Equilibrium liquidity discovery: an experimental investigation

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Abstract

This paper investigates liquidity formation in financial markets. Liquidity is to some extent a self-fulfilling phenomena: An investor who anticipates the market to be liquid will be more willing to participate, expecting her orders to receive good execution. If other potential participants share the same belief, the market will be actually liquid. Conversely, a common belief of low liquidity would result in a poorly liquid market. We study traders' propensity to coordinate on the high liquidity allocation depending on whether *i)* this allocation is a Nash equilibrium, *ii)* a preopening period precedes the actual market, and *iii)* market in the past proved to be liquid. Using a laboratory experiment, we show that *i)* when it is not a Nash equilibrium, traders do not coordinate on the high liquidity allocation, *ii)* a preopening period improves the level of coordination not only on the high but also the low liquidity equilibria, *iii)* high liquidity in the past fosters coordination on the high liquidity equilibrium when there is a preopening period.

1 Introduction

Concentrated-trading patterns in transaction data is a well established empirical fact. Financial markets tend to exhibit periods of high trade, high liquidity, intertwined with periods of low trade, low liquidity (see e.g. Sarkar and Schwartz, 2006, for a recent account of this phenomenon).

Common explanations for such a clustering of trading volume have long relied on the intuition that a self-fulfilling process is at work: an investor who anticipates the market to be liquid will be more willing to participate, expecting her orders to receive good execution. If other potential participants share the same belief, the market will be actually liquid. Conversely, a common belief of low liquidity would result in a low liquid market.

But what drives liquidity coordination? Using a laboratory experiment, we study traders' propensity to coordinate on the high liquidity allocation depending on whether i) this allocation is a Nash equilibrium, ii) a preopening period precedes the actual market, and iii) market in the past proved to be liquid.

The market microstructure literature has long emphasized that different levels of liquidity may arise in a market when uninformed investors can decide when or where to trade. Admati and Pfleiderer (1988) use an extended version of Kyle (1985) where uninformed agents can choose the timing of their trade. They show that uninformed traders choose to cluster together so that the market experiences periods of high liquidity followed by periods of relative illiquidity. Pagano (1989) models competing marketplaces. He shows that, when agents can only trade in one of the two markets, network effects induce liquidity to be concentrated in one market or the other. Finally, Dow (2004) fully endogenizes the motive for uninformed trading: uninformed traders are hedgers with an initial risk exposure correlated with the asset payoff. The presence of informed traders reduces the willingness to trade of uninformed traders. Dow (2004) shows that there can be multiple equilibria, some with a high level of liquidity and others with a low level of liquidity.

This literature shows that there can be liquidity traps: financial markets can be stuck in a self-sustained (or self-fulfilling) low liquidity state, because agents have very pessimistic beliefs about the likelihood of a coordination outcome favorable to liquidity formation. Liquidity trap is not an abstract concept only meant to be discussed by financial economists. Market organizers themselves are fully aware that such a coordination failure is a real potential outcome and they tried to prevent it from happening. To do so, one of the tools that have been implemented is preopening periods.

Does a preopening period help enhancing coordination on high liquidity allocations? The empirical literature has shown that preopening periods do convey useful information about opening prices.[1] But why is is so? This question is relevant because orders submitted during the preopening period are not binding and can be canceled at any time before the opening. Due to these features, the preopening period can be subject to manipulations, in which case orders submitted during the preopening period have a poor informative content. If we neglect the cost of submitting an order during the preopening period (a not very demanding assumption), participation to the preopening period enables costless, nonbinding, and nonverifiable communication: orders posted during the preopening period might be just plain "cheap talk".

We study these issues in the context of experimental financial markets. Subjects are students at Toulouse University. Each experimental session includes 15 replications. We use a 2 by 2 cross-cohort design where we manipulate both the existence of a high liquidity equilibrium and market structure. For some cohorts, the Pareto-dominant high liquidity allocation is a Nash equilibrium in the first and the last five replications of the game while it is not an equilibrium in the middle five replications. For the other cohorts, the Pareto-dominant high liquidity allocation is a Nash equilibrium in the middle five replications of the game while it is not an equilibrium in the first and the last five replications. These features allow us to study both the effect of the high liquidity allocation being an equilibrium and the effect of history on coordination. Also, for some cohorts, trading occurs in a single call market while, for other cohorts, trading occurs in a call market preceded by a preopening period.

Our main results are as follows. First, when it is not a Nash equilibrium, traders do not coordinate on the high liquidity allocation whether there is or not a preopening period. This suggests that traders realize that communication during the preopening period is not credible. Second, a preopening period improves the level of coordination not only on the high but also the low liquidity equilibria. This result shows that the presence of a preopening period may lead to a trade-off: when there is a preopening period, traders are more likely to coordinate on the same level of liquidity but

[1] Several papers have investigated the role of preopening period in price formation and liquidity discovery. Biais, Hillion and Spatt (1999) show that preopening prices at the Paris Bourse include useful information for stock pricing. Cao, Ghysels, Hatheway (2000) shows that market maker preopening quotes on Nasdaq contribute to price discovery. Davies (2003) investigates the trading activity of registered traders on the Toronto Stock Exchange. Vives (1995, JET) theoretically studies information revelation during the preopening period. Dia and Pouget (2005, WP) propose a model where traders use the preopening period to implement sunshine trading, i.e., to preannounce their liquidity needs.

at the same time traders are not more likely to choose the high liquidity equilibrium. Third, high liquidity in the past fosters coordination on the high liquidity equilibrium when there is a preopening period. Overall, the preopening period appears as a useful coordination device. However, its capacity to enhance market liquidity appears to depend on traders' beliefs, shaped through market history. Prior trust or distrust in the credibility of the messages sent during a preopening period is a key factor driving the preopening's contribution to market liquidity.

The theoretical literature on Cheap Talk[2] has pointed out the conditions under which pre-play communication is or is not credible. When agents' preferences are not well aligned, messages sent during a pre-play communication phase are less likely to be deemed credible. For instance, if an agent participates in a zero-sum game, his gains will be the other's losses, and vice-versa. Thus, any message he may send before the actual play occurs will not be trusted, and he will not trust messages sent by the others. Another classical type of game where pre-play communication is not expected to enhance coordination is the prisoner's dilemma, because it is just another extreme case of conflicting interests.

By contrast, if there exists positive gains from trade, messages are more likely to be trusted and coordination is more likely to be achieved. For instance, in a typical Stag Hunt game (Skyrms, 2001), there exists a conflict between mutual benefit and risk: agents would be glad to coordinate on a Pareto-dominant Nash equilibrium, but may chose instead to individually select a safer, risk-dominant strategy, leading to a Pareto-dominated outcome.[3] Pointing out that pre-play messages sent in this conflicting context are not *self-signaling* (because the sender wants to be believed whatever his actual plan is), Aumann (1990) conjectured that coordination will eventually fail. Others, like Farrell and Rabin (1996), while acknowledging the force of Aumann's argument, have questioned its practical relevance.

Many experimental studies have been conducted to understand how the intensity of the risk/payoff conflict inherent to the Stag Hunt game impacts strategic behavior (Battalio, Samuelson, Van Huyck, 2001, and Schmidt, Shupp, Walker and Ostrom, 2003), and to measure the impact of pre-play communication on coordination.

In a laboratory experiment, Cooper, DeJong, Forsythe, and Ross (1992) found that two-way communication facilitates coordination on payoff-dominant outcomes, in the context of a Stag Hunt

[2]See e.g. Farrell and Rabin (1996).

[3]Harsanyi and Selten (1988).

style, 2-player, complete information game.[4] Our experimental design is similar to theirs, with the following differences. First, we study two games: one in which cooperation is a Nash equilibrium, and one in which cooperation is not a Nash equilibrium. The latter case will allow us to check that pre-play communication cannot create coordination on Pareto-dominant but non-Nash equilibria, and to spot manipulative behaviors. Second, in our design, subjects will play different sequences of our two games, allowing us to measure the impact of history: in particular, we will be able to assess if players who have observed manipulative behaviors in the past (while playing the single Nash game) are less likely to coordinate in subsequent two-Nash games than those who have experienced cooperative behaviors in the past. Third, we offer a financial market interpretation of our experimental results.[5,6]

The remaining of the paper is organized as follows. Section 2 describes our model. Section 3 lists our three hypotheses. Our experimental design is presented in Section 4, and Section 5 discusses our experimental results. Then, Section 6 concludes.

2 Model

There is a buyer and a seller. They differ in terms of their private valuation of the asset. The buyer assigns value v to the asset, up to $\bar{q}$ units, and then 0. The cost to the seller of providing the good is c up to $\bar{q}$ units, and then infinity. Potential gains from trade are: $(v-c)\bar{q}$. The asset is traded on a discrete pricing grid: $\{\underline{p}, p, \bar{p}\}$. For simplicity assume a symmetric structure: $\underline{p} = p - \delta$, $\bar{p} = p + \delta$, $v = \bar{p} + \epsilon$ and $c = \underline{p} - \epsilon$. Thus the potential gains from trade can be expressed as: $2(\delta + \epsilon)\bar{q}$.

The asset is traded in a uniform price call auction. Buyers can post schedules of limit orders to buy, thus submitting a demand curve to the market.

Symmetrically, sellers can submit supply curves, by placing schedules of limit orders to sell. The supply and demand curves are then confronted to determine the transaction price. This price is set to maximize the number of shares traded. If more than one price maximizes volume, then the transaction price is an arithmetic average of the candidate prices.

For simplicity, assume the buyer has the choice between only two schedules of limit orders. He

[4] Blume and Otmann (2007) found similar result in a design involving more than two players.

[5] Forsythe, Lundholm, and Rietz (1999) propose a financial interpretation of a cheap talk game tested in a laboratory experiment. Their experimental design is centered toward information asymmetry, though.

[6] A survey of experimental evidence on behavior in games with communication is proposed in Crawford (1998).

can opt for a rather low-aggressivity schedule, which we denote by $B1$. This schedule involves a limit order to buy q units if the price is not above p, and another limit order to buy $\bar{q} - q$ units if the price is not above $\underline{p}$. Alternatively, he can opt for a more aggressive schedule, which we denote by $B2$. This involves a limit order to buy q units if the price is not above $\bar{p}$, and another limit order, to buy $\bar{q} - q$ units if the price is not above p.

Symmetrically, the seller can choose between two schedules: $S1$ and $S2$. The former corresponds to a low aggressivity and involves a limit order to sell q units if the price is not below p, and another limit order to sell $\bar{q} - q$ units if the price is not below $\bar{p}$. The latter corresponds to high aggressivity and involves a limit order to sell q units if the price is not below $\underline{p}$, and another limit order to buy $\bar{q} - q$ units if the price is not below p.

If both traders opt for aggressive limit orders (i.e., place schedules $S2$ and $B2$), the market clearing price is p and the corresponding volume is $\bar{q}$. On the other hand, if both traders opt for less aggressive orders (i.e., place $B1$ and $S1$), then the price is still p, but trading volume is lower, and equal to q. Now turn to the asymmetric cases: If the buyer is aggressive, but not the seller ($B2$ and $S1$ are chosen) then again trading volume is low and equal to q, but the price is pushed upward to $(\bar{p} + p)/2$. If the seller is aggressive, but not the buyer ($B1$ and $S2$ are chosen) then again trading volume is low, but the prices is pushed downward to $(p + \underline{p})/2$.

Thus, each trader faces a typical monopolist trade-off: He can choose to trade more, generating more profits, but at the risk of an adverse price move. This risk depends on whether or not the other trader aggressively provides liquidity. We refer to this risk as liquidity risk.

The situation faced by traders can be represented in a normal game form, where the payoff of the seller is the first number in each cell, and the payoff of the buyer is the second number in each cell:

Buyer:

Seller:

	$B1$	$B2$
$S1$	$q(\epsilon + \delta), q(\epsilon + \delta)$	$q(\epsilon + \frac{3\delta}{2}), q(\epsilon + \frac{\delta}{2})$
$S2$	$q(\epsilon + \frac{\delta}{2}), q(\epsilon + \frac{3\delta}{2})$	$\bar{q}(\epsilon + \delta), \bar{q}(\epsilon + \delta)$

Note that, in the bottom right cell, trading volume is $\bar{q}$, so that total gains from trade are $2\bar{q}(\epsilon + \delta)$, while in the other cells, trading volume is q and total gains from trade are $2q(\epsilon + \delta)$. In the diagonal cells, the gains from trade are evenly split between the participants. In the off-diagonal cells, the trader with the less aggressive schedule earns greater gains than his or her counterparty.

Relying on this characterization of the payoffs, we now turn to describing the equilibrium of this game. Suppose a trader wants to maximize his minimal possible gain, across all possible actions of his counterparty. Then he or she will choose to provide limited liquidity, and opt for $S1$ in the case of the seller and $B1$ in the case of the buyer. Also, if a trader anticipates that his counterparty will offer limited liquidity, then his best response is to also offer restricted liquidity. Hence, $(S1, B1)$ is a Nash equilibrium. Finally, if a trader anticipates that his counterparty will place an aggressive schedule, then he or she prefers to also aggressively supply liquidity if and only if:

$$\bar{q}(\epsilon + \delta) \geq q(\epsilon + \delta + \frac{\delta}{2}),$$

that is:

$$(\bar{q} - q)(\epsilon + \delta) \geq q\frac{\delta}{2},$$

i.e., the benefits of trading a high quantity more than outweigh the cost of trading at a less favorable price. Under that condition $(S2, B2)$ is a Nash equilibrium. In this high liquidity equilibrium, whereby each trader, anticipating the market will be liquid, participates actively, so that the market is indeed very liquid. We collect these results in the next proposition:

Proposition 1 $(S1, B1)$ *is a Nash equilibrium, and emerges if traders want to maximize their minimum possible gain. If* $(\bar{q} - q)(\epsilon + \delta) \geq q\delta/2$*, then* $(S2, B2)$ *is also a Nash equilibrium, and there also exists an equilibrium in mixed strategies where agents choose to trade aggressively with probability* $\frac{q}{\bar{q}-q}\frac{\delta}{2(\epsilon+\delta)}$.

The outcome $(S2, B2)$ is Pareto dominant. But it might fail to emerge, if the condition stated in Proposition 1 does not hold. Even if that condition hold, the high liquidity equilibrium may still fail to emerge, if the traders coordinate on restricted liquidity, possibly because of risk considerations.

3 Hypotheses

When $(S1, B1)$ is the unique Nash equilibrium and there is no preopening period, market participants are expected to play the dominant, low liquidity, strategy.

When there is a preopening period, pre-play communication can occur. However, participants may try to manipulate the market, by playing aggressively ($S2$ or $B2$) during the preopening, but backing off to the less aggressive one ($S1$ or $B1$) in the call. Realizing that, players will stick to $S1$ and $B1$ in the call, whatever the outcome of the preopening was.

As emphasized by Farrell (1987), when non equilibrium actions are announced, players behave as if no announcement was made. Indeed, declaring his intention to play aggressive in the call by playing aggressive in the preopening is not credible because the message is just not *self-committing* (Farrell, 1988): the sender has no incentive to conform to his declaration if he expects it to be believed.

When $(S1, B1)$ is the only Nash equilibrium, players' interests are simply too misaligned for cheap talk to be informative. This leads us to our first hypothesis:

Hypothesis 1 *When it is the unique Nash equilibrium, the low aggressivity profile* $(S1, B1)$ *is chosen with or without a preopening period. Low liquidity thus prevails.*

An empirical implication of this hypothesis is that preopening prices and trading volume are not good predictors of call prices and volume when $(S1, B1)$ is the unique Nash equilibrium.

What can be expected when $(S2, B2)$ is also a Nash equilibrium? In this case, an aggressive preopening order may constitute a credible signal of a true desire to coordinate on high liquidity. Messages $S2$ and $B2$ are indeed self-committing.

However, as Aumann (1990) noted, to be highly credible a message needs also to be *self-signaling*: the sender wants it to be believed if and only if he plans to carry it out. This is not the case here, since a player always wants his counterparty to play the aggressive action, whatever his own planned action is. Quoting Blume and Ortmann (2007), the counterparty could respond by saying "You would have said that anyway." and the credibility of the sender's message may be therefore undermined.

While a relevant theoretical insight, *self-signaling* may not be necessary in practice for a message to be trusted: Charness (1998, 2000), confirming an intuition of Farrell and Rabin (1996), experimentally shows that cheap talk can promote coordination even when messages are not *self-signaling*.

Following this experimental result, preopening is expected to be used by players as a coordination device, in order to coordinate on the high liquidity Pareto optimal equilibrium. Players will tend to announce aggressive actions in the preopening period, and abide to their announce in the subsequent call.

Hypothesis 2 *When $(S1, B1)$ and $(S2, B2)$ are both Nash equilibria, the Pareto optimal equilibrium $(S2, B2)$ will be more frequent with preopening than without.*

Under this hypothesis, preopening prices and trading volume will be good predictors of call prices and trading volume.

In the background of Aumann's critique lies the tension between mutual benefits and risk: even in the presence of a Pareto optimal Nash equilibrium, agents may select a Pareto dominated, but risk-dominant, Nash equilibrium. If Hypothesis 2 is indeed invalid and agents do face a strong selection dilemma, how would they choose?

A possible alternative view to Hypothesis 2 is that agents learn to trust or distrust pre-play communication through history. If they observe that preopening orders do not predict orders in the call, they will learn that preopening orders are not credible, and cheap talk will remain just noise. Conversely, if agents start by playing games where preopening orders do predict call orders, they will learn that preopening orders are credible, and preopening messages will be more likely to be trusted afterward. This way, history shapes beliefs about the information content of pre-play messages.

Our alternative to Hypothesis 2 is therefore:

Hypothesis 3 *If participants start by playing a game where $(S1, B1)$ is the unique Nash equilibrium, they will tend to stick to this equilibrium even after switching to a game where $(S2, B2)$ is also a Nash equilibrium, and a preopening period will not help. Conversely, if participants start by playing the two-Nash equilibrium game, they will tend to keep playing the high-liquidity outcome, especially with a preopening.*

4 Experimental design

The experiment is run with 48 students from three different graduate finance programs at Toulouse University. We build 5 cohorts, each of them including between 6 and 12 students. The experiment was programmed and conducted with the software z-Tree (Fischbacher, 2006).

We use a 2×2 design. The first treatment refers to market structure. We study a single call market and a call preceded by a preopening period. The preopening period is organized as a call where no transaction occurs. The orders posted during the preopening are not binding. Price and volume during the preopening period are announced to the players before they proceed to the call auction. The second treatment refers to the properties of the high liquidity allocation. We study the case where the high liquidity allocation is not a Nash equilibrium and the case where it is a Nash equilibrium. We also ensure that, in addition to being the maximin equilibrium, the low liquidity Nash equilibrium is always the risk dominant equilibrium.

Sessions include 15 replications. Subjects participate in one of two types of sessions. In the first type of sessions, the high liquidity allocation is a Nash equilibrium in the first and last five replications, but not in the middle five replications. On the contrary, in the second type of sessions, the high liquidity allocation is a Nash equilibrium in the middle five replications, but not in the first and last five replications.

For simplicity, we choose the following parameters:

$$c = 0, \underline{p} = 1, p = 2, \bar{p} = 3, v = 4, \text{ and } q = 8.$$

We set $\bar{q} = 9$ to study the case where the high liquidity allocation is not a Nash equilibrium. We obtain a typical Prisoner's Dilemma game, bringing into play a conflict between individual rationality and mutual benefit:

$\bar{q} = 9$	$B1$	$B2$
$S1$	$(16, 16)$	$(20, 12)$
$S2$	$(12, 20)$	$(18, 18)$

Trading volume is 8 in all cases but $(S2, B2)$, where it is 9. Trading price is 2 in the symmetric cases, and 1.5 or 2.5 in the asymmetric cases, depending on which player is the most aggressive one.

Alternatively, we set $\bar{q} = 11$ to induce high liquidity as a Nash equilibrium. In this case, the game is a typical Stag Hunt game, bringing into play a conflict between personal risk and mutual benefit:

$\bar{q} = 11$	$B1$	$B2$
$S1$	$(16, 16)$	$(20, 12)$
$S2$	$(12, 20)$	$(22, 22)$

Trading volume in the case $(S2, B2)$ is 11. The mixed strategy is to select the aggressive schedule with probability $2/3$, for an expected gain of $56/3$.

To summarize, each cohort plays the game 15 times. Each cohort is divided in two groups: one plays with a preopening, the other without. Each sub-cohort is divided into two groups: one will start in a situation where high liquidity is a Nash equilibrium (thus, playing a sequence "11-9-11" for $\bar{q}$), the other where it is not (playing a sequence "9-11-9" for $\bar{q}$). Subjects in a sub-cohort are randomly divided into buyers and sellers. Roles are fixed for the entire session. At each round, each seller will have to choose between $S1$ and $S2$. Each buyer will have to choose between $B1$ and $B2$. We also allow subjects to not submit any orders. This corresponds to actions $S0$ and $B0$ for sellers and buyers, respectively. The computer collects all the choices and randomly matches one seller and one buyer within a given sub-cohort. Payoffs are determined according to the above normal form game tables. At the end of each replication, trading gains are announced to the participants. Subjects are not told with whom they were matched. They however know what the other subject chose and what is the outcome of the game. We do not publicly tell the subjects the outcomes of the matches in which they did not participate in. When there is a preopening period, the same two players are matched both for the preopening period and the subsequent call market.

In each cohort, we first explained the game to the students (during one hour and thirty minutes), making sure they understand the mechanics of the market, and at the same time avoiding to tell them how to play.

5 Experimental results

We start by looking at the individual actions selected during the experiment. The data collected shows that subjects played the weakly dominated strategies $S0$ or $B0$ less than 1% of the time. Figure 1 shows the proportion of stategies $S2$ or $B2$ played. When $(B1, S1)$ is the only Nash equilibrium ($\bar{q} = 9$), participants mostly play $B1$ or $S1$, the dominant strategy, around 90% of the time. This is in line with Hypothesis 1. The result is stronger when a preopening precedes the call. When $(B2, S2)$ is also a Nash equilibrium ($\bar{q} = 11$), participants play $B2$ or $S2$ 60% of the time. However, this percentage is lower when they play a preopening before the subsequent call market than when they do not, which contradict Hypothesis 2.

To investigate further this point, we look at the market outcomes. Figure 2 presents the frequencies of the different matches during the call markets when there is no preopening period. When $(B1, S1)$ is the dominant strategy equilibrium, it arises 67% of the time. In this case, we also observe 29% of the time unsuccessful attempts to coordinate on the Pareto-dominant outcome. These coordination failures largely outweigh the 3% of coordination successes. When $(B2, S2)$ is also Nash equilibrium, partcipants successfuly coordinate on it 40% of the time. Still, coordination fails 45% of the time.

How does a preopening period affect these results? Figure 3 presents the same variables as Figure 2 for the case where there is a preopening period. First, we observe a dramatic reduction of coordination failures in both types of games. The rate of coordination failures decreases from 29% to 11% and from 45% to 26% for the single Nash case and the two-Nash case, respectively. When $(B1, S1)$ is the unique Nash equilibrium, preopening fosters coordination on it (89%), and eliminates all coordination on the Pareto dominant but strategically dominated outcome $(B2, S2)$. When $(B2, S2)$ is also Nash equilibrium, coordination on it improves, reaching 46%, from 40% without preopening. In this case, coordination on the risk-dominant outcome $(B1, S1)$ also improve a lot, increasing to 28%, from 15% without preopening. Thus, a preopening period significantly improves coordination on Nash equilibria. Moreover, when there are two Nash equilibria, both become more frequent.

To understand why preopening affects the market outcome in such a strong way, we now examine the matches that occurred during the preopening period. Frequencies are presented in Figure 4. When $(B2, S2)$ is Nash, the outcome $(B2, S2)$ arises 67% of the time during the preopening. It seems that an outcome $(B2, S2)$ in the preopening is interpreted by both parties as a credible announcement that they will play the same outcome during the call. On the contrary, when $(B1, S1)$ is the sole Nash equilibrium, an outcome $(B2, S2)$ in the preopening in not interpreted as credible, and in most cases the players will back off to the Nash equilibrium during the call. Still, $(B2, S2)$ occurs 36% of the time during the preopening.

Figure 5 shows how a player plays in the call depending on how he played in the preopening. When $(B2, S2)$ is Nash, participants who played $B2$ or $S2$ in the preopening stick to their word 65% of the time, playing $B2$ or $S2$ in the call, thus achieving good coordination. On the contrary, when $(B1, S1)$ is the unique Nash equilibrium, they stick to their word only 5% of the time. In this case, playing $B2$ or $S2$ in the call appears to be a non credible promise, that will not be fulfiled in the subsequent call. Players know that these annoucements are just blatant attempts to manipulate, and don't pay much attention to them.

Since our experimental data does not support Hypothesis 2, let us now turn to our alternative hypothesis. Hypothesis 3 emphasizes the role of history in shaping the beliefs about preopening announcements' credibility. Figure 6 breaks down the frequencies of market outcomes by type and sequence of games, in the case where there is no preopening period. We observe that when $\bar{q} = 11$ (two Nash equilibria), participants play more often $(B2, S2)$ when they started to play with potential coordination gains ("11-9-11"). This result suggests that a history of high liquidity is more likely to induce future liquidity to be high.

Figure 7 shows how a preopening period changes these numbers. We observe that coordination failures are more frequent when participants start to play with potential coordination gains. It may be due to the fact that some players become too optimistic after having played in a $\bar{q} = 11$ setting during the first 5 replications. History makes a big difference when $\bar{q} = 11$: while the outcome $(B2, S2)$ occurs 25% of the time for the sessions starting with a low liquidity dominant stragegy, the same outcome occurs 56% of the time for the sessions starting with high liquidity as an equilibrium. These results support Hypothesis 3.

To get additional insights about how a player's personal experience shapes his beliefs, we proxy a player's belief by the number of times his opponents played $B1$ or $S1$ during the first five replications. When this number is lower or equal to 2, we say the participant has "good memory". If this number is greater that 2, the participant has "bad experience".

Figure 8 shows the proportion of actions $B2$ or $S2$ played on the last ten replications, conditional on agents' beliefs formed during the first five replications and proxied as stated above. Without preopening, the frequency of $B2$ or $S2$ is barely impacted by the beliefs. On the contrary, preopening makes a big difference: players with bad experience play $B2$ or $S2$ only 20% of the time, compared to 47% for those with good memory.

Figure 9 breaks down these numbers by type of game. When $\bar{q} = 9$, past experiences don't matter much, and players keep playing the only Nash equilibrium. By contrast, when $\bar{q} = 11$, preopening helps good memory to foster coordination on high liquidity Pareto dominant equilibrium.

6 Conclusion

This paper proposes an experimental investigation of equilibrium liquidity discovery in financial markets. We study traders' propensity to coordinate on a high liquidity allocation depending on whether *i)* this allocation is a Nash equilibrium, *ii)* a preopening period precedes the actual market, and *iii)* market in the past proved to be liquid. We show that *i)* when it is not a Nash equilibrium, traders do not coordinate on the high liquidity allocation, *ii)* a preopening period improves the level of coordination not only on the high but also the low liquidity equilibria, *iii)* high liquidity in the past fosters coordination on the high liquidity equilibrium when there is a preopening period.

Overall, these results suggest that the preopening mechanism is a useful coordination device. However, its capacity to enhance market liquidity appears to depend on traders' beliefs, shaped through market history. Prior trust or distrust in the credibility of the messages sent during a preopening period is a key factor driving the preopening's contribution to market liquidity.

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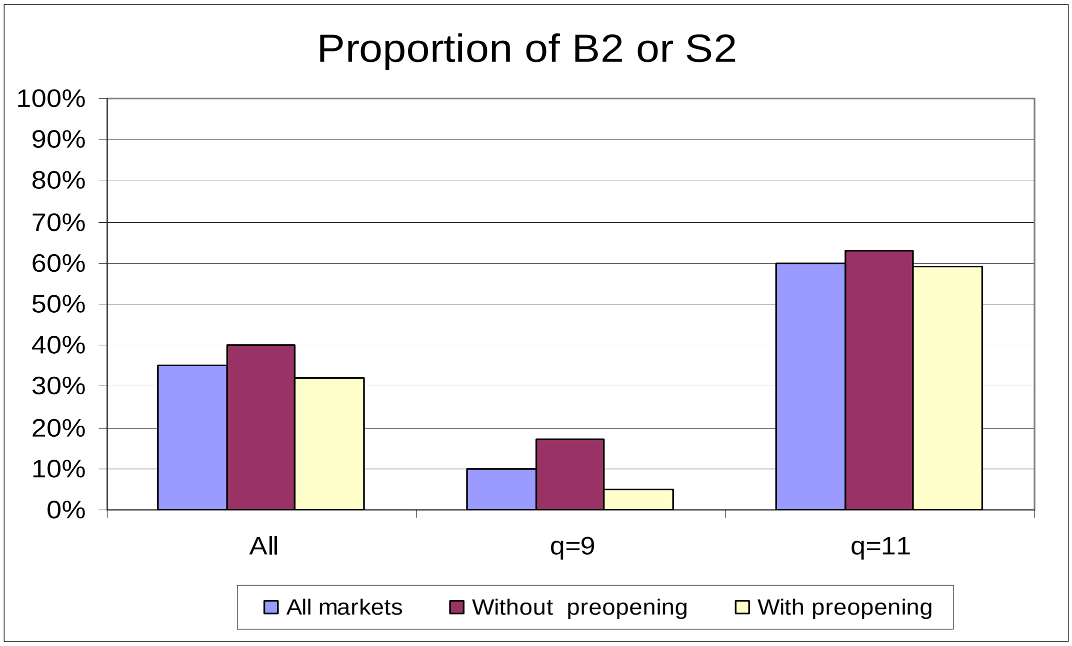
Proportion of B2 or S2
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
All
q=9
q=11
All markets
Without preopening
With preopening

Fig.1

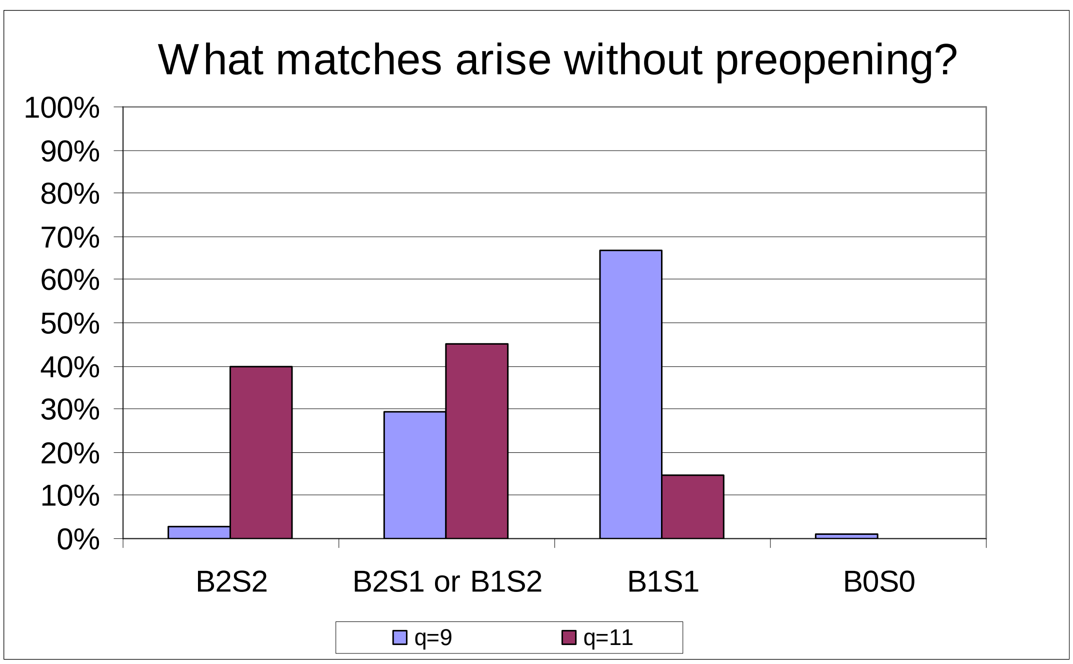
What matches arise without preopening?
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
B2S2
B2S1 or B1S2
B1S1
B0S0
q=9
q=11

Fig.2

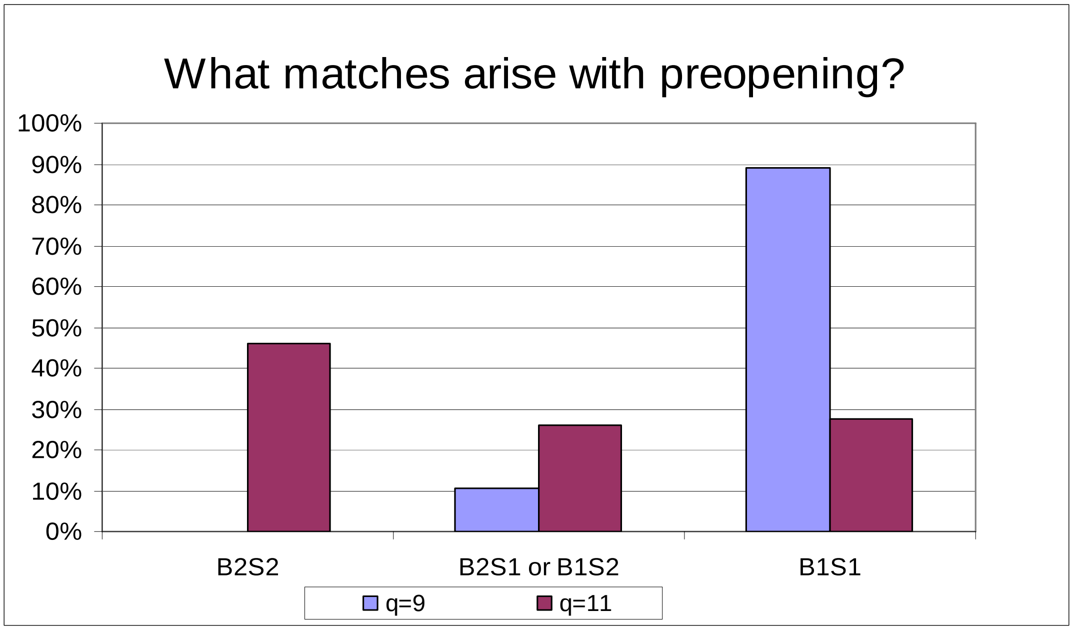
What matches arise with preopening?
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
B2S2
B2S1 or B1S2
B1S1
q=9
q=11

Fig.3

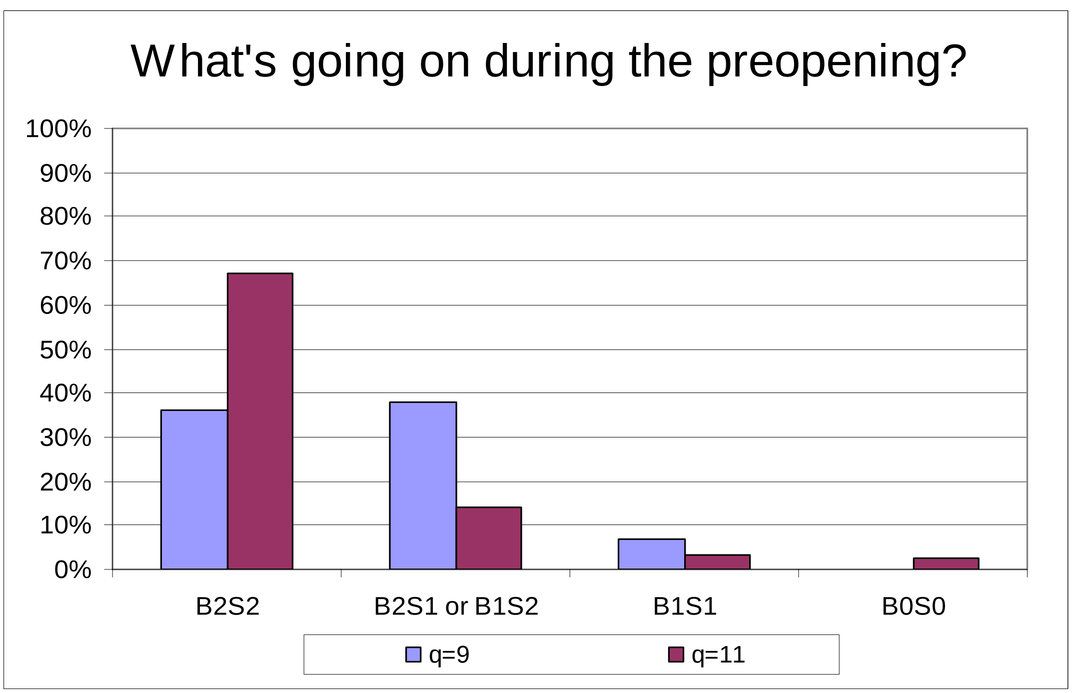
What's going on during the preopening?
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
B2S2
B2S1 or B1S2
B1S1
B0S0
q=9
q=11

Fig.4

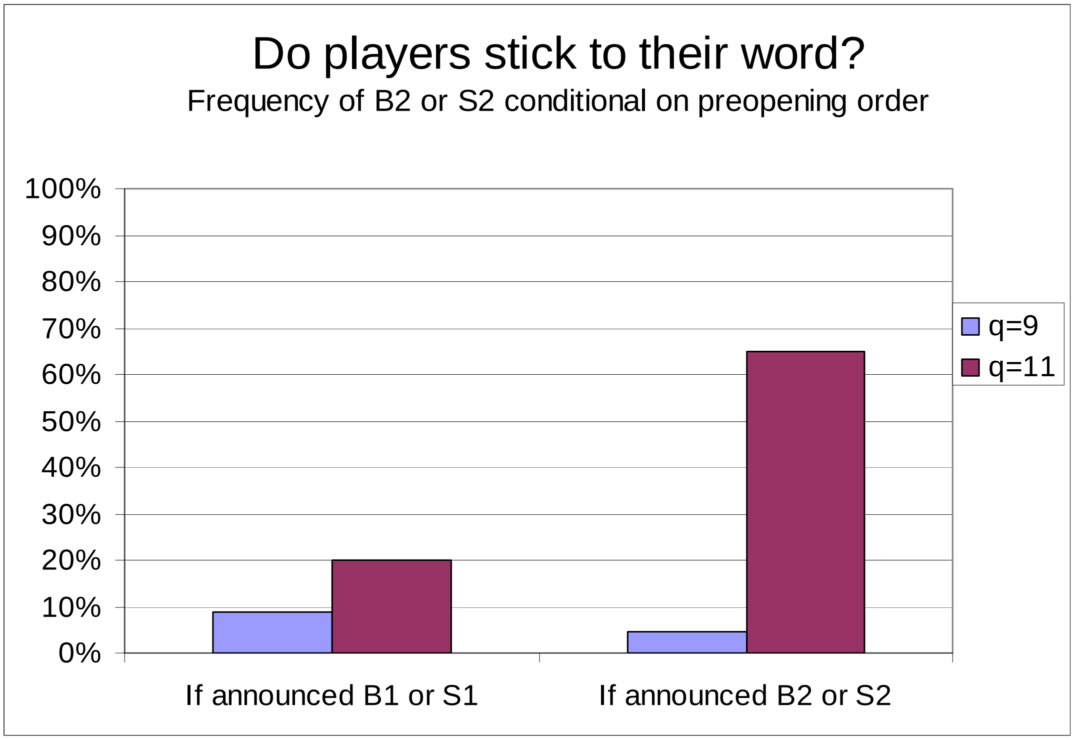
Do players stick to their word?
Frequency of B2 or S2 conditional on preopening order
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
If announced B1 or S1
If announced B2 or S2
q=9
q=11

Fig.5

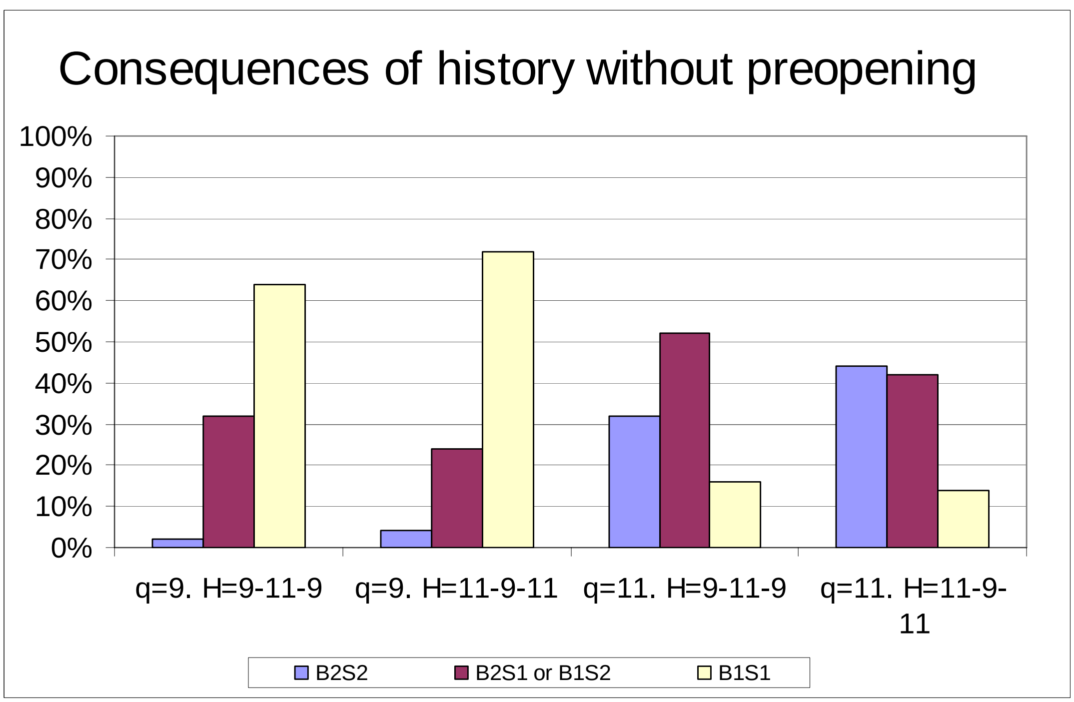
Consequences of history without preopening
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
q=9. H=9-11-9
q=9. H=11-9-11
q=11. H=9-11-9
q=11. H=11-9-11
B2S2
B2S1 or B1S2
B1S1

Fig.6

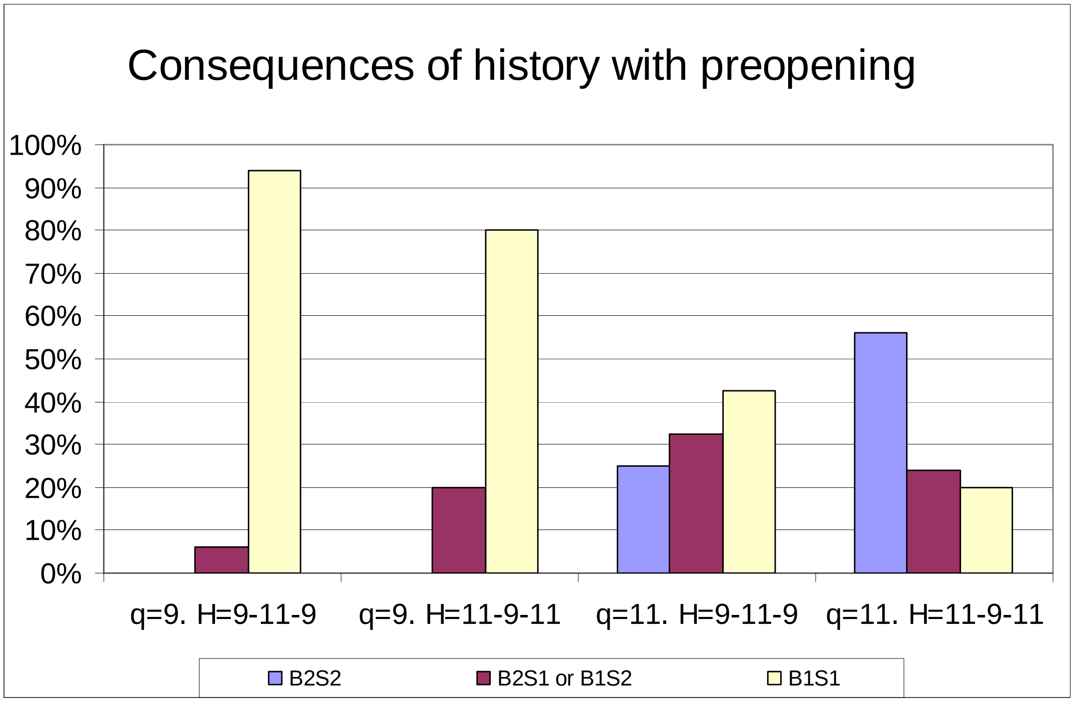
Consequences of history with preopening
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
q=9. H=9-11-9
q=9. H=11-9-11
q=11. H=9-11-9
q=11. H=11-9-11
B2S2
B2S1 or B1S2
B1S1

Fig.7

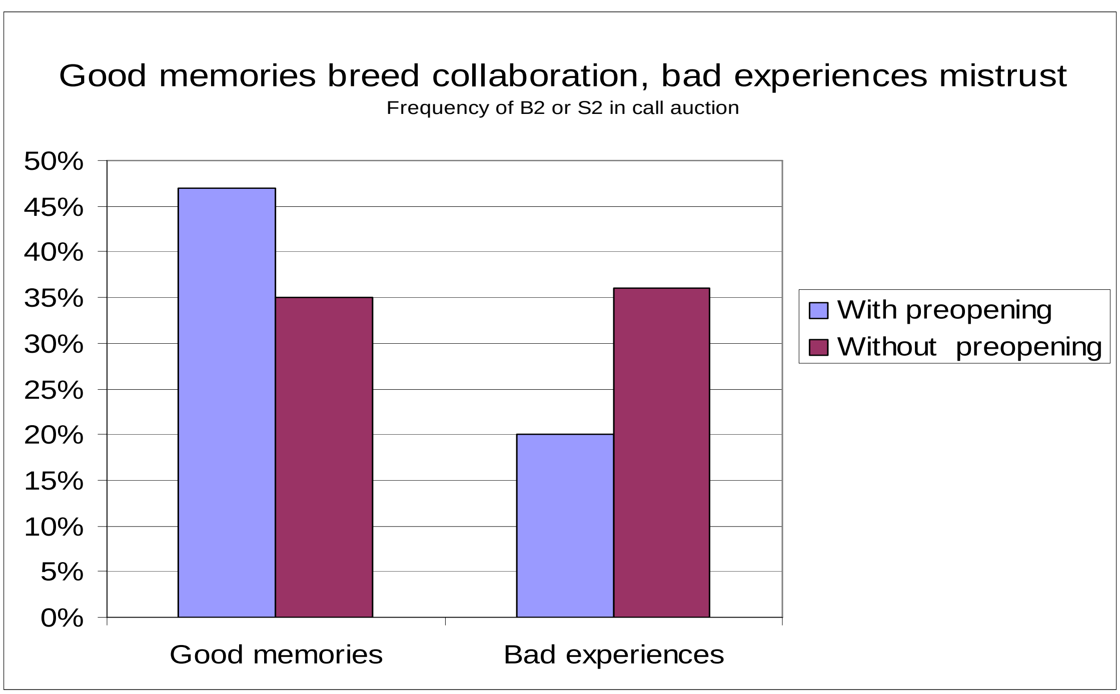
Good memories breed collaboration, bad experiences mistrust
Frequency of B2 or S2 in call auction
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
Good memories
Bad experiences
With preopening
Without preopening

Fig.8

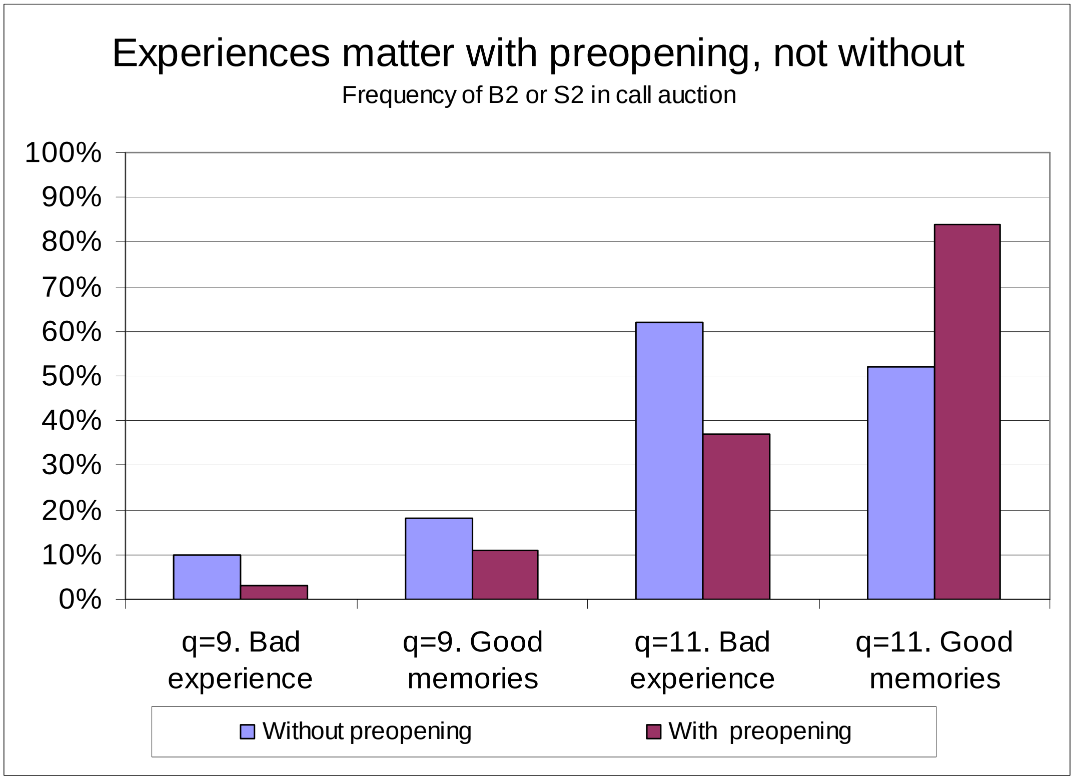
Experiences matter with preopening, not without
Frequency of B2 or S2 in call auction
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
q=9. Bad experience
q=9. Good memories
q=11. Bad experience
q=11. Good memories
Without preopening
With preopening

Fig.9