Speculative Attack and Informational Structure: an Experimental Study

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Abstract

This paper addresses the question of whether public information destabilises the economy in the context of signals of different nature. We present an experimental evaluation of the speculative attack game of Morris and Shin (1998). Our objective is twofold: to evaluate whether public information destabilises the economy within a context of signals of different nature and to enlarge upon the results of Heinemann, Nagel and Ockenfels (2004) (HNO). Our evidence suggests that in sessions with both private and common signals, the fact that the common signal plays a focal role enhances the central bank's welfare: it reduces the probability of crisis and increases its predictability. Therefore, we raise doubts about the policy implications of HNO's findings. The new policy lesson is that the central bank has more control over the beliefs of traders if it discloses one clear signal when agents also get private information from other sources.

JEL Classification Numbers: F3, C9.

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1. Introduction

The policy response to the recent turbulence in international financial markets has been to call for increased transparency through information disclosures from governments and other official bodies as well as from the major market participants (International Monetary Fund, 1998; Basel Committee on Banking Supervision, 1999). Increased transparency could prevent the occurrence of speculative crashes and, simultaneously, make sure that unsustainable pegs be corrected early enough. Indeed, public information is expected to reduce efficiency losses stemming from coordination failures; since market expectations are influenced by central bank disclosures — and in return have an impact on financial variables — monetary policy is more effective if it can coordinate market expectations. However, there is an ongoing debate over the optimal modes of information disclosure. This paper addresses the question of whether or not public information destabilises the economy in a context of signals of different nature.

Theoretically, the impact of public information is large — public information is extremely effective at influencing decisions and coordinating actions. There is even a danger arising from the fact that it is too effective at doing so. For example, the model of Morris and Shin (2002) predicts that agents are more likely to follow public as opposed to private information when signals are equally precise — agents overreact to public information and thereby magnify the damage done by any noise.

Empirically, the impact of public and private information on the coordination of agents has been studied by experimental economists. While Cabrales, Nagel and Armenter (2003) wonder about which equilibrium prevails if agents possess either private or public information, Heinemann, Nagel and Ockenfels (2004, HNO hereafter) also compare the individual impact of such informational structures on the decision making process. They present an experiment which imitates a speculative attack model *à la* Obstfeld (1996) and Morris and Shin (1998) and show that the predictability of an attack is slightly higher in public information as opposed to private information, but the prior probability is also higher in public information. While this experiment tends to validate the global game theory, it nevertheless appears that the destabilising effects of public information, linked with the existence of multiple equilibria, can be less severe than what is predicted theoretically.[1] This suggests that public information is not necessarily conducive to the propagation of common knowledge — even if public announcements would theoretically lead to higher order beliefs tantamount to common knowledge, differences in the treatment of public information seem to create sufficient private beliefs to avoid self-fulfilling beliefs equilibria and thus common knowledge.

HNO consider two informational treatments in the context of the speculative attack game: public information about the fundamental state of the economy on the one hand, and private information on the other. In this paper, we propose an experiment which analyses the impact of public information on how agents coordinate when they receive both a public signal and an additional signal, either public in the first treatment or private in the second. Both informational assumptions arguably reflect real-world conditions. Indeed, in the exchange rate market, economic agents can be confronted with several situations and in particular they can receive a single public announcement from the central bank while drawing their own opinion of the economic situation. They could also receive two public signals sent by two different members of the central bank in an uncoordinated fashion or disclosed by two different journals. As the most likely situation in exchange rate markets seems to be the presence of both public and private signals, this perspective deserves greater emphasis in our analysis.

We thus have two main objectives. First, we aim at empirically evaluating the relevance of the informational structure during a speculative attack, and especially, examining the marginal contribution of public and private signals. Our evidence suggests that in the public and private information treatment, the public signal always plays a more important role in the decision made by agents; success and thus probability of an attack clearly depend more on the public signal. The main result is that the probability of a crisis diminishes, and crises become easier to predict in the presence of simultaneous private and public signals than in otherwise equal treatment with two common signals. In terms of economic policy, our result suggests that the central bank has more control over the beliefs of traders if it discloses one clear signal, when agents get additional private information from other sources. Second, we propose to enlarge upon the results acquired by HNO. Most of HNO's results are robust to the introduction of a public signal except in terms of predictability. Although HNO do not claim that there is much difference in players' behavior when they receive public versus private signals, they nevertheless argue that predictability of attacks is slightly better with public information than with private information. Here, we show that the same result is obtained if the public signal is augmented with private information, thus calling into question some of the policy implications of HNO's finding.

The new policy lesson is that multiple public signals — e.g. several members of the central bank speaking out in an uncoordinated fashion — are more destabilising than private information and a single public signal. In this respect, our approach gives some foundations to the criticisms directed at the International Monetary Fund and some central banks considering their policy of information disclosure. First, among other institutions, the IMF took several initiatives in order to encourage countries to disclose all the relevant information about their respective economic and financial climates. One of the most important accomplishments to this end is the *Special Data Dissemination Standard* (SDDS).2 In this way, the IMF tries to form part of the "information game" that is played in global financial markets. However, in its effort to increase the flow of accurate and comprehensive information and to enhance transparency, the IMF gives a considerable variety of information packets that are sometimes hard to interpret, potentially leading to confusion. Second, concrete examples of controversial central bank communication strategies include those of the European Central Bank. While the US Federal Reserve System has conveyed a clear and consistent message to market participants both in terms of price stability and growth, the European System of Central Banks, due to its multinational nature and its confusing "two pillar" monetary strategy, has been much less able to communicate its intentions and to explain its concrete interest-rate decisions (Blinder, Goodhart, Hildebrand, *et al.*, 2001).3 Our main result suggests that the communicative deficiencies of the Euro-system have been intrinsically linked to its adopted strategy, and that, by contrast, the Fed has benefited from an inherent advantage in terms of information dissemination. The format of central banks' communication is critical to their ability to properly convey their intentions to market participants. Our study emphasises that it is important for central banks to disclose a single, clear signal given that market participants also form their own opinion of the economic outlook. A corollary to this conclusion is that increased transparency leads to an enhanced understanding of the motives and actions of central banks, as has been evidenced by the Bank of England and the Reserve Bank of New Zealand, known for their excellent provision of information. More broadly, our approach can explain how fragmented communication may exacerbate coordination problems in financial markets (Gai and Shin, 2003). Indeed, although a collection of indicators taken together may convey a coherent message, the fragmented nature of the communicative process leaves open the possibility that some market observers may fail to capture the intended picture or otherwise remain uncertain as to whether everyone has grasped it correctly.

The remainder of this paper is structured as follows. Section 2 sums up the main theoretical results concerning the role of the informational structure in speculative attack games. Section 3 lays out the experimental design based on HNO. Section 4 details the results of the experiment in terms of agents' decision, probability of an attack, predictability of an attack and coordination. Section 5 compares our results with the study by HNO — and section 6 concludes the paper.

2. Theoretical predictions

The possibility of analysing the role of information disclosure is relatively recent. The literature on "global games" shows that there can exist a unique equilibrium within a framework where multiple equilibria would occur in a situation of common knowledge on economic fundamentals. The existence of the unique equilibrium in such games allows for the study of the impact of information by means of comparative statics. After briefly presenting the reduced form of the speculative attack game, we give the theoretical results under different informational assumptions.

The speculative attack game as a coordination game in incomplete information

We describe a very simple version of the model of Morris and Shin (1998), inspired by Heinemann (2002). The game consists of an infinite number of small traders $i \in [0,1]$ who decide whether to attack or not. The fundamental state is denoted by *Y*. A lower *Y* is interpreted as a better state of the economy. If the proportion of traders who attack exceeds a hurdle function $a(Y)$ (a'<0), the attack succeeds and each attacking agent receives a reward equal to *Y*. However, if the attack fails, the attacking agents get 0. Whatever happens, non-attacking agents always receive a reward equal to *T*.

Predictions with respect to the informational structure of the game

We give here the main theoretical predictions of this game under different informational structures.

Public information

In the second-generation models with common knowledge on economic fundamentals *Y*, coordination is due to a sunspot (i.e. a public announcement), which coordinates the actions of all the speculators. A canonical model is presented by Obstfeld (1996), in which three zones of fundamental states exist:

- if $Y < T$, the fundamental state is so good that no attack can occur;
- if $Y > \overline{Y}$, the fundamental state is so bad that it is certain there will be a devaluation;
- if $T<Y<\overline{Y}$, there are two pure strategy equilibria: an attack can either occur or not.

In such a context, the simple fact that a signal would constitute common knowledge coordinates agents' on one particular equilibrium (rather than on another). There is an indeterminacy in the theory, which is linked to the coordinating power of public information. Here, beliefs are self-fulfilling and the result is linked to a change in anticipations and not directly to fundamentals, in the sense that worse fundamentals are more likely to lead to the bad equilibrium in the zone of indeterminacy. We call this situation the Common Information game (CI).

Such an analysis raises doubts about the advantages of public information disclosure as advocated by international financial institutions. The existence of multiple equilibria does not allow for any policy prescription.

Two public signals

The analysis can be extended to a situation in which agents receive two noisy public signals Z_1~U[Y-ε, Y+ε] and Z_2~U[Y-ε, Y+ε], where ε is a noise. When those signals have the same precision (and this is common knowledge), then all economic actors will coordinate upon the average signal. We thus have the same reasoning that follows. We call this situation the Two Common Signal (TCS) game.

The next Figure illustrates the different cases.4

Insert Figure 1 Here

Private information

Morris and Shin (1998) assume that the fundamental state Y has a uniform distribution on a sufficiently large support. Traders get random noisy private signals X_i, the distribution of which is uniform conditionally and independently on [$Y-\varepsilon_i$, $Y+\varepsilon_i$], where ε_i is sufficiently small. Each trader expects the other traders to receive signals more or less high compared to theirs with an equal probability. Common knowledge of the fundamental state disappears; it is replaced by an equilibrium condition – agents compare the expected payoff of a successful attack, weighted by the probability of success, to the transaction costs they would certainly incur. There is a critical state of the economy below which an attack always occurs and above which an attack can never occur.

Private information, by avoiding total coordination on a pure self-fulfilling equilibrium, thus leads to the determination of a potentially better situation than public information, in terms of economic stability. We call this situation the Private Information game (PI).

Heinemann and Illing (2002) show that more precise private information reduces the probability of a speculative attack. In order to minimize the probability of speculative attacks, the government should provide the agents with the best possible private information but eschew common knowledge due to the danger of multiple equilibria.

Simultaneous private and public signals

Between the two previous extreme cases (exclusive existence of public information or private information), Morris and Shin (2004) and Hellwig (2002) introduce both noisy private and public information into the framework. The state Y of the economy is assumed to be normally distributed: $Y \sim N(Z, \tau^2)$. Public information is the prior mean Z and private information is given by $X_i = Y + \varepsilon_i$, $\varepsilon_i \sim N(0, \sigma^2)$.

Morris and Shin (2004) show that under certain conditions pertaining to the precision of public and private signals, equilibrium uniqueness can be guaranteed; uniqueness requires that private information be sufficiently precise *vis-à-vis* public information. In other words, the equilibrium is unique as long as the noise is relatively small. We call this situation the simultaneous Private and Common Signals game (PCS).

This framework changes the results in terms of policy implications compared to previous models. Morris and Shin (2004) find that the effects of private and public signals' precision are at best ambiguous. Extending previous results, Metz (2002) shows that with both public and private signals there exists an interaction between the two types of information; public and private information can have opposite effects on the prior probability of a crisis, depending on the prior mean of fundamentals. In the case of a bad fundamental state of the economy, the more precise public information is and the less precise private information is, the higher is the probability of a speculative attack. Conversely, in a situation of good fundamentals a higher precision of the public signal and a lower precision of the private signal lead to a reduction in the probability of crisis.

Bannier and Heinemann (2005) reconsider the problem of information disclosure when a central bank is threatened by a speculative attack on a fixed exchange rate by traders. Optimal risk and economic transparency are contingent upon the prior probability of the expected mean of fundamentals; each time the prior probability of the mean of economic performance is under a certain threshold, the central bank should commit to taking the maximal risk and diffuse private information with a maximal precision. For good prior expectations, by contrast, the optimal policy requires that the central bank avoid any risk and disseminate private information with the lowest possible precision.

Sbracia and Zaghini (2001) also study models with both public and private information. According to them, "*providing public information seems to be more convenient when fundamentals are 'rather bad' […] than when fundamentals are 'rather good'*" (Sbracia and Zaghini, 2001, p. 216). The idea is the following: in a good state, with almost totally precise private information, there is no risk of attack; however, in bad states, with precise public information, multiple equilibria offer a chance to avoid attacks.

Morris and Shin (2002) underline that one of the drawbacks to this previously mentioned global game literature is that the study of the role of public information (owing to comparative statics) is rendered difficult by the complex effect arising from the interrelation between better fundamental information and changes in strategic uncertainty. They thus propose a more simple beauty contest model that avoids such a drawback by giving equilibrium uniqueness for any parameter of the model. They are able to study the role of the precision of private and public signals on welfare. They show that the noise in the public signal is given more weight than the noise in the private signal, which reflects the coordination motive of the agents and the disproportionate influence of the public signal in influencing the agents' actions. In terms of welfare effects, they get the following result: while welfare is unambiguously increasing alongside the increasing precision of private signals, increased precision of public information is beneficial only when the agents' private information is not very precise. Therefore, "*when the private sector agents are already very well informed, the official sector would be well advised not to make public any more information, unless they could be confident that they can provide public information of very great precision*" (Morris and Shin, 2002, p.1529). The rationale for such a conclusion is that agents "overreact" to the public signal while suppressing the informational content of the private signal. This underlines the importance of shared knowledge.

After evoking theoretical predictions of speculative attack models under different informational assumptions, we now turn to the description of the experimental design of the game.

3. Experimental design

There exists only one experimental study that tests the global game approach applied to speculative attacks — that of HNO. This study brought to light the fact that there is no huge difference in the treatments of public and private information by agents. This paper tries to take this result into account and to go beyond it by testing the model under different informational assumptions. We draw our inspiration from their protocol in designing our own.

The protocol of HNO

HNO ran 25 sessions in total (in Germany and in Spain) with 345 participants (15 participants per session). Each session includes two stages with 8 independent rounds per stage. In each round, subjects where submitted to 10 independent situations, in which they had to decide between two alternative choices (A or B).

- Action A represents the safe choice, giving a positive and constant payoff T, which can be interpreted as a way of avoiding the costs linked to a speculative attack. It is a certain payoff. The two steps of each session were differentiated by the payoff linked to the choice A: in half of the sessions they started with T=20, then they took T=50 at the second stage; in the other sessions, they reversed the order.

- Action B is the risky action and can be interpreted as the attack, giving a payoff Y, if the number of subjects choosing B exceeds a certain threshold $a(Y)=15(80-Y)/W$, and 0 otherwise (the formula was given in the instructions but also explained by an example and a table).5 Action B can thus give a positive payoff to the agent if a sufficient number of players chooses B (this payoff is a function of the number of attacking agents but also of the fundamental value), and 0 otherwise.

More precisely, for each situation, the state Y is randomly selected from a uniform distribution on the interval [10,90]. In common information sessions, players knew the precise value of Y and knew that everyone shared this information. In private information sessions, each agent received a noisy private signal. Signals X_i were randomly selected from a uniform distribution on the interval [Y-10,Y+10] for each player separately; the received value was thus potentially different for each subject. Subjects knew that each received only private information and that they shared the knowledge of the random process.

The rules of the game, including the structure of uncertainty, were common information among the subjects of each session. The experiment avoided any connotation that might be associated with "speculation" or "attack" — subjects were simply asked to choose between two actions A (the safe action) and B (the risky action).

Our proposed protocol

To be able to compare the results of our experiment to the results of HNO, we drew up a protocol as closely related as possible to theirs. Any slight modifications do not have any impact on the unfolding of the game.

We firstly took the same number of players (15 players) and kept the uniform distribution for convenience, although theoretical models use normally distributed signals. However, our values for Y were integers. Secondly, we added a phase where we asked participants questions about their understanding of the game in order to avoid an educational phase in the first rounds of the experiment. We asked simple questions for which answers could be found in the instructions; participants only proceeded when they answered correctly to the questions.6 Finally, we carried out 20 sessions and chose a fixed value for W (W=60). But in each session we kept the two stages with T=20 and T=50. The main change concerns the two treatments that are envisaged in the new experiment.

We ran 10 sessions with Two Common Signals (TCS) and 10 sessions with both Private and Common Signals (PCS). Subjects7 were seated in a random order at PCs. Instructions were read aloud and questions were answered in private. Throughout the sessions the students were not allowed to communicate and could not see others' screens. Students could only participate once in the experiment.

Analogously to HNO, in each situation, the state Y was selected randomly with a uniform distribution on the interval [10,90] and was the same for all the agents. Our two treatments (simultaneous public and private information, and common multiple information) were constructed as follows:

- In simultaneous noisy public and private information sessions, each subject received a private signal X_i randomly selected with a uniform distribution on the interval [Y–10,Y+10] and all the subjects received on top of that the same signal Z also randomly selected on [Y–10,Y+10] — the private value X_i received by each agent was potentially different whereas the value Z was identical for every agent — everyone knew this structure and shared the knowledge of the random process.
- In two noisy public information sessions, all the agents received two common signals Z_1 and Z_2 and knew with certainty that all participants received these two signals; each signal was randomly selected with a uniform distribution on the interval [Y–10,Y+10] and everyone knew this structure and shared the knowledge of the random process.

Average payment per subject was 15 euros. Session length was around 75 minutes. The instructions are available upon request by the author. Now we will evaluate the impact of those different informational contexts on the mechanism of agents' coordination.

4. Experimental evidence from the impact of the informational structure

In this section, we examine the impact of the informational structure on the decision of agents, the probability of an attack, the predictability of an attack and the coordination of agents. But let us first give some general considerations about subjects' behavior.

General considerations about subjects' behavior

Before going into the details of the agents' behaviors, it is important to mention that the agents followed threshold strategies and tended to consider the public signal more than the private one under the PCS condition.

The existence of threshold strategies

Subjects used threshold strategies even though those strategies were not imposed on them. We call a subject's behavior "consistent with undominated thresholds" in some periods, if her or his behavior in that period was consistent with the existence of a threshold and did not exhibit any dominated actions. Accordingly, in the TCS treatment, action B (the risky action) is dominated by A (the safe action) if Max $\{Z_1 ; Z_2\} < T - \varepsilon$ and A is dominated by B if Min $\{Z_1 ; Z_2\} > \overline{Y} + \varepsilon$. In the PCS treatment, action B is dominated by A if Max $\{X ; Z\} < T - \varepsilon$ and A is dominated by B if Min $\{X ; Z\} > \overline{Y} + \varepsilon$. A subject's behavior is consistent with a threshold strategy as a mean of signals, if the highest mean signals, for which the subject chose A, is smaller than the lowest mean signals at which he or she chose B. This definition of threshold as a mean of signals is theoretically relevant as subjects obtained two signals of equivalent precision.8

Result 1: Irrespective of the treatments, most of the subjects followed an undominated threshold strategy (more than 80% in average).

On average more than 70% of the players for the first round, and more than 89% for the last round played undominated threshold strategies.9 Hence, playing threshold strategies does not seem to require as strong assumptions as theory predicts (i.e. common knowledge of the game structure).

The determinant signal for individual decision

Inside a treatment, what determines the decisions of agents? More especially, which is the signal that mainly drives agents' decision? To answer such a question, we use logistic regressions done on individual decisions. Table 5 (in Appendix B) shows that:

- in PCS, the public signal plays a more important role in the decisions taken by agents;
- on the contrary, in TCS sessions, there is no clear use of one of the two public signals.

Indeed, in eighteen out of twenty cases, agents took the public signal more into account in the PCS treatment — whereas in the TCS treatment in ten out of twenty cases agents took the first public signal more (or equally) into account than the second. This means that agents tend to consider the public signal as a focal point. The Sign Test shows that such a result is highly significant ($p = 0.999$). Moreover, this is confirmed by the comments written by participants.

Result 2: Faced with a private and a public signal, agents tend to consider more the public one, as predicted by theory.

As a consequence, the advantages and drawbacks of the potential for overreaction to public information have to be considered seriously by policy makers to determine how much they should disclose, in what form, and how often. As Morris and Shin (2002, p.1522-1523) put it:

> "*Frequent and timely dissemination would aid the decision-making process by putting current information at the disposal of all economic agents, but this has to be set against the fact that provisional estimates are likely to be revised with the benefit of hindsight. By their nature, economic statistics are imperfect measurements of sometimes imprecise concepts, and no government agency or central bank can guarantee flawless information. This raises legitimate concerns about the publication of preliminary or incomplete data, since the benefit of early release may be more than outweighed by the disproportionate impact of any error*".

In what follows, we try to grasp the implications of this result and to find out whether it raises problems as feared by Morris and Shin (2002).

Thresholds to successful attacks

Not surprisingly, in all sessions, subjects tended to choose A for low signals or states and B for high signals or states. In consequence, the total number of players who chose B was rising in positive correlation with a rising Y. Tables 1 and 2 give an indication of the states where action B (the risky action or the attack) was successful in different sessions. For each treatment, we give an interval: the smaller number is the highest state up to which action B always failed; the larger number is the state from which point action B was always successful (in both tables, an asterisk indicates treatments where states with successful and failed attacks can be clearly divided). The midpoint of the interval measures how thresholds depend on exogenous conditions.

Insert Table 1 Here

Insert Table 2 Here

In both sessions, most of the time we could not identify thresholds that clearly divided successful and failed attacks. There is usually an overlap of states with both successful and failed attacks. Random signals could deviate from the state by ten units on the *Y*-scale. As a consequence, success or failure of an attack at any given state is unpredictable even if all individual strategies are known. At low states an attack may occur just because many subjects got much higher signals or vice-versa. In addition, this feature might also be due to the fact that receiving several signals (two instead of one in HNO) hampered participants in defining a clear threshold above which they attack and under which they do not attack. For sessions with PCS, the lack of total common information should have worsened this effect because it hinders subjects' ability to coordinate on the same strategy. Those features are illustrated by Figures 2 and 3.

Insert Figure 2 Here

There are eighty *Y*-values selected in one stage. Dots indicate the associated number of subjects who chose B. The hurdle function is the minimal number of B-players needed in order to get a reward while playing B. Dots below the hurdle function indicate states at which point there was no successful attack. Dots on or above the hurdle indicate successful attacks. Two points indicate the highest state up to which action B always failed and the lowest state from which point B was always successful. In the example of Figure 2, states with successful and failed attacks overlap (i.e. there are dots above and below the hurdle function within the interval defined by the two points already mentioned).

Insert Figure 3 Here

In the example of Figure 3, states with successful and failed attack also overlap.

However, judging from Tables 1 and 2, subjects seem to have coordinated a bit more on thresholds that clearly divided successful from failed attacks in sessions with PCS. Perhaps the existence of a single common signal helped participants to decide on a threshold by serving as a focal point. This intuition is indeed confirmed by the analysis of probability and predictability of attacks and coordination.

Probability and Predictability of Attacks

To answer the question whether public information raises or lowers the probability on the one hand and the predictability of an attack on the other, we compare the characteristics of the states of successful and failed attacks in PCS and TCS treatments.

Table 3 contains a statistic of midpoints of the intervals of indeterminacy as a measure of thresholds to success. Mean thresholds to success give an indication on the probability of an attack and standard deviation of average thresholds across sessions is used to explore how information condition influences the predictability of an attack. In addition, the average width of intervals of indeterminacy (i.e. between the highest state up to which action B always failed and the lowest state from which point action B was always successful) will be used as a measure of agents' coordination.

Insert Table 3 Here

The mean threshold to success is always higher in simultaneous private and public signals than in the otherwise equal treatment with two common signals. The standard deviation is, however, larger in the TCS than in the PCS condition. Those results can be explained by the fact that in the PCS condition, the existence of a single public signal served as a focal point, whereas in the TCS treatment there could be confusion in identifying focal points (the first common hint, the second one or the mean of these two values).

Probability of a successful attack

The higher the threshold to success, the smaller is *ex ante* probability for states at which subjects succeed in playing B. This is interpreted as a lower prior probability for speculative attacks that cause devaluation. For a systematic analysis of the influence of information and other control variables on mean thresholds we use linear regressions. We determine whether threshold states Y^*, from which point onward an attack is likely to occur, depend on various exogenous conditions or not. Regression 1 shows that T explains 58% of all data variation; Regression 2 shows that information and order of treatment increase this to 82% (see Table 6, Appendix C). The significant positive coefficient of the information-dummy in Regression 2 proves Result 3.

Result 3: The probability of an attack is higher in TCS than in PCS sessions.

However, order also has a strong influence. As was the case with HNO (2004), thresholds tend to be somewhat surprisingly higher in sessions where we started with a low payoff for the secure action A (T=20) than in sessions where we started with a high payoff (T=50). Therefore something seemingly irrelevant (such as the order in which participants are asked to play) can have a greater impact on the probability of attack than some other obviously relevant element (information). This would explain, for example, those instances where there has been an attack at a moment where news had no discernable bearing on it. In some sense, attacks are not really predictable (or have at least a probability of occurrence which can vary according to irrelevant news).

Predictability of a successful attack

We now consider whether there is any difference in the predictability of thresholds related to the information condition. Comparing the standard deviations of average thresholds across sessions in Table 3 above, it seems that the information condition has a slight impact on the dispersion of observed thresholds among otherwise equal treatments. This impression is supported by separate regressions of thresholds for both information conditions. Indeed, Regressions 3 and 4 (see Table 6, Appendix C) show that there is indeed a small difference between TCS and PCS conditions. Moreover, the standard deviation of residuals goes in the same direction (1.80 in TCS sessions and 1.76 in PCS sessions). Nevertheless, if informational structure has an impact on predictability, the impact of "irrelevant" variables (such as the order) is much higher. This means that speculators can overreact to irrelevant news and coordinate on "sunspots".

Result 4: The predictability of an attack is slightly higher in PCS than in TCS sessions.

As a consequence, in terms of economic policy, we can draw the following conclusion from our previous results: the central bank can reduce the probability of an attack and has more control over the beliefs of traders if it discloses one clear (and precise) single signal, even if agents get private information from other sources. By giving several public signals, it lowers its focal potential. The loss of predictability linked to uncontrolled private information is largely outweighed by the increase in predictability related to the existence of a focal point. What, then, is the impact of such an existing focal point on coordination failures?

Coordination Failures

We now turn to the analysis of coordination as a function of the informational structure given to participants. The differences in coordination can be measured by the average width of the interval within a session between the highest state up to which action B (the risky action) always failed and the lowest state from which point action B was always successful (see Table 3 above). These intervals tend to be wider for TCS. We check whether the difference between the lowest state, from which point all attacks succeeded, and the highest state, up to which point all attacks failed, has any relation to exogenous conditions. Taking an average over all sessions with TCS, the intervals of states for which there is no clear indication whether attacks failed or succeeded has a width of 8.6. In treatments with both private and public signals, its width is 5.7 on average. In TCS sessions the range of states for which a state falls into the region of indeterminacy increases by about 3 compared to PCS sessions. Regression 5 (see Table 7, Appendix C) shows that the difference in informational conditions is not significant.

Result 5: There is no significant difference in coordination achievement between sessions with PCS and with TCS.

5. Comparison of the results with HNO

In this section, we provide a comparison of our experimental results with the previous experiment done by HNO.10 This comparison aims at testing the robustness of policy implications of HNO when adding some new signal and at having a better understanding of the coordinating effect of public information and its potential drawbacks linked with self-fulfilling beliefs. We confirm most of the results of HNO. However, one important result — in terms of predictability — does not seem to be robust when adding one signal.11

Robustness of HNO's conclusions

The following four points tend to reinforce the conclusions of HNO.

- Undominated thresholds: A large majority of the agents followed strategies consistent with undominated thresholds. This was less striking in our case than in HNO, probably because receiving two signals rendered the cognitive process more difficult than the one signal given in HNO.
- Comparative statics: In both informational conditions, calculated mean thresholds follow the comparative statics of the global game solution for variations of T, meaning that, for example, capital controls can be efficient in limiting the occurrence of speculative attacks.
- Informational effect (on the probability of an attack): In sessions with PCS, estimated mean thresholds are higher than in sessions with TCS. This result shows the robustness of the result of HNO according to whom those thresholds are higher with PI than with CI. Adding a public signal does not change the result.
- Order effect: Our results confirm the fact that in sessions starting with T=50, estimated mean thresholds are lower than in sessions starting with T=20.

This leads us to our sixth result.

Result 6: The experiment by HNO is robust to the addition of a public signal in each treatment with respect to the use by subjects of threshold strategies, the comparative statics of the global game solution, the probability of the attack and the order effect.

Question of coordination and predictability

- Coordination: HNO found that in private information sessions, the standard deviation of thresholds within a session is larger than in common information sessions. This is no longer the case when adding a public signal in each treatment. However, we must mention that this result is hardly significant. In addition, an explanation can be found in the fact that HNO had precise public information, while here we have noisy public signals.
- Predictability of an attack: Whereas the dispersion of thresholds across different sessions is about the same for both informational conditions in HNO, we get a small difference between our two treatments — namely predictability of successful speculative attacks is slightly higher in PCS sessions than in TCS ones. This reversal of results might be explained by the fact that the single common signal serves as a coordination point, similar to the CI treatment in HNO. The fact of having a private signal accompanying the public one avoids the self-fulfilling beliefs that might be destabilising.

Result 7: Adding a public signal to the treatments of HNO does not reinforce their conclusions in terms of coordination and predictability of an attack.

As opposed to HNO, we have here a confirmation of the theoretical objection to public information.

6. Concluding remarks

The main results of the paper are that agents tend to overreact to a public signal when they also receive a private one — and that the probability of an attack is lower and its predictability higher when agents receive a single public signal in addition to private information from another source than when they receive two uncoordinated public announcements. It thus seems that the conclusion of HNO in terms of the predictability of an attack is not robust to the addition of a public signal in the two treatments. An interesting extension of our research would be to experimentally analyse in greater depth the effects of informational precision on subjects' decisions. Indeed equilibrium selection in global game models typically relies on the relative precision of public versus private signals.

The main economic policy conclusion we can draw from our experiment is the following: the central bank can reduce the prior probability of a crisis and raise its focal potential if it discloses a single signal, in a context where agents additionally get private information from diverse sources. Such a conclusion presents clear evidence in a context where the format of financial institutions' communication has become part and parcel of national and international financial institutions' strategy. In this respect, the examples of the relatively poor communication strategy of the International Monetary Fund and the European Central Bank, both hardly able to speak with one voice, perfectly illustrate our findings. Our result suggests that financial institutions' communicative deficiencies are intrinsically linked to the strategy they adopt by explaining how fragmented communication may exacerbate coordination problems in financial markets. This study therefore makes a case for financial institutions to clarify their objectives, improve their published forecasts and try to limit the multiplicity of alternative viewpoints.

Appendix

A - Variables used in linear regressions and logistic estimation

The next table explains the variables used for linear regressions and logistic estimation.

Insert Table 4 Here

B - Logistic estimation

We use the following logit model:

$$P(\mathrm{De}) = \frac{1}{1 + e^{-(\mathrm{De})}}$$

where De = 1 if the participant chose decision B and 0 if the participant chose decision A. We assume that De is linearly related to the variables explained in the two cases below.

De_i = a + b Pr + c Pu + u for PCS sessions or De_i = a + b Pu1 + c Pu2 + u for TCS sessions, where u is the error.

The results of the logistic estimation are summed up in Table 5. We also calculate the marginal effects of each signal in each session. We give the *t*-statistic in bracket.

Insert Table 5 Here

C - Linear regressions

For all the linear regressions, we give the coefficient of the explanatory variable and the *t*-statistic in brackets.

Table 6 sums up the results from regressions 1, 2, 3 and 4 which determine the influence of the different explaining variables on the level of threshold.

Regression 1: $Y^* = \gamma_0 + \gamma_1 T + u$.

Regression 2: $Y^* = \gamma_0 + \gamma_1 T + \gamma_2 \text{ Info} + \gamma_3 \text{ Ord} + \gamma_4 \text{ TO} + u$.

Regressions 3-4: $Y^* = \gamma_0 + \gamma_1 T + \gamma_3 \text{ Ord} + \gamma_4 \text{ TO} + u$.

Insert Table 6 Here

Table 7 sums up the results of regressions 5, 6 and 7 which determine the influence of the different explanatory variables on the variation of thresholds.

Regression 5: $\Delta Y^* = \delta_0 + \delta_1 T + \delta_2 \text{ Info} + \delta_3 \text{ Ord} + \delta_4 \text{ TO} + u$.

Regressions 6-7: $\Delta Y^* = \gamma_0 + \gamma_1 T + \gamma_2 \text{ Ord} + \gamma_3 \text{ TO} + u$.

Insert Table 7 Here

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Notes

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[1] The rationale for the fact that the experiment shows similarities in agents' behavior in both informational contexts is the following (Heinemann, 2002): on the one hand, transparency increases predictability and reduces efficiency losses linked with non-coordinated activities; on the other, public information increases the probability of an attack by reinforcing the agents' beliefs in the capacity of the group of coordinating on the efficient strategy.

[2] Recall that the SDDS which was approved by the Interim Committee in April 1996 requests member countries to provide voluntarily to the IMF macroeconomic data about their monetary and financial situation. The SDDS is expected to encourage sound macroeconomic policies and to improve the functioning of financial markets by rationalizing the formation of international investors' anticipations.

[3] Note that in May 2003 the ECB revised its monetary policy approach, in order to clarify its external communication. Such a change is precisely justified by our approach.

[4] In the case of one public signal Y, $\varepsilon=0$.

[5] In 4 sessions, they applied W=100, in the others W=60.

[6] To control for risk aversion of agents, for 12 sessions we proposed a choice between an alternative with a fifty-fifty chance of earning either 5 euros or nothing. On average, 10.5 out of 15 subjects chose the lottery. We could not identify any interesting result however.

[7] Most of the participants were early or middle-stage business, economics or engineering students.

[8] With several signals, it is not immediately clear, empirically, which definition of threshold strategy to choose: the mean of the signals, the lowest signal, the highest one? Subjects seemed to follow more threshold strategies as a mean of signals.

[9] This means that, for some participants, learning had an impact on the understanding of the advantage of playing threshold strategies.

[10] Nevertheless, the following results have to be read with caution because, even if this experiment was as close as possible to the protocol of HNO, as we have already mentioned, there were some differences. More especially, coordination games are very sensitive to different subjects pools.

[11] We do not present any robustness analysis as in HNO (dealing with experienced players, high-stake sessions, high number of rounds). While the sessions with experienced subjects and the sessions with a high number of rounds did not bring any additional results, HNO found that high-stake sessions led to higher thresholds due to stronger risk aversion. We can imagine that the same conclusion would hold in our experiment without changing the results.

Figures

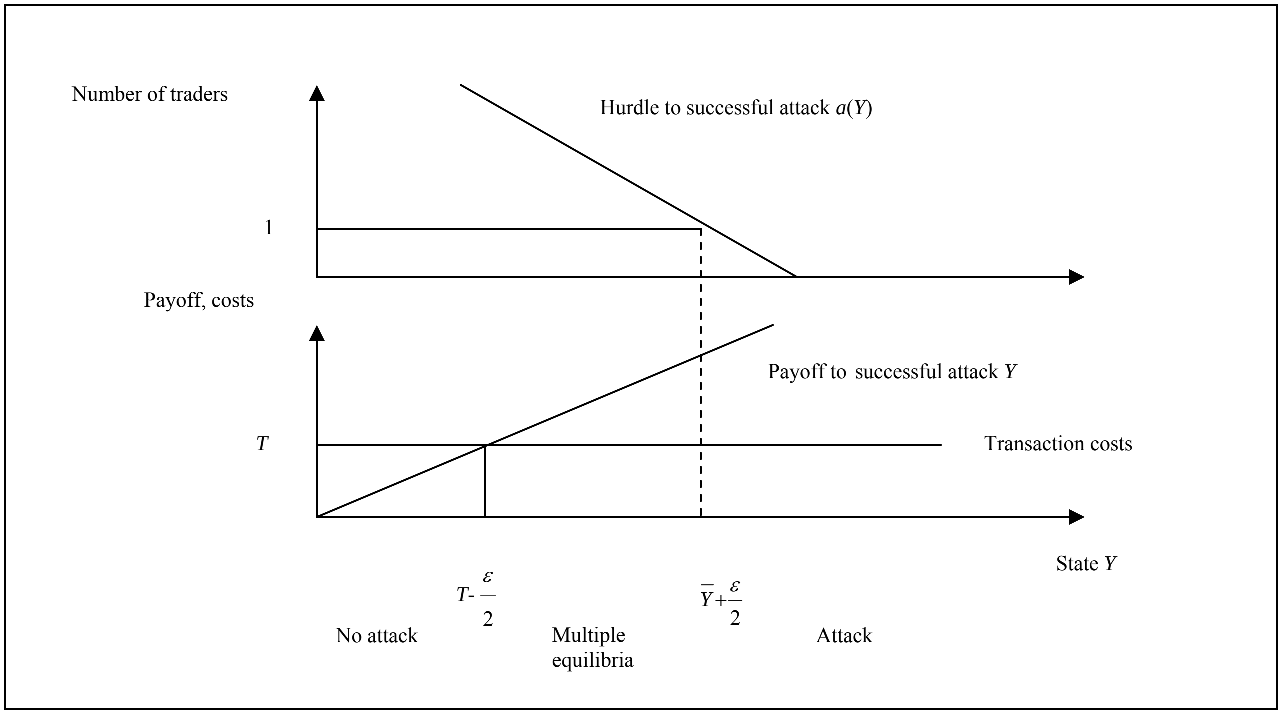

Figure 1. The speculative attack game under different informational assumptions.

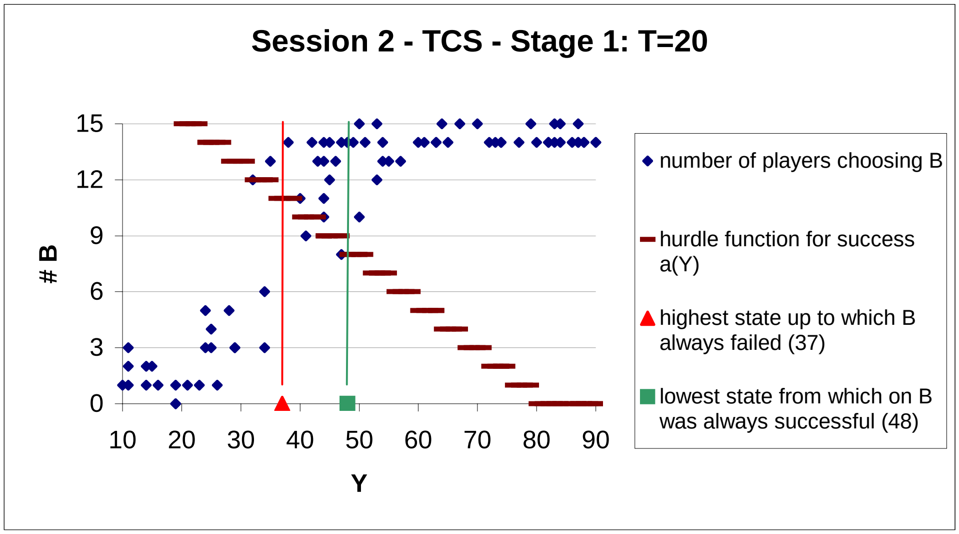

Figure 2. Combined data from all eight periods of one stage of a session with TCS.

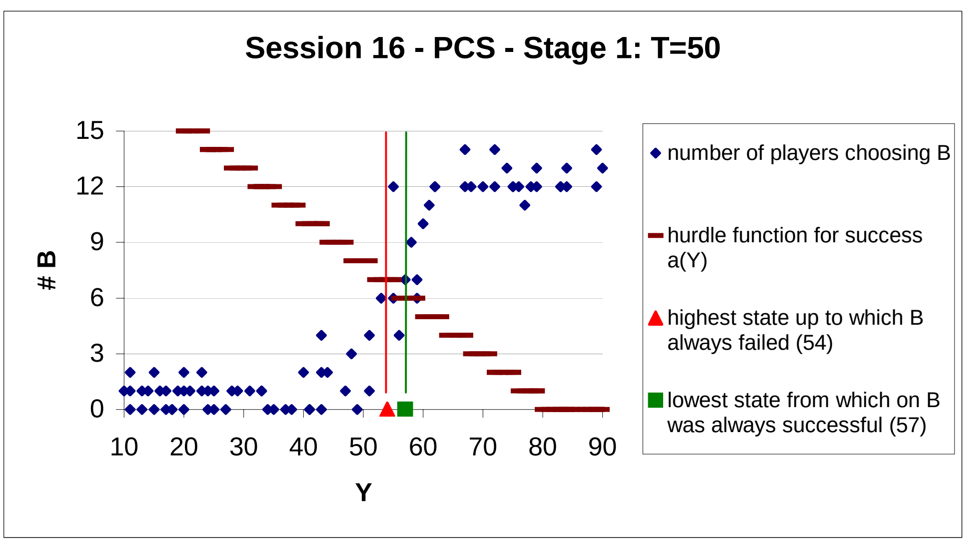

Figure 3. Combined data from all eight periods of one stage of a session with both PCS.

Tables

Sessions with two common signals		*Thresholds to success*	
Session	Order	T = 20	T = 50
1	20/50	41 – 44	56 – 61
2	20/50	37 – 48	52 – 61
3	20/50	45 – 48	54 – 55*
4	20/50	42 – 43*	53 – 62
5	20/50	43 – 52	54 – 55*
6	50/20	26 – 32	30 – 57
7	50/20	30 – 38	37 – 56
8	50/20	25 – 32	26 – 56
9	50/20	33 – 39	50 – 57
10	50/20	23 – 33	54 – 56*

Table 1. Thresholds to success in sessions with two common signals.

Sessions with private and common signals		*Thresholds to success*	
Session	Order	T = 20	T = 50
11	20/50	45 – 46*	52 – 55
12	20/50	47 – 49*	57 – 59*
13	20/50	46 – 51	47 – 59
14	20/50	46 – 50	49 – 62
15	20/50	37 – 39	49 – 62
16	50/20	39 – 41*	54 – 57
17	50/20	30 – 37	33 – 55
18	50/20	32 – 36	54 – 58
19	50/20	35 – 37	54 – 63*
20	50/20	36 – 39	53 – 55

Table 2. Thresholds to success in sessions with private and common signals.

Treatment	*T = 20*	*T = 50*
Sessions with TCS		
Mean thresholds to success	37.7	52.10
Standard deviation of average thresholds across sessions	7.2	5.8
Average width of the interval of indeterminacy within a session	6.4	10.9
(Number of sessions)	(10)	(10)
Sessions with PCS		
Mean thresholds to success	40.90	54.30
Standard deviation of average thresholds across sessions	5.7	3.8
Average width of the interval of indeterminacy within a session	3.2	8.3
(Number of sessions)	(10)	(10)

Table 3. Observed mean thresholds to success and average width of the interval.[a]

[a] Between the highest state, up to which action B always failed and the lowest state, from which point action B was always successful.

Name	*Nature*	*Definition*	
T	dummy	0: payoff for secure action T=20	1: T=50
Info(rmation)	dummy	0: session with two common signals	1: session with simultaneous private and common signals
Ord(er)	dummy	0: session starting with T=50	1: session starting with T=20
TO	dummy	0: if Order = 0 or T = 20	1: if Order = 1 and T=50
Pr (Private signal)	number	Value of the private signal in PCS sessions.	
Pu (Public signal)	number	Value of the common signal in PCS sessions.	
Pu1 (1st public signal)	number	Value of the first common hint in TCS sessions.	
Pu2 (2nd public signal)	number	Value of the second common hint in TCS sessions.	
De(cision)	dummy	0: if the participant chose decision A	1: if the participant chose decision B
Y*	number	Mean between highest state up to which all attacks failed and lowest state from which point all attacks succeeded in all 8 periods	
ΔY*	number	Distance between the two states defining Y*	
a	number	Results from logistic estimation	
b	number	Results from logistic estimation	
c	number	Results from logistic estimation	

Table 4. Variables used in linear regressions and logistic estimations.

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
Session	Information	Order	T	Parameter estimation (t-values)			Marginal effect of Pu1 in TCS and Pr in PCS	Marginal effect of Pu2 in TCS and Pu in PCS
				a	b	c		
1	TCS	20/50	20	9.12 (14.71)	0.13 (6.57)	0.08 (4.41)	0.029	0.018
1	TCS	20/50	50	25.03 (10.53)	0.16 (6.77)	0.28 (8.62)	0.001	0.002
2	TCS	20/50	20	3.30 (13.81)	0.01 (0.86)	0.08 (8.06)	0.001	0.001
2	TCS	20/50	50	11.51 (15.78)	0.10 (7.81)	0.11 (8.29)	0.018	0.022
3	TCS	20/50	20	7.61 (16.57)	0.09 (6.57)	0.08 (6.95)	0.022	0.021
3	TCS	20/50	50	20.96 (12.76)	0.19 (8.56)	0.20 (9.35)	0.038	0.040
4	TCS	20/50	20	6.02 (17.45)	0.04 (3.86)	0.09 (7.61)	0.011	0.022
4	TCS	20/50	50	13.85 (14.86)	0.12 (8.32)	0.11 (7.16)	0.013	0.012
5	TCS	20/50	20	4.09 (17.40)	0.04 (3.67)	0.05 (4.73)	0.009	0.011
5	TCS	20/50	50	15.60 (13.61)	0.07 (2.81)	0.21 (7.48)	0.018	0.052
6	TCS	50/20	20	19.02 (9.36)	0.34 (7.76)	0.39 (8.52)	0.028	0.023
6	TCS	50/20	50	13.73 (13.50)	0.14 (9.76)	0.12 (6.67)	0.000	0.000
7	TCS	50/20	20	3.28 (14.14)	0.08 (6.13)	0.02 (1.79)	0.013	0.018
7	TCS	50/20	50	6.81 (18.47)	0.05 (5.10)	0.07 (6.68)	0.008	0.002
8	TCS	50/20	20	11.62 (11.07)	0.24 (9.75)	0.21 (7.78)	0.013	0.026
8	TCS	50/20	50	11.03 (14.95)	0.07 (5.06)	0.14 (8.73)	0.018	0.015
9	TCS	50/20	20	6.80 (17.82)	0.07 (5.68)	0.05 (4.18)	0.017	0.013
9	TCS	50/20	50	7.91 (12.71)	0.08 (4.65)	0.18 (8.69)	0.000	0.001
10	TCS	50/20	20	7.78 (17.50)	0.17 (8.08)	0.03 (2.38)	0.028	0.008
10	TCS	50/20	50	3.03 (12.92)	0.04 (3.98)	0.07 (5.84)	0.004	0.006

11	PCS	20/50	20	10.24 (15.48)	0.12 (8.12)	0.11 (7.57)	0.022	0.021
11	PCS	20/50	50	20.80 (11.33)	0.16 (6.60)	0.21 (8.29)	0.022	0.029
12	PCS	20/50	20	5.37 (16.93)	0.04 (3.44)	0.07 (6.08)	0.019	0.015
12	PCS	20/50	50	20.72 (11.48)	0.19 (7.57)	0.17 (7.49)	0.010	0.014
13	PCS	20/50	20	6.70 (16.82)	0.08 (6.63)	0.06 (5.39)	0.007	0.014
13	PCS	20/50	50	7.07 (17.84)	0.05 (4.23)	0.07 (5.49)	0.024	0.027
14	PCS	20/50	20	6.56 (17.25)	0.06 (5.13)	0.07 (6.31)	0.015	0.019
14	PCS	20/50	50	20.06 (10.65)	0.11 (5.28)	0.25 (7.18)	0.008	0.019
15	PCS	20/50	20	6.70 (16.64)	0.06 (4.68)	0.11 (8.08)	0.008	0.016
15	PCS	20/50	50	21.55 (11.23)	0.13 (6.69)	0.26 (8.81)	0.007	0.014
16	PCS	50/20	20	3.38 (15.60)	0.04 (3.58)	0.06 (5.97)	0.007	0.008
16	PCS	50/20	50	5.20 (18.52)	0.04 (3.80)	0.05 (4.43)	0.006	0.009
17	PCS	50/20	20	10.81 (10.03)	0.16 (6.13)	0.21 (7.63)	0.015	0.017
17	PCS	50/20	50	13.72 (14.20)	0.12 (7.49)	0.13 (7.99)	0.000	0.001
18	PCS	50/20	20	10.10 (12.21)	0.12 (5.95)	0.19 (8.66)	0.009	0.011
18	PCS	50/20	50	15.95 (13.19)	0.12 (7.52)	0.15 (7.17)	0.000	0.001
19	PCS	50/20	20	10.89 (14.79)	0.06 (3.27)	0.13 (7.18)	0.007	0.017
19	PCS	50/20	50	7.88 (14.02)	0.09 (5.38)	0.16 (7.92)	0.002	0.003
20	PCS	50/20	20	6.40 (18.15)	0.05 (4.56)	0.06 (5.05)	0.012	0.013
20	PCS	50/20	50	3.96 (14.14)	0.04 (3.57)	0.08 (6.56)	0.004	0.007

Table 5. Results of logistic estimations.[a]

[a] The first column is the session number. The next two columns give session specific conditions. Column 4 indicates the treatment specific payoff to action A. Columns 5, 6, and 7 are results of

logistic regressions based on data of the last four periods of each treatment. Columns 8 and 9 give the marginal effects of each signal.

No.	*Data source (number of observations)*	*Explaining variables: estimated coefficients (t-values)*					*R^2 Adjusted R^2*
		Intercept	T	Info	Ord	TO	
1	All treatments	39.37	13.85				0.58
	(40)	(29.05)	(7.22)				0.57
2		32.47	16.95	2.65	11.15	-6.20	0.82
		(22.5)	(9.30)	(2.10)	(6.11)	(-2.40)	0.80
3	Treatment with PCS	36.20	17.40		9.40	-7.90	0.82
	(20)	(20.58)	(6.99)		(3.78)	(-2.25)	0.79
4	Treatment with TCS	31.40	16.50		12.90	-4.50	0.86
	(20)	(17.48)	(6.50)		(5.08)	(-1.25)	0.84

Table 6. Regressions explaining thresholds to success.

No.	*Data source (number of observations)*	*Explaining variables: estimated coefficients δ_i (t-values)*					*R^2 Adjusted R^2*
		Intercept	T	Info	Ord	TO	
5	All treatments	6.60	7.30	-2.80	-1.10	-4.60	0.26
	(40)	(2.96)	(2.59)	(-1.40)	(-0.39)	(-1.15)	0.18
6	Treatment with PCS	3.60	4.40		-0.80	1.40	0.24
	(20)	(1.56)	(1.35)		(-0.25)	(0.30)	0.09
7	Treatment with TCS	6.80	10.20		-1.40	-10.60	0.39
	(20)	(2.20)	(2.33)		(-0.32)	(-1.71)	0.27

Table 7. Regressions explaining the width of the interval of indeterminate outcomes.