e+95)-u(e-15)},\ w_{L_{3/0}} \equiv \frac{u(e)-u(e-57)}{u(e-3)-u(e-57)}\}$*. The beliefs outside* Δ_L *induce that after observing the out-of-equilibrium price* $\bar{p}_i = p^H$*, retailer* i *deviates from* $q_i = 0$ *and Equilibrium* L *is not sustainable.*

Proof. See Appendix B. □

It is important to note that the *passive beliefs* restriction, widely used in the literature about secret contracting, supports equilibrium L. With *passive beliefs* a retailer that receives an out-of-equilibrium offer does not update its beliefs about the offer retailer gets, so that the belief sticks to the equilibrium offer (McAfee and Schwartz, 1994). In equilibrium L, a retailer expects that both itself and its rival will get the equilibrium offer p^L. Upon out-of-equilibrium offer $\bar{p}_i = p^H$, this retailer continues to believe that the other retailer receives p^L. This implies $w(p^H_{-i}|\bar{p}_i = p^H) = 0$. The *passive beliefs* are de facto in the subset of retailer i's beliefs Δ_L that supports equilibrium L. This finding is summarized in the following corollary of Lemma 2.

Corollary 1. *In equilibrium* L*, the passive beliefs imply* $w(p^H_{-i}|\bar{p}_i = p^H) = 0$*, and therefore belong to the sub-set* Δ_L *and support equilibrium* L*.*

Similarly, equilibrium H is supported by beliefs such that, after observing the out-of-equilibrium price $\bar{p}_i = p^L$, retailer i chooses to buy 2 units, $q_i = 2$, and not 0, 1 or 3 units. This happens when, upon receiving the out-of-equilibrium price $\bar{p}_i = p^L$, retailer i thinks that it is sufficiently unlikely the rival gets price p^H. In other words, retailer i's out-of-equilibrium belief, $w(p^H_{-i}|\bar{p}_i)$, has to lie below a certain threshold that we denote w_H. Lemma 3 more formally defines the subset of out-of-equilibrium beliefs supporting equilibrium H:

Lemma 3. *There exists a subset of retailer i's out-of-equilibrium beliefs, denoted by* $\Delta_H = \{w(p^H_{-i}|\bar{p}_i) \in [0,1] \mid w(p^H_{-i}|\bar{p}_i) \in [0, w_H]\}$*, which supports equilibrium* H*. The parameter* w_H *bounds this set and is such that* $w_H = \min\{w_{H_{0/2}} \equiv \frac{u(e+27)-u(e)}{u(e+27)-u(e+29)}, w_{H_{1/2}} \equiv \frac{u(e+27)-u(e-2)}{u(e+52)-u(e-2)+u(e+27)-u(e+29)}, w_{H_{3/2}} \equiv \frac{u(e+27)-u(e+6)}{u(e+57)-u(e+6)+u(e+27)-u(e+29)}\}$*. The beliefs outside* Δ_H *imply that after observing the out-of-equilibrium price* $\bar{p}_i = p^L$*, retailer* i *deviates from* $q_i = 2$ *and Equilibrium* H *is not sustainable.*

Proof. See Appendix C. □

Once more, it is worth noting that the *symmetric beliefs* restriction, sometimes used in the literature about secret contracting, supports equilibrium H. With *symmetric beliefs* a retailer that receives an out-of-equilibrium offer thinks that the other retailer gets the exact same offer (McAfee and Schwartz, 1994). In equilibrium H a retailer expects that both itself and its rival will get price p^H. Upon receiving out-of-equilibrium $\bar{p}_i = p^L$, this retailer thinks the other retailer also gets p^L. This implies that $w(p^H_{-i}|\bar{p}_i = p^L) = 0$. The *symmetric beliefs* thus belong to the subset of retailer i's beliefs Δ_H that supports equilibrium H. This finding is summarized in the following corollary of Lemma 3.

Corollary 2. *In equilibrium* H *the symmetric beliefs imply* $w(p^H_{-i}|\bar{p}_i = p^L) = 0$*; they therefore belong to the subset* Δ_H *and support equilibrium* H*.*

Note that subset Δ_H is unlikely to include *passive beliefs* and, conversely, subset Δ_L is unlikely to include *symmetric beliefs*. Consider equilibrium H: *passive beliefs* imply $w(p^H_{-i}|\bar{p}_i = p^L) = 1$, which is superior to w_H as soon as $w_H < 1$. For equilibrium L, *symmetric beliefs* imply $w(p^H_{-i}|\bar{p}_i = p^H) = 1$, which is superior to w_L as soon as $w_L < 1$. Both *passive* and *symmetric beliefs* are thus extreme beliefs in our framework, and they each support a particular equilibrium.

2.3 The equilibrium selection

Which equilibrium is more reliable? Eguia *et al.* (2018) argue that the equilibrium most likely to be played is the one sustained by the largest set of beliefs. According to this criterion, the focal equilibrium of our game is thus equilibrium L (respectively equilibrium H) whenever the size of Δ_L is larger (respectively smaller) than the size of of Δ_H. Or, equivalently, when $w_L > w_H$, the equilibrium in which the supplier proposes $p^L = 15$ to both retailers, is a better prediction, whereas when $w_H > w_L$, the equilibrium in which the supplier proposes $p^H = 36$ to both retailers, is a better prediction.

Compared with Eguia *et al.* (2018), our belief sets account for the retailers' level of risk aversion. Therefore, according to the LSB criterion, the equilibrium most likely to be played depends on the retailers' level of risk aversion. In addition, we observe that belief sets depend on the initial endowment, providing risk aversion is strictly positive (see Lemma 2 and 3). We thus argue that the focal equilibrium depends on both the retailers' level of risk aversion r and on the initial endowment e, provided that risk aversion is strictly positive. When retailers' risk aversion is nil, i.e. $r = 0$, retailers are risk neutral and the focal equilibrium does not depend on e, which is the case in Eguia *et al.* (2018) framework. Consequently, in our framework and in contrast to Eguia *et al.* (2018), varying e modifies the size of the belief sets, provided that retailers are strictly risk averse, which may impact the equilibrium played.

As mentioned previously, a rise in the initial endowment makes risk-averse retailers locally less sensitive towards risk. We control the retailers' local sensitivity towards risk aversion through the variation of their endowment and analyse the effect on equilibrium selection. The next section investigates this issue.

3 Experimental design

In this section, we propose an experiment based on the previous framework, to assess the strength of this effect on the profile of the equilibrium actions, the participants' strategies, and the participants' beliefs. This section describes the treatments, derives behavioral predictions, and finally analyzes the participants' actions and beliefs.

3.1 The participants' tasks and the treatment variable

Our experiment divides into two parts. The first and main part presents participants with a game based on the framework of Section 2. The second part provides a lottery choice to the participants.

The lottery choice task (displayed in Appendix D) is a version of the widely-used task designed by Eckel and Grossman (2002, 2008) that aims to measure the participants' level of risk aversion. This task - hereinafter the EG task - is a single-choice design where subjects are asked to choose one lottery from six different ones where the probabilities of low and high outcomes are always 0.5 in each lottery. In an experiment, Dave *et al.* (2010) compared the behavior in EG task to that in Holt and Laury (2002)'s task and found that subjects considered EG task to be simpler to understand. The EG task provides more reliable estimates of risk aversion for subjects with limited mathematical ability.[5]

For the first and main part, we consider the framework of vertical relationships of the previous section. We consider two distinct treatments: one with a high initial endowment $e = 69$, hereinafter named *treatment HE*, and one with a low initial endowment $e = 28$, hereinafter named *treatment LE*. Compared to the first treatment, risk aversion plays a greater role in the second treatment as explained in section 2.

In both treatments, we ask the supplier to secretly offer p^H or p^L to each retailer. In the meantime, we ask each retailer to secretly choose a quantity *for each* supplier's possible offer. The retailers decide on both a quantity which is either 0 or 1 units in case the supplier offers p^H, *and* a quantity which is either 0, 2 or 3 units in case the supplier offers p^L. We thus follow Eguia *et al.* (2018) in the experiment by restricting the quantities that the retailers can choose following

[5] Note that performing the risk test after accumulating earnings in the 2-stage game might theoretically impact subjects' choices in the risk test. However, subjects are not aware of their earnings from the first part before performing the lottery task. In addition, it is very unlikely that they are able to compute the expected payoff they get from the first task since only 1 period out of 25 is randomly drawn for payment. Actually, it is very unlikely that they remember all their potential payoffs.

a supplier's offer. This is to facilitate both the participants' choice[6], and the analysis[7]. Note that all payoffs are available in a simulator when the participants make their decisions.

In addition, and simultaneously to the quantity choice, the retailers are asked to reveal their beliefs about their rival's offer. In other words, we ask them to guess the offer the supplier would make to the rival for each possible move. We ask these two specific questions: "Imagine the supplier offers you a high price, what price do you think it will offer to the other retailer?" and "Imagine the supplier offers you a low price, what price do you think it will offer to the other retailer?".[8]

Treatment HE

Quantity bought by retailer i \ Quantity bought by the other retailer	0	1	2	3
0	69	69	69	69
1	103	100	46	45
2	206	98	96	62
3	129	126	75	45

Treatment LE

Quantity bought by retailer i \ Quantity bought by the other retailer	0	1	2	3
0	28	28	28	28
1	62	59	5	4
2	165	57	55	21
3	88	85	34	4

Both treatments

Price set by the supplier \ Quantity bought by the retailer	0	1	2	3
p^H	0	36	/	/
p^L	0	/	30	45

Table 1: Players' payoff matrices

[6] The objective of the restriction is to minimize the set of retailers' strategies. First, we keep the rejection strategies ("0 quantity"). Second, we keep the equilibrium strategies ("0 quantity" following PH and "2 quantities" following PL at Eq. L, "1 quantity" following PH and "2 quantities" following PL at Eq. H). Third, we keep the optimal deviations if beliefs are not sufficiently robust ("3 quantities" upon receiving unexpected price PL at Eq. H, "1 quantity" upon receiving unexpected price PH at Eq. L). Therefore, upon obtaining PH, a retailer can choose between 0 and 1 whereas, upon receiving PL, a retailer can choose between 0, 2 and 3.

[7] In addition, as we will see in the following, by restraining the strategy set, the thresholds w_L and w_H are respectively given by $w_{L_{1/0}}$ and $w_{H_{3/2}}$. Thereby, we avoid for instance, that in one treatment, w_L is given by $w_{L_{1/0}}$, while in the other treatment w_L is given by $w_{L_{2/0}}$ or $w_{L_{3/0}}$. The same is true for for w_H.

[8] Eliciting both actions and beliefs raises questions as to whether eliciting beliefs might change the action or not. This issue is discussed in the literature in which incentives for truthful reporting are based on the realization of a random variable by means of Proper Scoring Rules (PSR). Basically, a scoring rule measures the accuracy of a probabilistic prediction and its form can be linear, quadratic, logarithmic, etc. The reported results in this literature are inconclusive. Whereas some papers, albeit few (e.g. Smith, 2013 and Costa-Gomes *et al.*, 2014), report preliminary evidence of a causal effect between elicited beliefs and equilibrium actions in subjects' play, most papers state that there is no evidence of such an impact (Blanco *et al.*, 2010; Schotter and Trevino, 2014; Holt and Smith, 2016). In our experiment, the presence of a simulator should limit this impact insofar as participants can already have a clear overview of the impact of their actions. The additional understanding brought by the belief elicitation should be minimized.

As mentioned above, the participants make all their choices by observing the pay-off matrix of each player (retailer and supplier), summarized for both treatments in Table 1. All payoffs are in ECU. When all the participants have made their choices, the computer matches their decisions and displays their realized pay-offs. Note that if a retailer's belief matches the supplier's play, then this retailer is rewarded additionally 40 ECU.

Participants play this vertical contracting game for 25 periods. However, they are only rewarded the payoff of a random period. In addition, they do not necessarily interact repeatedly with the same participants since they play in groups, i.e. triplets of 1 supplier and 2 retailers, which are randomly rematched at each new period. In this section, we have focused on the task design in order to better understand the predictions derived in the next section. Section 3.3 further details the experimental procedure.

3.2 Predictions

As each retailer must secretly choose a quantity for each supplier's possible offer, we obtain the following thresholds w_L and w_H for both treatments:

$$w_L = \frac{u(e) - u(e-23)}{u(e+34) - u(e-23)}\ , \ \text{and}\ \ w_H = \frac{u(e+27) - u(e+6)}{u(e+57) - u(e+6) + u(e+27) - u(e+29)} \tag{5}$$

Note that $w_L = w_{L_{1/0}}$ because it is the only feasible threshold (see Lemma 2). Also, we have $w_H = w_{H_{3/2}}$ because for all parameter values considered we have $w_{H_{3/2}} < w_{H_{0/2}}$ and the remaining threshold is not feasible (see Lemma 3).

Figure 1 presents for both treatments HE and LE the differences between the two thresholds w_L and w_H with respect to the level of risk aversion. The level of risk aversion is on the x-axis while the difference between the two thresholds, henceforth the value $w_L - w_H$, is on the y-axis. The value $w_L - w_H$ represents the size difference between both subsets of beliefs Δ_L and Δ_H such that: i) when $w_L - w_H > 0$ then Δ_L is larger than Δ_H and equilibrium L is a better prediction than equilibrium H; and ii) when $w_L - w_H < 0$ then Δ_L is lower than Δ_H and equilibrium H is a better prediction than equilibrium L. In addition, the higher $|w_L - w_H|$, the greater the difference between the two subsets of beliefs Δ_L and Δ_H.

Consider risk-neutral retailers. We have $w_L = 0,403$ and $w_H = 0,428$ and, as in Eguia *et al.* (2018), the thresholds do not depend on the level of initial endowment e. In both treatments HE and LE, the difference between the thresholds is negative, $w_L - w_H = -0,025$. Equilibrium H is then theoretically a better prediction than equilibrium L, whenever $r = 0$. The following prediction summarizes this outcome.

Prediction 1. *According to the LSB criterion built under the risk-neutral retailers assumption, equilibrium H is a better prediction than equilibrium L in both treatments.*

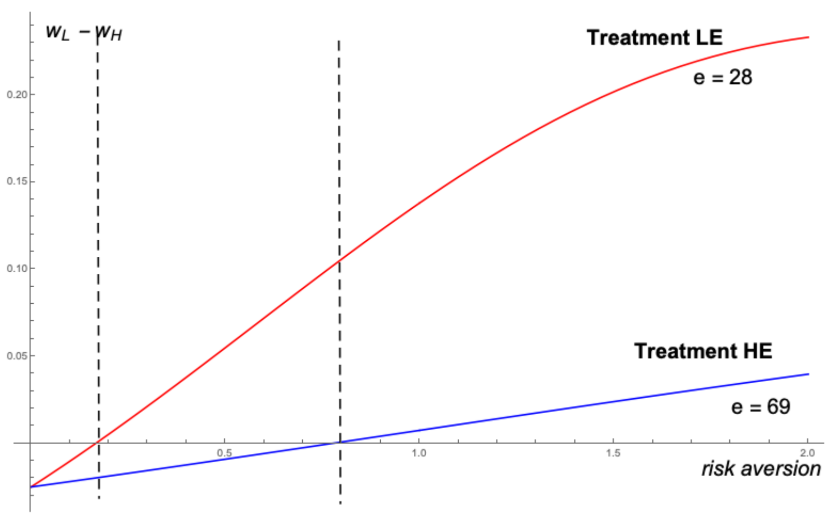


Figure 1: Threshold values with respect to different levels of risk aversion

For risk averse retailers, we observe three areas in Figure 1. For all $r \in]0, 0.17[$, w_L is lower than w_H irrespective of the treatment and equilibrium H is thus theoretically a better prediction than equilibrium L for both treatments. For all $r \in [0.17, 0.78[$, w_L is lower than threshold w_H in treatment HE but is higher in treatment LE. Equilibrium H remains a better prediction than equilibrium L only for treatment HE. In treatment LE, Equilibrium L becomes the better prediction. Finally, for all $r \in [0.78, +\infty[$, w_L is always higher than w_H irrespective of the treatment. Equilibrium L is now a better prediction than equilibrium H for both treatments. The following prediction summarizes these findings.

Prediction 2. *According to the LSB criterion built under the risk-averse retailers assumption:*

- $\forall r \in]0, 0.17[$ *equilibrium H is a better prediction than equilibrium L for both treatments.*
- $\forall r \in [0.17, 0.78[$, *equilibrium H is a better prediction than equilibrium L only in the treatment with a high initial endowment (HE). In the treatment with a low initial endowment (LE), Equilibrium L is the better prediction.*
- $\forall r \in [0.78, +\infty[$, *equilibrium L is then a better prediction than equilibrium H for both treatments.*

Finally, note that: (i) for both treatments the value $w_L - w_H$ increases with r; and (ii) for all $r \in]0, 1]$ the value $w_L - w_H$ increases at a higher rate in treatment LE than in treatment HE. In other words: (i) in both treatments the subset of beliefs supporting equilibrium L (bounded by w_L) increases with r more than the subset of beliefs supporting equilibrium H (bounded by w_H); and (ii) this effect is stronger in treatment LE than in treatment HE. These results imply that under the assumption that the retailers are not risk-neutral, we should witness more equilibrium L played in treatment LE than in treatment HE.

Prediction 3. *When the retailers are risk-averse, participants should play more equilibrium L in the treatment with a low initial endowment (LE) than in the treatment with a high initial endowment (HE).*

3.3 Experimental procedure

Each session of the experiment corresponded to a single treatment. We adopted a between-subjects design in which participants participated in a singular treatment with random group composition in every new period. When participants arrived in the laboratory, they received a personal code to preserve their anonymity and were randomly assigned to a computer station. They were then given an envelope containing a show-up fee of 5 €. Each session had 12 participants who were randomly matching into groups of one supplier and two retailers. Participants were told that they would keep this role of either supplier or retailer throughout the 25 periods of the game, but that the computer would randomly re-match them into another group at each new period.

Before the experiment started, the experimenter read the instructions aloud to the participants. The participants could also read the instructions by themselves since they were also projected on a common screen. This clearly indicated that the instructions were identical for all the participants. At the end of the instructions, participants answered a questionnaire to check their understanding. After the questionnaire, participants played with a simulator of payoffs (see Appendix E) for about 5 minutes before playing the game. To make the participants fully aware of the other participants' payoffs and facilitate their understanding of the game, they had access to a simulator on the left-hand side of their screen.

During the game, the participants simultaneously stated their actions and beliefs in every period. At the end of each period, they received full feedback regarding the other participants' decisions in the same group. The computer re-matched participants in each new period. When the game ended, the participants were asked to perform the risk elicitation task (the lottery choice task). They had not been aware that this risk elicitation would occur, though they were aware that there would be several parts to the experiment.

Only one period of the vertical contracting game was used for the payment of the first part of the experiment. The total amount of ECU earned in the experiment was converted into euros at the following conversion rate: 1 ECU = 0.05 €. In total, subjects earned on average 20.43 €. This amount includes a show-up fee of 5 €, the payoff for the game, the payoff for the risk elicitation task, and finally an end-game fee of 9.5 € (in LE) or 7.75 € (in HE). Our treatment variable lies in the payoff of the game. To give another view of its weight in the game, note that its value amounts to 3.45 € in treatment HE and 1.4 € in treatment LE. It then respectively represents 64.5% of retailers' average earnings in HE and 34% of retailers' average earnings in LE.[9]

The payoff of the game also divides into the payoffs from the action and the payoff from the belief elicitation task. As we pay both actions and beliefs, the validity of the elicitation might be challenged by hedging motives. Subjects might use stated beliefs to hedge against adverse outcomes in the rest of the experiment. While hedging can indeed be a problem in belief-elicitation

[9] More precisely, the subjects' average earnings details as follows in euros across roles and treatments. *Suppliers*: Show-up fee: 5; Game: 2.85 (HE) 2.9 (LE); Risk test: 3.25 (HE) 2.3 (LE); End-game fee: 7.75 (HE) 9.5 (LE); *Retailers*: Show-up fee: 5; Game: 5.35 (HE) 4.1 (LE); Risk test: 2.5 (HE) 2.9 (LE); End-game fee: 7.75 (HE) 9.5 (LE).

experiments, it is less likely to be so when the hedging possibilities are not strong and prominent (Blanco *et al.*, 2010; Armantier and Treich, 2013; Schotter and Trevino, 2014). In our experiment, the retailer's payoff, if its stated belief is correct, is 40 ECU (2 €), which is a small fraction of its average payoff to the game. Thus, the risk of hedging is minimized.

We ran 18 sessions with 12 participants each, so 216 participants in total were recruited. The participants were split equally across roles and treatments: there were 36 suppliers and 72 retailers in each treatment. No participant came to more than one session. All of them were students from different disciplines (e.g. Mechanics, Physics, Economics) with minimum undergraduate mathematical skills but no prior knowledge of game theory. They were recruited through our laboratory online system. The experiment was programmed and conducted with the experimental software z-Tree (Fischbacher, 2007).

4 Participants' characteristics

This section gives an overview of the participants' demography and levels of risk aversion across the two treatments. Participants were randomly assigned a session. It was however still possible that their characteristics might be correlated with the type of treatment afterwards. In order to fully extract the impact of the initial endowment on the participants' behaviors, we want to check that there is no correlation between the participants' characteristics and the type of treatment they played.

Table 2 summarizes the distributions of the participants' demographic characteristics. In this table, μ denotes the mean and σ denotes the standard deviation. We ran several Mann Whitney tests (MW) and a Kolmogorov-Smirnov test (KS) to verify whether the two samples of subjects were identical. The MW and KS are non-parametric tests that allow for small sample sizes. The MW has the additional particularity of dealing with discrete outcomes. In our setting, we use them to test the hypothesis that the subjects' characteristics are identical between the two treatments. We display the "p-value" associated with each MW and KM. Applying the usual significance level at 0.05, we reject the hypothesis if and only if the p-value is less than (or equal to) 0.05. Table 2 confirms that the participants' characteristics are not significantly different between the two treatments (KS = 0.996 for age; the MW = 0.8918 for gender; MW = 0.4140 for field of study).

Treatment	HE		LE	
	μ	σ	μ	σ
Gender (% of male)	53	0.50	54	0.50
Age (years)	20.57	1.40	20.56	1.15
Field (% sciences)	51	0.50	57	0.50
Number of Subjects	216			

Table 2: Participants' demography

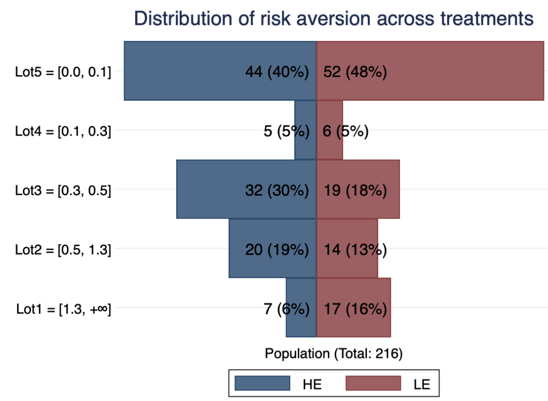


Figure 2: Participants' risk aversion levels

Figure 2 exhibits the distribution of the 216 subjects with respect to their levels of risk aversion across treatments (proxied by the lottery number chosen by the subjects). In each treatment more than half of the subjects are strictly risk averse ($r > 0.1$). Retailers and suppliers do not significantly differ with respect to their level of risk aversion (MW = 0.30). Overall, subjects' risk attitudes are not significantly different across treatments (MW = 0.77). The computed mean r for all subjects is 0.49, which sets the subjects in the second area of Figure 1 where $r \in [0.17, 0.78[$.

We conclude that there is no evidence of correlation between the participants' characteristics and their assigned treatment. We now start our main analysis.

5 Results

In this section we detail the participants' strategies and equilibrium actions. We also devote a specific subsection to the analysis of the retailers' elicited beliefs.

5.1 Suppliers

Consider the suppliers' pricing decision. Figure 3 displays an overview of the partition of the supplier's offers, and gives the MW test between treatments. Table 8 in Appendix G gives the exact frequency and the magnitude of the variations between the treatments.

Result 1. *i) The supplier's strategy "offer a low price to both retailers" (p^L, p^L) is significantly more frequent in treatment LE than in treatment HE. ii) This strategy predominates in both treatments.*

More precisely, we note that (i) the symmetric low price offer (p^L, p^L) predominates in both treatments; (ii) symmetric price offers (p^L, p^L) & (p^H, p^H) are more recurrent in treatment LE than in treatment HE, and (iii) the symmetric price offer (p^L, p^L) is more present in treatment LE than in treatment HE (it increases by 11%). In other words, from treatment HE to treatment LE, we find more equilibrium offers and these offers are those of equilibrium L. The Mann Whitney test confirms the significance of this difference in pricing distributions (MW = 0.00).

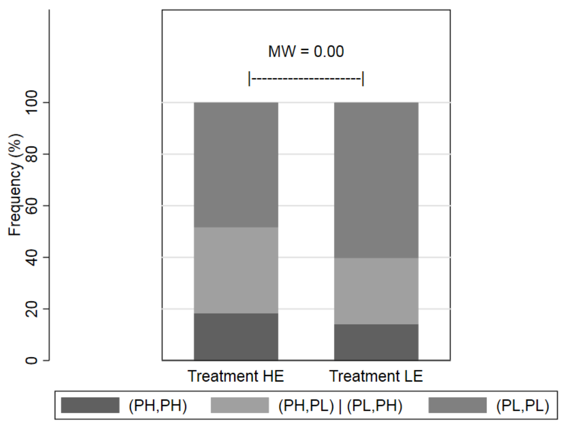


Figure 3: Suppliers' strategies

Variable	Coef.	z-stat.
Treatment LE	0.75*	1.79
Period	0.04***	4.14
Treatment LE × Period	-0.01	-0.50
Number of Observations	1 800	
Log Likelihood	-1569.70	

*** : p < .01, ** : $p < .05$, * : $p < .1$

Table 3: Logit regression on the suppliers' choices

We also perform a mixed effects ordered logit regression of their choices with respect to a treatment dummy, a period dummy and the interaction of both previous variables (see Table 3 which summarizes the whole table available in Appendix F). This analysis tells us that a supplier is significantly more likely to offer a low price rather than a high price in the low initial endowment treatment (Treatment LE > 0*).

As expected, Prediction 1 is rejected, the supplier's strategy is not in line with the equilibrium selected by the LSB criterion built under the risk-neutral retailers assumption. Moreover, we clearly have a treatment effect as described by Prediction 3. However, we may note that if we consider the estimate aggregate level of r then the result for treatment HE does not follow Prediction 2 exactly.

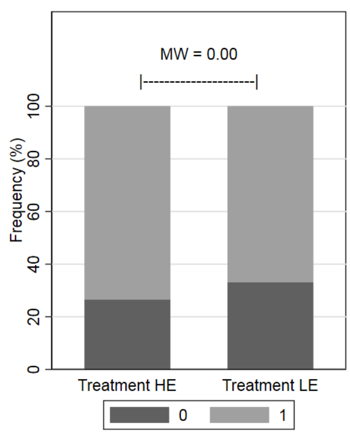
For such a level of r, the suppliers' strategies should support the equilibrium L only in treatment LE (see Figure 1).

5.2 Retailers

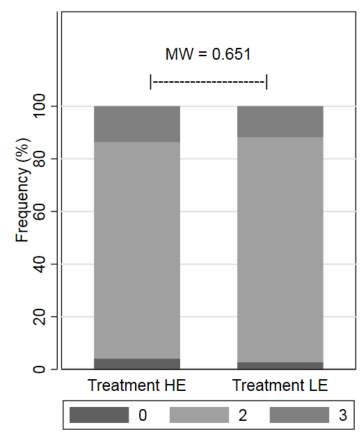
5.2.1 Retailers' strategies

Consider now the retailers' quantity decisions. Figure 4 displays an overview of the partition of the retailers' decisions and gives the MW test between treatments. Table 8 in Appendix G gives the exact frequency and the magnitude of the variations between the treatments.

Result 2. *i) The retailer's strategy "buy 0 units when the high price is offered" is significantly more present in treatment LE than in treatment HE. ii) In both treatments, the retailer's strategy "buy 1 unit when the high price is offered" prevails.*



(a) Reaction to p^H



(b) Reaction to p^L

Figure 4: Retailers' strategies

From treatment HE to treatment LE, retailers decide to buy 0 units at a significantly higher frequency in the event of receiving p^H (increase by 6%), while there is no evidence of a behavioral change when they receive p^L (participants still decide to buy 2 units at p^L, irrespective of the treatment). The respective Mann Whitney values are 0.00 and 0.6507. However, even if from treatment HE to LE we find more "buys 0 units at the high price" strategies, the "buys 1 unit at the high price" strategy still prevails (see Figure 4(a)).

Compared with Eguia *et al.* (2018), we enable retailers to be risk averse and we find that they actually are (see Section 4). So we can now investigate the effect of retailers' risk aversion on the above significant change in their reactions to price offer p^H. Table 4 provides a summary of two logistic regressions of the retailers' choices following a high price offer denoted by Model 1 and Model 2. Remember that retailers in this case choose between rejecting the offer (buy 0 units) and accepting the offer (buy 1 unit). Our dependent variable is therefore 'Reaction_PH' which takes value 1 for acceptance and 0 otherwise. In addition, we take acceptance as the baseline choice in both regressions.

Result 3. *The retailer's strategy "buy 0 units when the high price is offered" is more likely to be played when the retailers are increasingly risk averse. This effect is stronger in Treatment LE.*

	Model 1		Model 2	
Variable	Coef.	z-stat.	Coef.	z-stat.
Treatment LE	0.542***	3.62	0.433***	2.46
Period	-0.001	-0.15	-0.001	-0.15
Treatment LE × Period	-0.018*	-1.77	-0.019*	-1.81
Lot1	-		0.994***	4.99
Treatment LE × Lot 1	-		-0.106	-0.43
Lot 2	-		-0.092	-0.58
Treatment LE × Lot 2	-		-0.136	-0.60
Lot 3	-		-0.059	-0.46
Treatment LE × Lot 3	-		0.372***	1.97
Lot 4	-		-0.520	-1.64
Treatment LE × Lot 4	-		0.029	0.07
Lot 5	-		(omitted)	
Treatment LE × Lot 5	-		(omitted)	
Constant	-1.00***	-9.11	-1.028***	-7.86
Log Likelihood	-2182.0		-2135.5	
Number of Observations	3600		3600	

*** : p < .01, ** : $p < .05$, * : $p < .1$

Table 4: Logit regression on retailers' strategies following offer PH

Model (1) derives the simpler regression using as explanatory variables: the type of treatment, the period, and the interaction between treatment and period. The result tells us that there is a natural behavior to reject relatively less a high price than to accept it (*Constant*<0). This behavioral pattern softens in Treatment LE ($Treatment$>0) which implies that retailers reject relatively more than they accept when their endowment increases. This corresponds to the treatment effect we found.

Model (2) refines the analysis based on retailers' elicited level of risk aversion. It runs a more focused regression using proxies of risk attitude as additional explanatory variables: the lottery number that subjects choose in the risk test, the interaction of these lottery choices, and the treatment they play. We find that the natural behavioral pattern, of relatively less rejection than acceptance of a high price, mainly comes from low risk-averse retailers, those who chose Lot5 ($Constant$<0, $Constant$ being now associated to subjects who chose Lot5). The presence of high-risk averse retailers, those who chose Lot1, softens this pattern ($Lot1$>0). Interestingly, low risk-averse retailers, again those who chose Lot5, still reject relatively more than they accept when in Treatment LE ($Treatment$ >0). Yet, the effect is weaker ($Treatment(Model2) < Treatment(Model1)$) than the general effect and is actually greatly reinforced by the presence of medium risk-averse retailers, those who chose Lot3 ($Treatment$*$Lot3$ >0).

To sum up, Table 4 confirms the presence of a treatment effect: retailers are more likely to reject than to accept when in treatment LE. This analysis also shows that risk aversion per se affects the way of contracting. High risk-averse retailers decrease the likelihood of having equilibrium H in treatment HE. This somehow supports Prediction 2 that high risk-averse retailers should consider equilibrium L as a better prediction than H in HE. In addition, low and medium risk-averse retailers' choices are at the core of the treatment effect: they increase the likelihood of having equilibrium L in Treatment LE. This sharpens Prediction 3: the treatment effect mainly comes from low and medium risk-averse retailers.

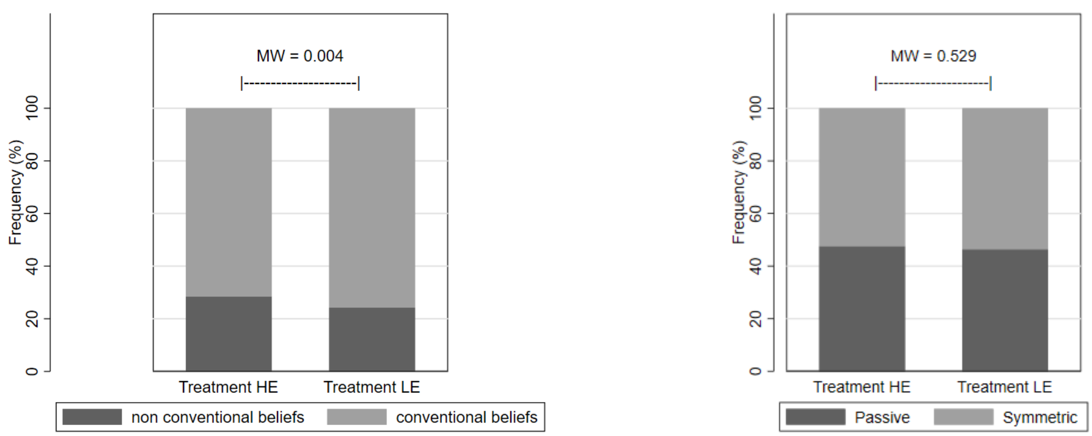
The retailers' strategies are more in line with the strategy supporting equilibrium H than the strategies supporting equilibrium L in both treatments. In view of the estimated aggregate value of r, this result does not follow Prediction 2. Indeed, for $r = 0.49$ the retailers' strategies should support equilibrium H in treatment HE and L in treatment LE (see figure 1). Nonetheless, the analysis of the retailer's strategies based on retailers' elicited level of risk aversion shows that increasing risk aversion decreases the likelihood of having equilibrium H in both treatments, which supports

Prediction 2.

5.2.2 Elicitation of retailer's beliefs

Consider now the retailers' beliefs elicited.[10] Figure 5 displays an overview of the partition of the retailers' beliefs and gives the MW test between treatments. We classify the subjects' answers to the belief elicitation task (detailed in Section 3.1) into three categories. When, irrespective of the supplier's offer, a retailer expects the rival to get p^L, the expectation is based on *passive beliefs*. When a retailer expects the rival to get the exact same price as the offer received from the supplier, it is based on *symmetric beliefs*. We define *passive beliefs* and *symmetric beliefs* as *conventional beliefs*. In any other case, we consider that the retailer has beliefs which are not consistent with the equilibria mentioned in Section 2. We define these beliefs as *non-conventional beliefs*.

Result 4. *i) In treatment LE and compared to treatment HE, there are significantly more passive beliefs and symmetric beliefs. ii) There is a majority of symmetric beliefs in both treatments.*



(a) all beliefs

(b) conventional beliefs

Figure 5: Retailers' beliefs

Our results show that there are more *conventional beliefs* in treatment LE than in treatment HE (see Figure 5(a)), but within the *conventional beliefs* themselves the proportions of passive

[10]Remember that, as the elication of beliefs occurs before price offers, the beliefs are independent of the real price offers.

and symmetric beliefs are not significantly different from one treatment to the other (see Figure 5(b)). This means that when the initial endowment is low, the "formation" of *conventional beliefs* is favored but it does not trigger the emergence of a particular *conventional belief*. In this way, there is still a majority of symmetric beliefs in treatment LE.[11] As with retailers 'strategies (see Result 2 ii)), on the whole, retailers' beliefs support equilibrium H more than equilibrium L.

The next subsection details and analyzes the equilibrium actions played by the participants.

5.3 Equilibrium actions

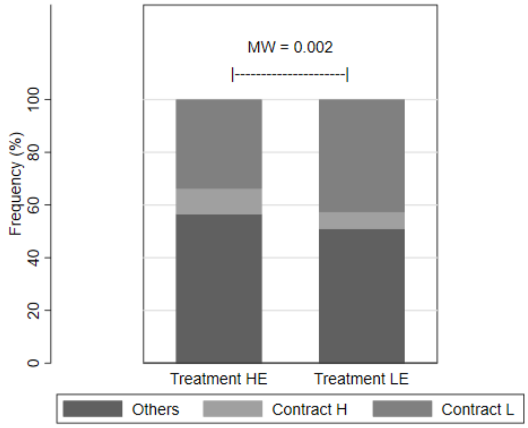
Combining the suppliers' equilibrium actions and the retailers' equilibrium actions, we obtain the partition of equilibrium actions detailed in Figure 6. Table 8 in Appendix G gives the exact frequency and the magnitude of the variation between the treatments. Equilibrium actions are defined as follows. *Equilibrium action L* stands for the equilibrium action profile in which the supplier offers a low price to both retailers, who each buy two units of inputs. *Equilibrium action H* stands for the equilibrium action profile in which the supplier offers a high price to both retailers, who each buy one unit. Finally, *others* includes all the other situations.

Result 5. *i) Participants in the treatment with a low initial endowment (LE) play significantly more equilibrium action L than those in the treatment with the high initial endowment (HE). ii) In both treatments participants play more equilibrium action L than equilibrium action H.*

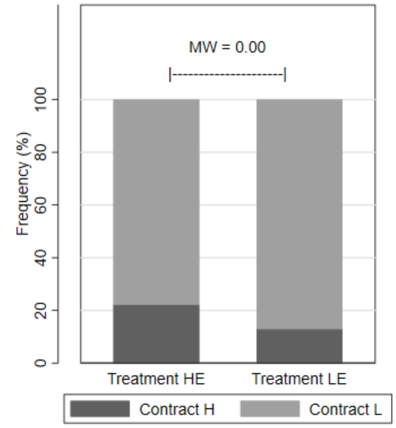
Provided an equilibrium action has been reached, we find that the participants in treatment LE play significantly more action profile L than those in treatment HE (MW = 0.00): equilibrium actions L increase by 9%, while equilibrium actions H and "others" decrease by 4% and 5% respectively. This result is in line with the previous ones: it confirms a treatment effect as given by Prediction 3, and Prediction 1 is *de facto* rejected. This clearly confirms the value to include risk aversion in the LSB criterion.

Our results on equilibrium actions, coupled with those on strategies and beliefs, also give us information on the role of actors in the equilibrium selection process. Let us sum up our findings.

[11] In treatment HE the symmetric beliefs represent 37% of all beliefs *vs* 34% for the passive beliefs; in treatment LE the symmetric beliefs represent 41% of all beliefs *vs* 35% for the passive beliefs.



(a) all eq. actions



(b) conditional eq. actions

Figure 6: Participants' equilibrium actions

We find that in both treatments the participants play more equilibrium actions L than equilibrium actions H. This is in line with the suppliers' choices where strategies (p^L, p^L) also prevail in both treatments. This contrasts, however, with the retailers' strategies, which, in both treatments, are more consistent with the strategy supporting equilibrium H than the strategies supporting equilibrium L. In view of the estimated aggregate value of $r = 0.49$, none of its results follow Prediction 2 exactly, nonetheless, these results indicate that suppliers are the pivotal actors in in the equilibrium selection process.

In particular, it seems that suppliers are reluctant to propose price p^H in treatment HE although they are expected to do so, according to Prediction 2. An interpretation is that this occurs because the suppliers overestimate the retailers' "buy 0 units when the high price is offered" strategy. This overestimation can be a consequence of the suppliers' overestimation of the retailers' risk aversion. Remember that the LSB criterion informs us that the higher the level of risk aversion, the higher the likelihood of subjects playing equilibrium L (see Figure 1). While the level of risk aversion is common knowledge in the theoretical framework, this is not the case in the experiment. An overestimation by the suppliers of the level of retailers' risk aversion may then explain why they play equilibrium L, while the retailers' strategy to "buy 1 unit when the price is high" prevails.

5.4 Dynamic perspective

Table 3 and Table 4 already provide some insights regarding the change of subjects' decisions over the periods. Precisely, Table 3 tells us that suppliers in treatment HE seem to offer more low prices as they play subsequent periods in the experiment (Period > 0***). However, this pattern does not extend to suppliers in treatment LE. On the other hand, Table 4 points out that retailers in treatment LE tend increasingly to accept more than they reject over the periods (Treatment$\times$Period < 0*). Nevertheless, this pattern is not highly significant and is absent in treatment HE. Overall, some learning dynamics is likely in the experiment and it is worth investigating in the present section.

Consider treatment LE. The retailers tend more and more to accept rather than reject over the periods. This behavior is nevertheless very smooth (in Table 4, the coefficient of the variable Treatment$\times$Period is -0.018 and is significant only at the 10% level). Likewise, the suppliers' choices do not exhibit significant changes over the periods. Conversely, there are more dynamics of play in treatment HE, especially from the suppliers. Figure 7 displays the suppliers' aggregate choices over 4-period-windows, except for period 1 which is used as a benchmark. We find that suppliers change their offers as they play subsequent periods. However, the directions of change seem to differ depending on the periods considered.

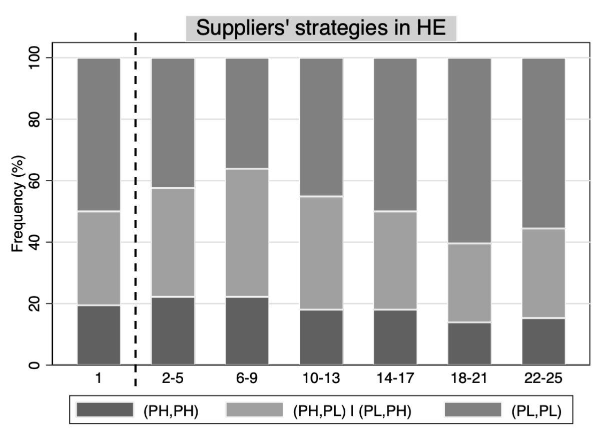


Figure 7: Dynamics of suppliers' strategies in HE

Table 5 provides an ordered Logit regression on the suppliers' choices at period t with respect to their choices at the previous period $t-1$ with interaction whether the period of interest is less than the 10^{th} period. We find that suppliers are more likely to set a high price at period t when having set two high prices at the previous period regardless of the period of interest (lagPP0_PeriodInf10 < 0** and lagPP0_PeriodSupEq10 < 0**). However, after the 10^{th} period, this behavior is less significant. In addition, after the 10^{th} period, suppliers are more likely to set a low price after having set two low prices (lagPP2_PeriodSupEq10 > 0**).

Variable	Coef.	z-stat.
LagPP0_PeriodInf10	-0.88**	-2.32
LagPP1_PeriodInf10	-0.40	-1.08
LagPP2_PeriodInf10	0.13	0.34
LagPP0_PeriodSupEq10	-0.77**	-2.08
LagPP1_PeriodSupEq10	-0.13	-0.36
LagPP2_PeriodSubEq10	0.68**	1.99
Number of Observations	900	
Log Likelihood	-888.38	

*** : p < .01, ** : $p < .05$, * : $p < .1$

Table 5: Logit regression on suppliers' choices at period t

Both Figure 7 and Table 5 show that suppliers tend to stick to high pricing strategies, related to equilibrium actions H, until approximately period 10 and then additionally converge towards equilibrium low pricing strategies, thus inducing equilibrium actions L.

To sum up, the dynamics playing out here suggests that suppliers may be the pivotal actors in our experiment. Moreover, the presence of a convergence delay towards pricing strategies inducing equilibrium actions L in treatment HE and the absence of such a convergence in treatment LE relate to Eguia *et al.* (2018)'s conjecture that when thresholds are close to one another it should be more difficult for the subjects to coordinate on the equilibrium action predicted by the criterion. This gives another insight to explain the reason why Prediction 2 is rejected in Treatment HE.

6 Conclusion

Sequential games with imperfect information often feature multiple equilibria which depend on players' out-of-equilibrium beliefs. The Largest Set of Beliefs criterion, proposed by Eguia *et al.* (2018) for this class of games, selects equilibrium actions without belief restriction but supposes that the players are all risk neutral. In this paper, we focus on a vertical contracting game with secret contracts and theoretically characterize the effect of players' level of risk aversion on such equilibrium selection. Specifically, we consider a risk neutral supplier making secret offers to two risk averse retailers. We then select the players' equilibrium actions by generalizing the LSB criterion so that it considers the retailers' risk aversion. We also revisit Eguia *et al.* (2018)'s experiment by considering the impact of a variation of risk averse retailers' initial endowment.

Our results show the need to include risk aversion in the LSB criterion. The presence of risk aversion affects the size of the belief sets that support each equilibrium, and as a consequence, a variation of the initial endowment modifies the players' strategies and equilibrium actions. If the LSB criterion without risk aversion does not predict any endowment effect on the players' strategies and equilibrium actions, we show theoretically and experimentally that this is not the case when risk aversion is considered. Finally, our results also suggest that suppliers can be pivotal actors in the coordination of players on the equilibrium. This result opens the way for future experimental research on the role of players playing first in the equilibrium selection process in sequential games with imperfect information.

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Appendices

A Proof of Lemma 1

To show equilibrium L and equilibrium H are Perfect Bayesian Equilibria in pure strategies (henceforth PBE), we show that no player deviates from equilibrium strategies given their beliefs and that these beliefs are consistent with equilibrium choices. We begin with the proof for equilibrium L and finish with the proof for equilibrium H.

- Proof equilibrium L

To prove the existence of the equilibrium L we consider "passive beliefs". We focus our proof on the case where $r = 0$. As the level of r doesn't modify the preferences over the payoffs our proof then extends to all values of r considered in our analysis.[12] In this equilibrium, the supplier sets $p^L = 15$ to both retailers thinking each retailer rejects $p^H = 36$ while buys 2 units at $p^L = 15$. Each retailer rejects p^H while buys 2 units at p^L thinking the supplier sets p^L to both retailers. It boils down to the following strategy vector $((p^L, p^L), (0, 2), (0, 2))$.

Retailers do not deviate. (i) On-path and given the beliefs, the price offered is $p^L = 15$, and the retailer i earns $\pi_i(q_i, 2) = e - 33 + P(q_i + 2)q_i - 15q_i$ if $q_i > 0$ and $\pi_i(q_i, 2) = e$ otherwise. We find $\pi_i(0, 2) = e$, $\pi_i(1, 2) = e - 2$, $\pi_i(2, 2) = e + 27$, and $\pi_i(3, 2) = e + 6$ which implies that $\pi_i(2, 2)$ is higher than the other profits for all admissible value of e. The retailer does not deviate on-path. (ii) Off-path and given beliefs, the price offered is $p^H = 36$, the retailer i earns $\pi_i(q_i, 2) = e - 33 + P(q_i + 2)q_i - 36q_i$ if $q_i > 0$ and $\pi_i(q_i, 2) = e$ otherwise. We find $\pi_i(0, 2) = e$, $\pi_i(1, 2) = e - 23$, $\pi_i(2, 2) = e - 15$, and $\pi_i(3, 2) = e - 57$ which implies that $\pi_i(0, 2)$ is higher than the other profits for all admissible value of e. The retailer does not deviate off-path.

Supplier does not deviate. Given the beliefs, the suppliers earns $\pi_0(p^L, p^L) = 15 \times 2 + 15 \times 2 = 60$. If it deviates bilaterally or multilaterally, it respectively earns $\pi_0(p^H, p^L) = 36 \times 0 + 15 \times 2 = 30$ and $\pi_0(p^H, p^H) = 36 \times 0 + 36 \times 0 = 0$ which is less than the previous profit. The supplier does not

[12] Note that because our concave utility function only applies to positive payoffs, the domain set of the initial endowment for which equilibrium L and H hold shrinks: the initial endowment must rise and reach a sufficiently high level to avoid negative payoffs.

deviate.

Belief consistency. Given beliefs, we see that each retailer rejects p^H and buys 2 units at p^L while the supplier offers p^L to both retailers. Therefore, beliefs are consistent; Equilibrium L is a PBE with passive beliefs.

- Proof equilibrium H

To prove the existence of equilibrium H we consider "symmetric beliefs". As previously, we focus our proof on the case where $r = 0$. In this equilibrium, the supplier sets $p^H = 36$ to both retailers thinking each retailer buys 1 unit at $p^H = 36$ while buys 2 units at $p^L = 15$. Each retailer buys 1 unit at p^H while buys 2 units at p^L thinking the supplier sets $p_i = p^H$ to both retailers. It boils down to the following strategy vector $((p^H, p^H), (1, 2), (1, 2))$.

Retailers do not deviate. (i) On-path and given the beliefs, the price offered is $p^H = 36$, and the retailer earns $\pi_i(q_i, 1) = e - 33 + P(q_i + 1)q_i - 36q_i$ if $q_i > 0$ and $\pi_i(q_i, 1) = e$ otherwise. We find $\pi_i(0, 1) = e$, $\pi_i(1, 1) = e + 31$, $\pi_i(2, 1) = e - 13$, and $\pi_i(3, 1) = e - 6$ which implies that $\pi_i(1, 1)$ is higher than the other profits for all admissible value of e. The retailer does not deviate on-path. (ii) Off-path and given the beliefs, the price offered is $p^L = 15$, and the retailer earns $\pi_i(q_i, 2) = e - 33 + P(q_i + 2)q_i - 15q_i$ if $q_i > 0$ and $\pi_i(q_i, 2) = e$ otherwise. We find $\pi_i(0, 2) = e$, $\pi_i(1, 2) = e - 2$, $\pi_i(2, 2) = e + 27$, and $\pi_i(3, 2) = e + 6$ which implies that $\pi_i(2, 2)$ is higher than the other profits for all admissible value of e. The retailer does not deviate off-path.

Supplier does not deviate. Given the beliefs, the supplier earns $\pi_0(p^H, p^H) = 36 \times 1 + 36 \times 1 = 72$. If it deviates bilaterally or multilaterally, it respectively earns $\pi_0(p^H, p^L) = 36 \times 1 + 15 \times 2 = 66$ and $\pi_0(p^L, p^L) = 15 \times 2 + 15 \times 2 = 60$ which is less than the previous profit. The supplier does not deviate.

Belief consistency. Given beliefs, we see that each retailer buys 1 unit at p^H and buys 2 units at p^L while the supplier offers p^H to both retailers. Therefore, beliefs are consistent; Equilibrium H is a PBE with symmetric beliefs.

B Proof of Lemma 2

After observing the out-of-equilibrium offer $\bar{p}_i = p^H$, retailer i does not deviate from the equilibrium L by purchasing one unit rather than zero unit whenever:

$$w(p^H_{-i}|\bar{p}_i = p^H).u(\pi_i(1,0,36)) + (1 - w(p^H_{-i}|\bar{p}_i = p^H)).u(\pi_i(1,3,36)) \leq u(e) \text{ or}$$
$$w(p^H_{-i}|\bar{p}_i = p^H).u(e - 33 + 103 - 36) + (1 - w(p^H_{-i}|\bar{p}_i = p^H)).u(e - 33 + 46 - 36) \leq u(e), \text{ or}$$
$$w(p^H_{-i}|\bar{p}_i = p^H) \leq w_{L_{1/0}} \equiv \frac{u(e) - u(e-23)}{u(e+34) - u(e-23)}$$

Similarly, purchasing two units (respectively three units) is not a profitable deviation whenever $w(p^H_{-i}|\bar{p}_i = p^H) \leq w_{L_{2/0}} \equiv \frac{u(e)-u(e-15)}{u(e+95)-u(e-15)}$ (respectively $w(p^H_{-i}|\bar{p}_i = p^H) \leq w_{L_{3/0}} \equiv \frac{u(e)-u(e-57)}{u(e-3)-u(e-57)}$).

As a consequence, the subset of retailer i's belief $w(p^H_{-i}|\bar{p}_i = p^L) \leq w_H$, with $w_L = \min\{w_{L_{1/0}}, w_{L_{2/0}}, w_{L_{3/0}}\}$, implies that purchasing either one, two or three units is not a profitable deviation from the equilibrium L after observing the out-of-equilibrium offer $\bar{p}_i = p^H$. This subset supports then the equilibrium L.

C Proof of Lemma 3

After observing the out-of-equilibrium offer $\bar{p}_i = p^L$, retailer i does not deviate from the equilibrium H by purchasing three units rather than two units whenever:

$$w(p^H_{-i}|\bar{p}_i = p^L).u(\pi_i(3,1,15)) + (1 - w(p^H_{-i}|\bar{p}_i = p^L)).u(\pi_i(3,2,15))$$
$$\leq w(p^H_{-i}|\bar{p}_i = p^L).u(\pi_i(2,1,15)) + (1 - w(p^H_{-i}|\bar{p}_i = p^L)).u(\pi_i(2,2,15)) \text{ or}$$
$$w(p^H_{-i}|\bar{p}_i = p^L).u(e - 33 + 3(45-15)) + (1 - w(p^H_{-i}|\bar{p}_i = p^L)).u(e - 33 + 3(28-15))$$
$$\leq \; w(p^H_{-i}|\bar{p}_i = p^L).u(e - 33 + 2(46-15)) + (1 - w(p^H_{-i}|\bar{p}_i = p^L)).u(e - 33 + 2(45-15)) \text{ or}$$
$$w(p^H_{-i}|\bar{p}_i = p^L) \leq w_{H_{3/2}} \equiv \frac{u(e+27) - u(e+6)}{u(e+57) - u(e+6) + u(e+27) - u(e+29)}.$$

Similarly, purchasing on unit (respectively zero unit) is not a profitable deviation whenever $w(p^H_{-i}|\bar{p}_i = p^L) \leq w_{H_{1/2}} \equiv \frac{u(e+27)-u(e-2)}{u(e+52)-u(e-2)+u(e+27)-u(e+29)}$ (respectively $w(p^H_{-i}|\bar{p}_i = p^L) \leq w_{H_{0/2}} \equiv$

$\frac{u(e+27)-u(e)}{u(e+27)-u(e+29)}$).

As a consequence, the subset of retailer i's belief $w(p^H_{-i}|\bar{p}_i = p^L) \leq w_L$, with $w_L = \min\{w_{H_{0/2}}$, $w_{H_{1/2}}$, $w_{H_{3/2}}\}$ implies that purchasing either zero, one, or three units is not a profitable deviation from the equilibrium H after observing the out-of-equilibrium offer $\bar{p}_i = p^L$. This subset supports then the equilibrium H.

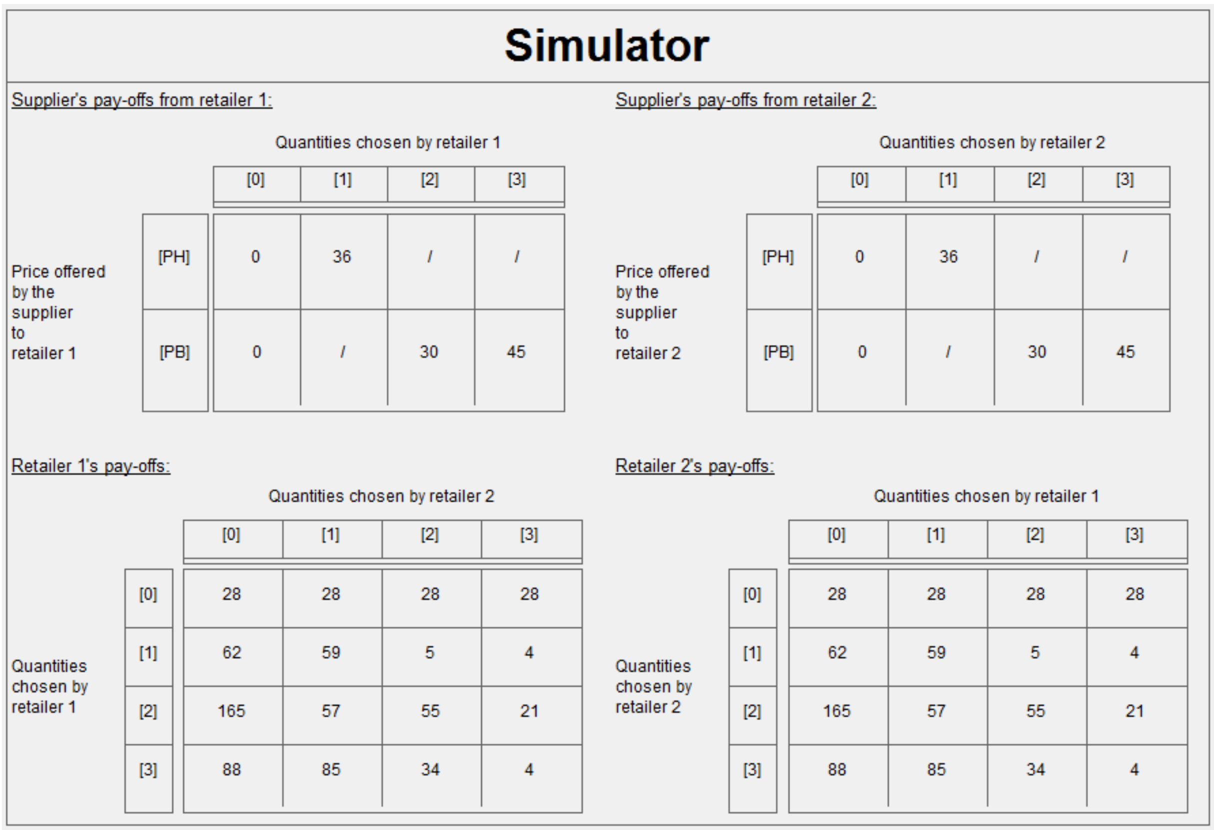
D Risk elicitation task

Number	Probabilities	Gains
1	50 % 50 %	2 € 2 €
2	50 % 50 %	3 € 1.5 €
3	50 % 50 %	4 € 1 €
4	50 % 50 %	5 € 0.5 €
5	50 % 50 %	6 € 0 €

Table 6: The ordered lottery selection (Eckel & Grossman's method)

Table 6 provides an overview of our risk elicitation task. We depart from the test designed by Crosetto and Filippin (2015) in their "EG treatment" (in line with Eckel and Grossman (2002, 2008)'s test (EG test/task) procedure) and divide all the outcomes by one half (due to budget constraints). Given the CRRA utility this theoretically does not affect the answers of the participants (see Moffatt (2015)). This test is a simple single-choice design where subjects are asked to choose one gamble from six different gambles where the probabilities of low and high outcomes are always 0.5 in each gamble. In an experiment, Dave *et al.* (2010) compared the behaviors in this task to those in the Holt and Laury (2002)'s task and found that subjects considered the former task to be more simple to understand. The EG task provided more reliable estimates of risk aversion for subjects with limited mathematical ability.

E Simulator of pay-offs for treatment LE



Simulator

Supplier's pay-offs from retailer 1:

Price offered by the supplier to retailer 1 \ Quantities chosen by retailer 1	[0]	[1]	[2]	[3]
[PH]	0	36	/	/
[PB]	0	/	30	45

Supplier's pay-offs from retailer 2:

Price offered by the supplier to retailer 2 \ Quantities chosen by retailer 2	[0]	[1]	[2]	[3]
[PH]	0	36	/	/
[PB]	0	/	30	45

Retailer 1's pay-offs:

Quantities chosen by retailer 1 \ Quantities chosen by retailer 2	[0]	[1]	[2]	[3]
[0]	28	28	28	28
[1]	62	59	5	4
[2]	165	57	55	21
[3]	88	85	34	4

Retailer 2's pay-offs:

Quantities chosen by retailer 2 \ Quantities chosen by retailer 1	[0]	[1]	[2]	[3]
[0]	28	28	28	28
[1]	62	59	5	4
[2]	165	57	55	21
[3]	88	85	34	4

Figure 8: Screenshot of simulator of players' pay-offs

F Robustness check of the supplier's strategy

Table 7 displays the results of the three-level mixed effects ordered logit regression of low prices offered by suppliers as a function of treatment, period and the interaction between treatment and period. We ran an ordered Logit regression since the number of low prices is discrete (0, 1 or 2) and they are ordered. The mixed effects simply account for unobserved heterogeneity. In our setting, this heterogeneity is captured through a random effect for sessions and then a random effect for subjects nested within sessions. In this model, the observations (a subject in a session at a given period) comprise the first level, the subjects comprise the second level, and the sessions comprise the third.

	Coef.	Std. Err.	Odds Ratio	z	Pr > $\lvert z \rvert$
Treatment LE	0.75	0.42	2.11	1.79	0.07
Period	0.04	0.01	1.04	4.14	0.00
Treatment LE * Period	−0.01	0.01	0.99	−0.50	0.62
Cut 1	−1.30	0.30			
Cut 2	0.57	0.29			
Session variance	0.22	0.24			
Subject variance	1.48	0.35			
Number of Observations			1 800		
Number of Groups			18		
Number of Subjects			72		
Log Likelihood			- 1569.70		
Wald χ^2			29.64		

Table 7: Three-level (session, subject, observation) mixed effects ordered logit regression of low prices with all periods

Note also that we keep the last periods even though there could be an "end-experiment" effect leading participants to try new actions in the last periods. The same regression without the 5 last periods increases the significance of the treatment effect. We keep the first periods of the experiment because participants explored simulators before playing the game, thus eliminating a potential "learning" effect. Treatment LE is a dummy variable that takes value one if the treatment is LE and zero otherwise.

Overall, we find that a supplier is significantly more likely (at a significance level of 0.10) to offer a low price rather than a high price in the low initial endowment treatment.

G Magnitude of treatment effects

Variable		Treatment HE	Treatment LE	Magnitude
Suppliers' price	(PH, PL)/(PL,PH)	33	26	-7
	(PH, PH)	18	14	-4
	(PL, PL)	49	60	+11
Retailers' reaction to PH	Reject	27	33	+6
	Accept	73	67	-6
Groups' equilibrium action	Others	56	51	-5
	Action H	10	6	-4
	Action L	34	43	+9

Table 8: Frequency of decision variables and magnitude of treatment effects in the experiment (all figures in %)

Note: Suppliers' and groups' variables: 900 observations (4 groups/suppliers*25 periods*9 sessions); Retailers' variables: 1800 observations (8 retailers*25 periods*9 sessions)