Aggregate Sentiment and Investment: An Experimental Study

Donja Darai* Shimon Kogan† Anthony M. Kwasnica‡ Roberto A. Weber*

September 22, 2014

Preliminary draft. Please do not cite or circulate.

Abstract

We theoretically and experimentally study an investment game with fundamental state uncertainty and input complementarities—i.e., a global game environment. Our particular focus is on how a sentiment index, closely modeled after consumer confidence surveys, aggregates private information and influences investment. We find that a sentiment index produces very similar results to a highly informative public signal regarding the underlying state. Both forms of public signals—one exogenous and highly precise, the other endogenous and noisier—increase investment in a range of states where public information can induce multiplicity of equilibria. The sentiment index also increases investment in some states in which the public signal does not. We also observe significant heterogeneity between groups in their mappings of private signals into sentiment reports.

Keywords: global games, consumer confidence, expectations, coordination

JEL classification: C72, C92, D84

*University of Zurich, Department of Economics.

†Interdisciplinary Center Herzliya (IDC) and University of Texas at Austin, McCombs School of Business.

‡Pennsylvania State University, Smeal College of Business.

1 Introduction

Sentiment indices, such as measures of consumer confidence, are discussed prominently as potential indicators of future investment, consumption and growth. Indeed, empirical evidence suggests that such measures predict important variation in economic activity, including consumer spending and stock prices (Acemoglu and Scott, 1994; Ludvigson, 2004; Lemmon and Portniaguina, 2006). While the idea that consumer confidence may predict economic fluctuations is intuitive, providing theoretical foundations for this channel and empirically identifying its causal effect are both topics of a large body of macroeconomic literature.

For example, expectations play a crucial role in theoretical models based on strategic complementarities that give rise to multiplicity of equilibria. In these models, output responds to exogenous shocks to fundamentals (e.g., shocks to technology), as well as to shocks to non-fundamentals, which can cause the economy to shift across equilibria (see, for example, Ball and Romer, 1991; Bryant, 1983; Cass and Shell, 1983; Cooper and John, 1988; Kiyotaki, 1988; Lorenzoni, 2009; Milgrom and Roberts, 1990; Murphy, Shleifer, and Vishney, 1989; Roberts, 1987; Shleifer, 1986; Weil, 1989). In such models, output can fluctuate due to changes in expectations that are not driven by shocks to fundamentals, providing a channel through which expectations, and sentiment, themselves may influence future economic outcomes. For example, Blanchard (1993) argues that the relationship between consumer confidence and the 1990-1991 recession was driven, at least in part, due to confidence measures reflecting "animal spirits" and negative shocks to confidence unrelated to expectations about fundamentals.

A large number of empirical papers attempt to identify relationships between changes in expectations, proxied using consumer confidence, and economic output. However, establishing a *causal* relationship between variation in consumer confidence, and output is challenging. Matsusaka and Sbordone (1995) use a VAR approach that attempts to isolate the joint-effects of shocks to fundamentals on consumer confidence and output. They reject the null hypothesis that changes to consumer confidence do not cause changes in output. Further, they show that shifts in consumer confidence explain between 13 and 26 percent of the output fluctuations. Harrison and Weder (2006) estimate a dynamic general equilibrium model with production externalities in which they extract consumer confidence from credit spreads. They find that the model can explain the output patterns observed around the U.S. Great Depression—the initial decline leading into the recession as well as the slow recovery from it. Likewise, Hall

(1993) studies the U.S. 1990-1991 recession and concludes that explanations based on responses to standard macroeconomic factors are not sufficient to explain this recession. Instead, he attributes it to consumers' "cascading of negative responses."

In contrast to these studies, other papers find that the relationship between expectations and output are largely driven by changes in fundamentals. For example, Barsky and Sims (2012) develop a New Keynesian stochastic general equilibrium model with two shocks: a persistent productivity shock (the fundamental shock) and a second shock arising from agents' noisy observation of the first shock (a non-fundamental shock). Their goal is to separate the news component in consumer confidence from the animal spirit component. Estimating the model using forward-looking questions in the consumer confidence survey, they find that most of the variation in confidence is associated with the news component.

In short, while a large body of literature recognizes the important relation consumer expectations and macroeconomic output may have, a definitive conclusion regarding the precise nature of this relationship remains absent. This is perhaps not surprising, given the highly complex relationships between economic fundamentals, which are hard to precisely identify, expectations, and future economic activity. The empirical challenge in establishing clear relationships in such a complex setting is twofold. First, using field data, it is difficult to establish a causal relationship between exogenous changes in consumer expectations and output. Second, even if there is a causal relationship between the two, it is unclear what drives this relationship—changes in expectations about fundamentals or changes in expectations unrelated to fundamentals.

This paper adopts an alternative, complementary, approach to the study of how expectations both reflect fundamentals and affect economic activity. In particular, we rely on the high degree of control afforded by laboratory environments to experimentally test a simple model of investment with complementarities and time-varying fundamentals, in which we manipulate the presence of aggregate confidence measures to test both how they reflect avialable information and how they influence future output. Of course, as with any laboratory investigation of complex phenomena, our experiment represents a vast simplification. However, the ability to manipulate key features of the environment allows us to test causal relationships in a manner that is impossible in field settings.

Specifically, we develop a novel game that incorporates key features of current models of investment under complementarities with incomplete information about fundamentals (Carlsson and van Damme, 1993; Morris and Shin, 1998). Players in the game are never fully aware of the payoff-relevant state realization, which models economic fundamentals, and simultaneously decide whether to make an investment decision whose outcome depends on the realized state and the investment decisions of other players. As with similar models, the perfect-information case—i.e., when players receive a common signal about the state that is sufficiently precise—can induce multiplicity of equilibria. But, with only private information, there is a unique equilibrium in cutoff strategies. Our analyses and experiment study both the case with private information and the one with a public, exogenous signal. Our novel contribution is to also incorporate a public endogenous signal, representing an aggregate sentiment measure, that obtains from individuals' responses to questions about their expectations regarding the future. In obtaining these expectations, we use wording very similar to that found in widely used measures of consumer and business confidence.

Our results demonstrate that an aggregate sentiment measure can be as effective as a highly precise exogenous public signal in coordinating behavior on more efficient equilibria, when compared to the case with only private information and no public signal. The sentiment index, due to its limited categories, can only provide a coarser measure of the fundamental state than the public signal. However, despite the confidence index's natural imprecision and "cheap talk" nature, the outcome of this condition is almost identical to that of the public signal treatment. In fact, the confidence index even induces efficient coordination in some ranges of states for which the public signal does not.

While the aggregate performance of the sentiment measure and the exogenous public device are similar, they achieve improved coordination and output via different mechanisms. The public signal improves coordination by providing precise information about the state, but cannot directly convey any information about intended behavior. On the other hand, our analysis indicates that the confidence measure also impacts expectations by influencing beliefs about aggregate investment. We observe this clearly in the heterogeneity with which groups map private signals into confidence reports, and in how they respond to the aggregate confidence measures. Hence, rather than simply representing "noisy" or "erratic" measures of existing information about fundamentals, the sentiment measures in our experiment contain valuable, and self-confirming, information about intentions that ultimately influences output.

The remainder of the paper is organized as follows. The next section reviews and connects our research to some of the existing theoretical work on games with complementary investment and incomplete information. Section 3 introduces the model, while Section 4 outlines the experimental design and predictions. Section 5 presents the results and Section 6 provides our conclusions.

2 Relation to Existing Literature

Our model follows the extensive literature on global games and the burgeoning experimental examination of behavior in these environments. The global game approach was originally proposed by Carlsson and van Damme (1993) as an equilibrium selection device in games with strategic complementarities and thus multiple equilibria—essentially, showing that uncertainty about the payoff structure along with a small amount of private information could create a unique Bayesian equilibrium that often converged toward a particular equilibrium of the complete-information game as private information became more precise. These models have been extensively applied to analyze important macroeconomic phenomena, such as currency crises (Morris and Shin, 1998) and bank runs (Goldstein and Pauzner, 2005), in which complementarity and coordination play important roles.

A central feature of this research is that the indeterminacy of multiple equilibria can be avoided in favor of actions that are guided by fundamentals, by adding a small amount of private information. However, when public information exists alongside private information it is possible that a sufficiently precise public signal can recreate the multiple equilibrium problem, whereby the public signal dominates any individual's private information and induces equilibirum multiplicity (Hellwig, 2002). More recently, research has focused on how even endogenously generated public signals—such as market prices, opinion polls, or surveys—may also result in multiple equilibria (Angeletos and Werning, 2006). These results, however, are highly reliant on particular models of public and private information structures that may not closely parallel the real world; Morris and Shin (2006) demonstrate that such results are highly sensitive to modeling assumptions.

Our approach here is to examine the impact of both exogenous (an aggregation of all the private signals) and endogenous (sentiment measures) public signals in an environment with state uncertainty and complementary investment decisions—i.e., a simple setting with the properties of the above global games approach. Importantly, we develop a simplified setting in which the relationship between the state, individuals' actions, and payoffs is intended to be easy to understand for experimental subjects. For example, for the purpose of such simplicity, we depart from prior work by modeling the underlying state variable and information using the uniform distribution rather than the normal distribution. While the results utilizing the normal distribution may be theoretically more tractable, they may be more difficult for experimental subjects to understand. To this setting, we introduce an aggregate sentiment measure that closely mimics such information sources in the real world. In that way, our experiments may act as a bridge between the application of the abstract theory and the complexity of the real world.

Our work is related to a growing experimental literature that studies models with features of global games. For example, in a pioneering study, Heinemann, Nagel, and Ockenfels (2004) find that the unique cutoff, global games prediction generally corresponds to observed behavior in private-information settings, which we also find. However, Heinemann, Nagel, and Ockenfels (2004) also find that the private-information global games predictions match behavior even when there is public information about the state variable, whereas we find a greater divergence toward high-investment equilibria under public information, which is consistent with the theoretical prediciton that the public information case can change behavior by inducing multiplicity.

Cornand (2006) examines the same environment studied by Heinemann, Nagel, and Ockenfels (2004) but adds an equally noisy public signal to an experiment with private signals and finds that subjects put too much weight on the public signal, thereby lowering efficiency. How much weight subjects put on private and public signals is studied by Cornand and Heinemann (2014) using variations of a simplified version of the game studied by Morris and Shin (2002). They find that subjects attach more weight to public than to private signals, but not as much as predicted in equilibrium. In contrast, we examine a more precise public signal, which is generated by aggregating the private information of all players. Hence, our public signal corresponds to the most informative possible aggregate signal, given the private information held by the players.

Recently, Szkup and Trevino (2013) examine costly information acquisition in a setting similar to Heinemann, Nagel, and Ockenfels (2004). In a two-person speculative attack environment, they show that while behavior is similar to the global games prediction of a threshold strategy there are important differences in the information acquisition phase. In particular, many subjects invest too much in the precision of their information (relative to the equilibrium prediction) since, most importantly for our research, when the information is more precise subjects tend to favor efficient (payoff dominant) equilibria over risk dominant equilibria. Qu (2013) closely follows the theoretical model of Angeletos and Werning (2006) and examines the role of endogenous information acquisition through both market prices and cheap talk; she finds that efficiency is improved with cheap talk but not with markets.

A key difference between the model we analyze and those presented in much of the experimental and theoretical literature has to do with the impact of the stochastic state variable on the strength of the strategic complementarity. In our experiment, the state variable directly impacts the payoffs from successful or unsuccessful coordination but does not impact the strength of strategic complementarity; the investment decision of the median player always determines whether investment is successful or not. On the other hand, in all global games experiments referenced above, and most of the theoretical literature, the state variable interacts with the level of strategic complementarity in the sense that the state determines the number of players needed for successful investment. Since it is well-known that the level of strategic complementarity can impact behavior in experimental coordination games, even with complete information (VanHuyck, Battalio, and Beil, 1990, 1991), we fix the level of strategic complementarity to eliminate one possible channel through which information may impact behavior. So, in our model, uncertain fundamentals involve only payoffs and not the degree of interdependence between players.

Our experiment also differs from some of the above work in that we examine endogenous information using a measure closely mirroring real-world sentiment indices, which are commonly used in practice. Thus, a large part of our interest is in the effects of a specific kind of information on behavior, one that is present in the world outside theory, rather than in more abstract and general forms of information.

3 Model

We present a model of joint investment decisions where the ultimate payoff of the investment may be uncertain. We begin by describing the game under the assumption of complete

Table 1: Game Payoffs

	$c(a) = 0$	$c(a) = 1$
$a_i = 0$	T	T
$a_i = 1$	X	$X + P$

information and extend it to the incomplete information settings we examine in the laboratory.

3.1 Joint investment with complete information

There are N (odd) players who simultaneously make binary investment decisions, $a_i \in \{0, 1\}$, where $a_i = 1$ indicates that the player invested. The payoffs for players are determined by a potentially uncertain state variable, X, representing the state of the economy. Payoffs also depend upon the investment decisions of all the players, given by $c : \{0, 1\}^N \to \{0, 1\}$, with $c(a) = 1$ indicating that sufficient numbers have chosen to invest, so that some investment "synergy," given by $P > 0$, has resulted. In our experiments, $c(a) = 1$ only if the median, or $\frac{N+1}{2}$ or more players, invest. Table 1 describes the payoffs from the four possible outcomes of the game. A player who does not invest is guaranteed a fixed payoff of T.

The following summarizes the theory for the complete information game:

- If $T > X + P$, then it is a dominant strategy for each player to not invest ($a_i = 0$), so non-investment is the only equilibrium.
- If $X > T$, it is a dominant strategy for each player to invest ($a_i = 1$), so investment by all players (thus achieving the synergy) is the only equilibrium.
- If $X \leq T \leq X + P$, there are two pure-strategy Nash equilibria. All players investing ($a_i = 1$) is a Nash equilibrium that achieves a Pareto-dominant payoff, but is risky in the sense that a deviation by other players may result in the lowest possible payoff of X. All players playing not invest ($a_i = 0$) is a Nash equilibrium that results in lower equilibrium payoffs, but is riskless in the sense that a payoff of T is guaranteed.[1]

[1]When there are multiple equilbria, there is also obviously a mixed strategy equilibrium. If q is the symmetric probability that a player plays invest, then the mixed strategy Nash equilibrium is characterized by $1 - \frac{T-X}{P} = \sum_{k=0}^{((n-1)/2)-1} \binom{n-1}{k} q^k (1-q)^{n-1-k}$, where the right-hand side is simply the binomial probability that the number of the other $n-1$ players choosing to invest is less than $(N-1)/2$. Since the left-hand side is increasing in X, it is clear that the Nash equilibrium mixing probability q will be decreasing in X.

3.2 Joint investment with incomplete information

In many situations, including our experiment, the actual realization of the investment payoff state variable, X, may be unknown at the time of investment decisions. We assume that X is a random variable that is distributed uniformly between $[\underline{X}, \overline{X}]$. In this case, the expectation of X is given by $E(X) = \frac{\overline{X}+\underline{X}}{2}$. Assuming players are risk neutral, if they must decide on an investment strategy prior to revelation of the state variable, as long as $E(X) \leq T \leq E(X)+P$ we will continue to have two Nash equilibria as described by the third case above.

Now, assume that players receive a private signal regarding the state variable. In particular assume that each player receives an independently drawn signal, S, from the uniform distribution on $[X-\epsilon, X+\epsilon]$. Note that if the realization of the signal S is such that $E(X|s) < T-P$, then a risk neutral player has a dominant strategy to not invest. Conversely, if $E(X|s) > T$, then a risk neutral player has a dominant strategy to invest. However, in the range in between these expectations, the player must consider the strategies of the other players. In particular, identify a "global games" type unique Bayes Nash equilibrium where players follow a symmetric cutoff strategy of the following type:

$$a(s) = \begin{cases} 0 & if \quad s < S^* \\ 1 & if \quad s \geq S^* \end{cases}$$

Following the approach in Heinemann, Nagel, and Ockenfels (2004), and assuming the cutoff for the payoff synergy is given by the median, the probability of a successful investment is the probability that at least $\frac{N-1}{2}$ out of the $N-1$ other players also get signals of $s \geq S^*$ and therefore invest. The probability that any single player gets such a signal at the state X is given by

$$\frac{X - S^* + \epsilon}{2\epsilon}.$$

The expected utility of investing (playing $a_i = 1$ for a risk neutral player having observed the signal, s, assuming $s \pm \epsilon$ is contained entirely within $[\underline{X}, \overline{X}]$) is given by:

$$EU(s) = \frac{1}{2\epsilon}\int_{s-\epsilon}^{s+\epsilon} P\left[1 - B\left(\frac{N-1}{2} - 1, N-1, \frac{X - S^* + \epsilon}{2\epsilon}\right)\right] dX + s,$$

where $B(\cdot)$ is the cumulative Binomial distribution. The last term on the right follows from the fact that $E(X|s) = s$ and X is the guaranteed portion of the payoff from investment.

Therefore, in equilibrium, a player with signal S^* must be indifferent between investment and non-investment, or

$$EU(S^*) = \frac{1}{2\epsilon}\int_{S^*-\epsilon}^{S^*+\epsilon} P\left[1 - B\left(\frac{N-1}{2} - 1, N-1, \frac{X - S^* + \epsilon}{2\epsilon}\right)\right] dX + S^* = T. \quad (1)$$

Assuming $S^* \pm \epsilon$ is contained entirely within $[\underline{X}, \overline{X}]$ this defines a unique Bayes Nash equilibrium to the game. Given that states and signals are drawn from the uniform distribution, the equilibrium cutoff, S^*, is independent of the size of the signal noise term ϵ and is given by

$$S^* = T - \left(\frac{N-M-1}{N}\right) P, \quad (2)$$

where M is the maximal number of the $N-1$ other players such that investment by the player will not result in the synergy term being obtained (i.e. investment being successful). For example, in the case of the median, $M = \frac{N-1}{2} - 1$. An interesting feature of this equilibrium is that, in contrast with other models, the cutoff strategy does not depend upon the precision of the signal.[2]

To ensure that this is a unique Bayes Nash equilibrium, we must have that there exist signals on either end of the distribution such that a player with that signal will have a dominant strategy to play invest/not invest. To rule out the equilibrium where all players invest regardless of their signal we must have, at least, that the player who observes the lowest possible signal of $z = \underline{X} - \epsilon$ would strictly prefer to not invest, or $E(X|z = \underline{X} - \epsilon) < T - P$. Note that since $z = \underline{X} - \epsilon$ can only be generated by the state $\underline{X}$ we have that $E(X|z = \underline{X} - \epsilon) = \underline{X}$ so $\underline{X} < T - P$ is sufficient. By the same logic, $\overline{X} > T$ is sufficient to rule out the equilibrium where all players withhold investment regardless of signal.

4 Experimental design and procedure

The experiment consists of 30 periods. During the experiment, participants interact in groups of $N = 5$ and group composition remains the same across all periods. In all periods and all

[2]This suggests that improved signals via a public information device should not directly impact the unique cutoff strategy equilibrium, where such a unique equilibrium continues to exist. Formally, this result is only true if the players' signals continue to be drawn independently from the uniform distribution. While improved information signals through some sort of public information release may obviously create stronger correlation and eliminate uniformity of the residual private information, we feel this is at least suggestive evidence that public information sources should have a limited impact on the unique cutoff strategy.

treatments, participants play a game with the same underlying payoffs. In particular, the certain benefit from non-investment is $T = 14$, the synergy from sufficient group investment is $P = 10$, and the state variable (X) is uniformly distributed between $\underline{X} = 3$ and $\overline{X} = 15$.[3] In all treatments, subjects receive private signals about the underlying state variable, X. These signals are distributed uniformly with a noise term of $\epsilon = 3$. The sequence of signals and states received by subjects is randomly and independently drawn across periods and groups such that each group within a condition observes a unique sequence. However, across conditions we use the same sequences so that we have paired observations at the group and subject level.

We study three treatment conditions, which vary the information available to the subject before making the investment decision. In the *private* treatment condition each subject only receives the private signal described above. In the other two conditions subjects receive an additional signal. In the *public* condition they receive a public signal that equals the average of subjects' private signals within a group. In the *confidence* condition, subjects receive the private signal and are then asked to indicate their confidence about their earnings in the current period on the scale: -2 ("bad"), -1 ("somewhat bad"), 0 ("neither good nor bad"), 1 ("somewhat good"), to 2 ("good"). Specifically, the instructions ask subjects, "Do you think that during this period your group will have good earnings, bad earnings or what?" (see Appendix C for the complete instructions). This question is a close adaptation of one of the five questions used by the Michigan Consumer Sentiments Index (issued by University of Michigan and Thomson Reuters) to calculate the Index of Consumer Sentiment. Before making an investment decision, subjects receive the average answer provided in their group as a public signal. Table 2 summarizes the main characteristics of the three conditions, in terms of information available to subjects, number of sessions, groups, and participants.

Table 2: Treatment conditions

condition	private signal	public signal	# sessions	# groups	# subjects
private	yes	no	3	14	70
public	yes	yes, avg. priv. sig.	3	14	70
confidence	yes	yes, avg. confidence	6	28	140

In total 280 subjects participated in the experiment—70 subjects (14 groups) in the *private*

[3] Actual draws of signals and state variables are in increments of .1. We assume that the continuous uniform distribution is a good proxy for these draws.

and in the *public* condition and 140 subjects (28 groups) in the *confidence* condition. Across conditions, groups were linked by realized draws of the state variable (X) and private signals (s). Specifically, one group in the private condition, one group in the public condition and two groups in the confidence condition each received the same sequence of states and signals across all periods of the experiment, and there were 14 such random realizations.

We conducted sessions at the University of Zurich between April 2013 and August 2014. Subjects were recruited from the student populations at the University of Zurich and the Swiss Federal Institute of Technology Zurich. Responses to a voluntary questionnaire following the experiment reveal that 51.8% of participants were male and 16.8% studied economics or a subject related to economics.[4] The experiment was computerized using the z-tree software (Fischbacher, 2007) and subjects were recruited using hroot (Bock, Nicklisch, and Baetge, 2012). Before the beginning the experiment, instructions were read aloud to subjects and subjects had to answer quiz question on how payoffs are calculated. Once all subjects correctly answered the questions, the experiment started.

Payoffs were indicated in Experimental Currency Units (ECUs), which we converted into CHF at the rate of 1 ECU for 2 CHF at the end of the experiment.[5] Subjects were paid for one randomly selected period. Each session lasted approximately 90 minutes, and subjects earned, on average, CHF 46.68 (CHF 16.40 minimum, CHF 59.00 maximum), including a show-up fee of CHF 10.

4.1 Experimental Predictions

The Bayes Nash equilibrium described earlier provides a prediction for the *private* treatment condition. Using the parameters described above and assuming risk neutrality, the unique Bayesian equilibrium cutoff strategy characterized by Equation 2 is $S^* = 8$.

Providing formal analysis of the two public information treatment conditions (*public* and *confidence*) is more difficult, since characterizing the joint distribution of the pieces of public information is analytically challenging. While analysis of alternative information structures such as the normal distribution may have been easier theoretically, we chose the uniform information structure in order to make the experiment easier to understand for the subjects.

[4]The questionnaire also included demographic information and a question on subjects' general attitude towards risk (Dohmen, Falk, Huffman, Sunde, Schupp, and Wagner, 2011). Summary statics are provided for each session in Table A.2 in the Appendix.

[5]Exchange of CHF to USD was approximately 1.08 at the time of the experiment.

Likewise, in the *confidence* condition, the information provided by the subjects is cheap talk so there is undoubtedly a multiplicity of potential equilibria including those where the confidence signal is uninformative.

As an alternative, we will compare aggregate and individual behavior to three benchmark equilibria. The first is the unique Bayesian equilibrium we identified in the private condition and that we label the **global** equilibrium. The global game strategy prescribes sometimes investing and sometimes not investing in the range where there are multiple equilibria in the complete information game. Figure 1 shows the probability (conditional upon the underlying state) that an individual receives a signal that would make them invest under play of the **global** equilibrium (e.g. a signal greater than 8 is observed).

While there are a continuum of equilibria under complete information, we consider the most **efficient** and most **inefficient** equilibria under complete information as our two other benchmark equilibria. We do not expect either of these outcomes to fully emerge in the *public* or *confidence* conditions, but they represent reasonable performance limit points that we would expect to be achieved as either information precision increases (e.g. approaches complete information) or as expectations coordinate behavior on the most efficient outcomes or the least efficient but less risky (inefficient) outcomes. Specifically, the **efficient** equilibrium assumes the players invest other than when they have a dominant strategy not to do so (e.g. $X < 4$); the **inefficient** equilibrium assumes the players do not invest other than when they have a dominant strategy to invest ($X > 14$).

Table 3 provides a comparison of the differences in expected performance of the three benchmark equilibria, across possible distributions of states. For example, with our parameters, the efficient equilibrium yields an *ex ante* expected payoff of 19.04 whereas the *ex ante* expected payoff from the inefficient equilibrium is 14.88 (78% of the former) and the ex-ante expected payoff from the global game equilibrium is 17.75 (93% of the efficient equilibrium). These benchmarks are useful in order to consider the informational value of the more precise information via public signals; the best expected payoffs that can be achieved are those of the efficient equilibrium whereas the worst are those of the inefficient equilibrium.

Well known theoretical results examine the potential interplay between public and private information when the public signal is both exogenous and endogenous (Angeletos and Werning, 2006). While these models vary substantially in their theoretical analysis from our model,

Figure 1: Probability of individual investment under **global** equilibrium

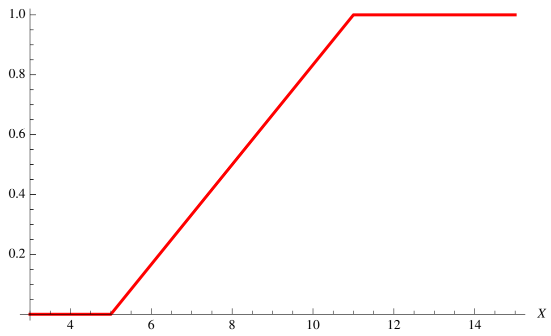


Table 3: Expected performance of theoretical benchmarks

	global	**efficient**	**inefficient**
Avg. Payoff	17.75	19.04	14.88
Avg. Investors	2.92	4.58	0.41
All players invest	42%	92%	8%
No players invest	25%	8%	92%

many of the basic insights hold. The primary result is that a sufficiently precise public signal restores multiplicity of equilibria, thereby resulting in actions that are not necessarily guided by fundamentals (or private information of fundamentals). Our approach here is to identify conditions on the mean of the public signal such that multiple equilibria exist (e.g. players have sufficient incentive to ignore their private information if they know everyone else is doing so). This analysis is detailed in Appendix B. Using our parameters, it follows that for $5.8 \leq \bar{s} \leq 12.2$ we know that there must exists both a "full investment" and a "zero investment" equilibrium.[6] These bounds are not tight, in that there might exist other situations where multiple equilibria exist. In the analysis that follows, we use these cutoff states to examine variation in behavior between these treatment conditions and the *private* condition already discussed.

5 Results

In this section we analyze how the different information environments influence individual and aggregate investment decisions. First, we provide a descriptive analysis of aggregate

[6]We cannot rule out the possible co-existence of a global game type of equilibrium as well.

investment and profits in all three conditions. Second, we use regression analysis to explore how the state and information condition determine outcomes. Next, we turn to individual investment behavior and classify subjects' investment strategies by the kind of strategies they employ. Finally, we focus on the *confidence* condition and analyze how subjects map their private signals into responses to the question about their confidence.

5.1 Investment and profit across conditions

The average number of investors is lowest in the *private* condition, with an average of 3.19 investors, and highest in the *confidence* condition, with an average of 3.81 investors.[7] In the *public* condition the average number of investors is, at 3.55, lower than in the *confidence* condition. The differences between the *private* and *public* conditions and between the *private* and *confidence* conditions are at least marginally statistically significant (two-sided pairwise Wilcoxon signed rank tests: p=0.059 and p=0.030, respectively, using the average investment over all 30 periods for a realized sequence of states as the independent observation). However, the difference between the *public* and the *confidence* condition is not significant (p=0.258).

Average profits are also significantly different between the *private* and the *public* conditions (17.67 vs. 18.16, p=0.006) and the *private* and *confidence* conditions (17.67 vs. 18.30, p=0.016), but not between the *public* and *confidence* conditions (p=0.470). Comparing realized profits with profit in the efficient equilibrium shows that subjects are able to obtain, on average, 92.67 percent of the maximum profit in the *private* condition, 95.36 percent in the *public* and 96.13 percent in the *confidence* condition, respectively.[8]

Comparing average profit in the *private* condition with the profit in the global game equilibrium shows that profits are remarkably close (17.67 vs. 17.75). The same holds for the observed and expected average number of investors in this condition (3.19 vs. 3.18). Hence, for this condition the prediction based on the global game approach does a good job of matching patterns in the aggregate data. But, for the other two conditions, profits are considerably higher and closer to those in the efficient equilibrium. It is interesting that

[7]The reported averages aggregate across periods and realized random variable sequences with one group per sequence in the *private* and *public* condition and two groups per sequence in the *confidence* condition. Table A.1 in the Appendix provides the data at the sequence level.

[8]To calculate the maximum profit available we assume that subjects play the efficient equilibrium with complete information (see Table 3). We then calculate for each period the ratio of subjects' obtained profit and these maximum possible profits.

profits do not differ between the *public* and the *confidence* conditions since subjects have—by construction of the treatment conditions—more precise information in the former than in the latter condition.

Result 1 *Investment outcomes are very similar across the* public *and* confidence *conditions and investment in these conditions is higher than in the* private *condition. We observe a similar pattern for earnings.*

Table 4: Average number of investors over time

	Avg. number of investors		
Period	*private*	*public*	*confidence*
1 - 5	3.21	3.44	3.62
6 - 10	3.21	3.40	3.68
11 - 15	3.27	3.59	3.74
16 - 20	3.39	3.79	3.93
21 - 25	3.23	3.73	4.10
26 - 30	2.84	3.34	3.80

We find no obvious time trends in either the average number of investors or the differences in investors across conditions. Table 4 shows the average number of investors in all three conditions, aggregated over five-period blocks . In line with the previous results, we observe that in each block of five periods investment is highest in the *confidence* condition and lowest in the *private* condition with investment in the *public* condition lying between the other two. In the following analysis, we only use data from periods 11 onwards, since subjects may experience a learning process, e.g. in terms of coordinating on the efficient or inefficient equilibrium, in the initial ten periods.[9]

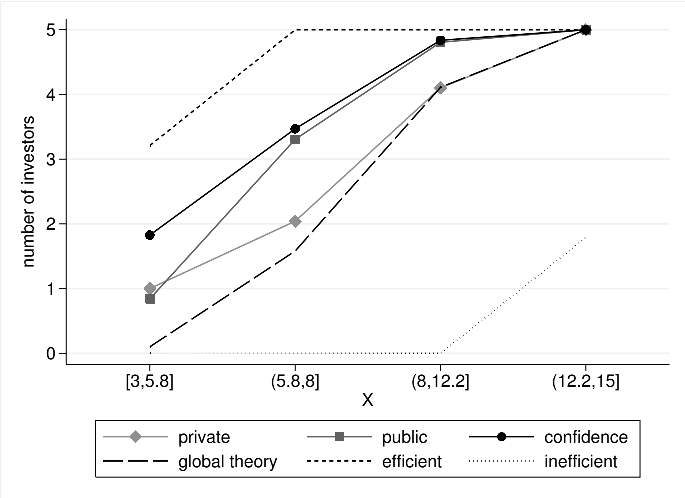
5.2 Investment by the value of the state

Figure 2 displays the average number of investors in each condition and the number of investors predicted by the three benchmark equilibria. The realized state is classified into four intervals, $[3, 5.8]$, $(5.8, 8]$, $(8, 12.2]$, and $(12.2, 15]$. These intervals are based on the theoretical predictions. That is, the bound of 8 is chosen since this is the cutoff signal in the global

[9]All results shown in the following are qualitatively similar if we use the data from all periods for the analysis.

game equilibrium and the bounds of 5.8 and 12.2 reflect the multiple equilibria bounds in the presence of a public signal.

Figure 2: Investment behavior across conditions and by value of the state X



The figure shows that behavior is very similar across conditions if X is above 12.2—all subjects in a group invest in this range, independent of the condition. This is in line with the predictions of the theoretical benchmarks; it is the dominant strategy to invest if $X \geq 14$.

If the underlying state is in the two middle ranges—i.e., between 5.8 and 12.2—the number of investors is very similar in the *public* and *confidence* conditions. But, it is substantially lower in the *private* condition, where investment is much closer to the global game prediction. Figure A.1 in the Appendix reveals that this difference is driven by a much higher frequency of all-invest outcomes in the *public* and *confidence* conditions. For the states in the intermediate ranges of (5.8,8] and (8,12.2], all-invest outcomes occur about two to four times as often in the *public* and *confidence* condition as in the *private* condition (respectively, for the two ranges of stages, 46.9% and 49.0% vs. 10.2%; 90.8% and 92.4% vs. 52.0%).

If the state is in the lowest range, below 5.8, the picture is a different one. In that case, the numbers of investors are very similar between the *private* and *public* conditions, but substantially higher in the *confidence* condition.[10] Investment in all three conditions in

[10]Using the average number of investors aggregated on the sequence level as independent observations, two-sided pairwise Wilcoxon signed rank tests show that the previously described differences, observed in Figure 2, are significant at the 10%-level at least. That is, the average number of investors is significantly different (i) between the *private* and the *confidence* condition in the ranges of [3,5.8], (5.8,8], and (8,12.2] (p=0.074, p=0.014, p=0.019); (ii) between the *private* and the *public* condition in the ranges of (5.8,8] and (8,12.2] (p=0.024, p=0.001); and (iii) between the *public* and the *confidence* condition in the range of [3,5.8] (p=0.056).

this range is also higher than predicted either by the global game prediction or the inefficient equilibrium benchmark.

To analyze the observed differences in investment between conditions in more details, and to understand how these differences depend on the underlying state, we estimate several linear regression models. The dependent variable is the difference in average investment between any two conditions, for a given period and realization of the random variables. We use data from Periods 11 to 30. We construct the differences in average investment and profits by exploiting the fact that our observations are paired by states and signals across conditions.[11] The independent variables are indicator variables for the different ranges of the state, the difference in average profits in the initial 10 periods, and their interactions.

The results are displayed in Table 5 and confirm the observations made in Figure 2. First, looking at Models 1, 3 and 5, we see that the insignificant constant terms in all three models reflect the fact that investment is, on average, identical in all three conditions for the highest interval of states ($(12.2, 15]$). As Figure 2 shows, this is where we observe full investment in all conditions.

Model 1 shows that the average investment is significantly higher in the *public* condition than in the *private* condition in the intermediate ranges of X, but not for very low or very high values of X). Model 3 shows that investment is higher in the *confidence* condition than in the *private* condition in all but the highest range of X. Finally, Model 5 shows that the difference between the *confidence* and the *public* conditions is only significant in the lowest range.

Given that outcomes of coordination games can depend on the history of initial play, we control for average profits obtained during the first 10 periods and its interactions with the current range of states in Models 2, 4, and 6. The results show that subjects are influenced by the history, especially for lower values of X. For example, a one unit increase in average initial profit raises the difference in average investment between the *public* and *private* condition by 0.2 to 0.3 points if the current state is in the lower range. Moreover, the level of influence for initial outcomes is largest in the interim range of values, where dominant strategies do not apply. Hence, history matters for how groups react to public information, particularly in

[11] So, for example, in models 1 and 2, each observation is the average investment in the public condition minus the average investment in the private condition, holding constant the period and the sequence of realized states.

those states in which public information can create multiple equilibria.

Table 5: Pairwise difference of investment between conditions and by range of state X

	Δ avg.inv$_{pub-priv}$		Δ avg.inv$_{conf-priv}$		Δ avg.inv$_{conf-pub}$	
	(1)	(2)	(3)	(4)	(5)	(6)
$X \in [3, 5.8]$ (d)	-0.032	-0.059	0.165***	0.031	0.197***	0.110**
	(0.045)	(0.040)	(0.056)	(0.048)	(0.055)	(0.044)
$X \in (5.8, 8]$ (d)	0.253***	0.209***	0.286***	0.105**	0.033	-0.120**
	(0.049)	(0.044)	(0.061)	(0.053)	(0.060)	(0.048)
$X \in (8, 12.2]$ (d)	0.141***	0.133***	0.147***	0.085*	0.006	-0.017
	(0.042)	(0.038)	(0.052)	(0.046)	(0.051)	(0.040)
Δ avg.profit$_{1-10}$		-0.000		-0.000		0.000
		(0.039)		(0.040)		(0.036)
Δ avg.profit$_{1-10}$ x $X \in [3, 5.8]$		0.215***		0.301***		0.271***
		(0.051)		(0.052)		(0.051)
Δ avg.profit$_{1-10}$ x $X \in (5.8, 8]$		0.332***		0.421***		0.515***
		(0.060)		(0.059)		(0.055)
Δ avg.profit$_{1-10}$ x $X \in (8, 12.2]$		0.035		0.115**		0.074
		(0.049)		(0.049)		(0.046)
Constant	0.000	0.000	0.000	0.000	-0.000	-0.000
	(0.032)	(0.030)	(0.040)	(0.035)	(0.040)	(0.030)
N	280	280	280	280	280	280
R^2	0.13	0.35	0.06	0.45	0.05	0.46

Linear regressions. Standard errors in parentheses. (d) for discrete change of dummy variable from 0 to 1. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Note: The unit of observation in these regressions is the difference in average investment for a particular sequence of states and signals. That is, in the *private* and *public* condition the average is based on one group per sequence and in the *confidence* condition it is based on two groups per sequence.

Result 2 *Differences in investment behavior across conditions depend on the state. In particular, behavior is similar across all three conditions for very high states; for intermediate states, investment is significantly lower in the* private *condition than in the other two conditions; and for very low states investment is significantly higher in the* confidence *condition than in the other two conditions.*

5.3 Individual investment behavior

In order to understand how aggregate investment outcomes, such as the number of investors in a period arise, we turn our attention to investment behavior at the individual level. We can classify subjects' investment strategies by the way they use their information to make investment decisions. More precisely, we classify subjects on the basis of whether they follow a **perfect** or **almost perfect** cutoff strategy. For estimating cutoffs, we use the private signal received by each subject in the *private* condition, the public signal in the *public* condition, and the average confidence report in the *confidence* condition. In order to subsequently compare cutoff thresholds across conditions, we also estimate cutoffs for the *confidence* condition using the (unobserved) public signal from the *public* condition.[12] Panel (a) of Figure A.2 in the Appendix shows an example of a subject following a perfect cutoff strategy and the corresponding cutoff.

Following a **perfect** cutoff strategy means that there is a single convex set of signals for which a subject never invests, another convex set for which the subject always invest, these two sets span the entire space of signals observed by the subject, and the latter set involves higher signals than the former. We also classify a subject as following a perfect cutoff strategy if there is one point on the boundary of these sets of signals where the subject both invests and does not. We then label as the subject's cutoff signal the median of the highest signal for which the subject chose not to invest and of the lowest signal for which a subject chose to invest.

Further, subjects can also follow an **almost perfect** cutoff strategy, following the definition used by Szkup and Trevino (2013). An almost perfect cutoff strategy means that the sets of signals overlap in at most in three instances. We esitmate the average cutoff of subjects following an almost perfect cutoff strategy using logistic regressions. That is, we regress a subject's investment decision on the private signal, public signal, or average confidence, depending on the condition, and then use the estimated coefficients to calculate the signal at which the subject is equally likely to invest or not invest.[13] Panel (b) of Figure A.2 in the Appendix shows an example of a subject following an almost perfect cutoff strategy and the estimated cutoff.

Table 6 reports the share of subjects that follow a perfect or an almost perfect cutoff strategy in each condition. From the table, it is clear that the majority of subjects follow some sort of cutoff strategy and that this is true in each condition. In the *private* condition 82.85% of subjects are classified as employing either a perfect or almost perfect cutoff strategy. In the *public* condition 72.86% are classified as using a cutoff strategy. In the confidence condition,

[12] Subjects do not observe the average of the signals, so they could not have feasibly used it as a cutoff. However, in the confidence condition, the public signal and average confidence are significantly positively correlated ($\rho = 0.813$ and p=0.000).

[13] The regression results are available from the authors.

this proportion is 80.71% for the aggregated confidence report. The vast majority of subjects that appear to employ a cutoff strategy use a perfect one, meaning they always invest below some threshold and always do so above that same threshold. There are also some subjects in each condition that always invest, i.e., who ignore the information they receive. The share of these subjects is highest (7.14%) in the *public* condition and lowest in the *private* condition (1.43%).

Table 6: Subjects following a cutoff strategy, periods 11-30

	private	*public*	*confidence*	
strategy	private sig.	public sig.	public sig.	avg. confidence
perfect cutoff	67.14 %	60.00 %	42.86 %	70.00 %
perfect & almost perfect cutoff	82.85 %	72.86 %	65.00 %	80.71 %
other[1]	17.14 %	27.14 %	35.00 %	19.29 %

[1] Other investment strategies also include subjects that always invest. In the *private* condition 1.43 % of subjects invest in every period, in the *public* condition these are 7.14 % of subjects, in the *confidence* condition these are 4.29 % of subjects. There are no subjects that never invest in any of the conditions.

Table 7: Average cutoffs employed in cutoff strategies

	perfect cutoff[1]		perfect & almost perfect[2]	
condition	mean	std. dev.	mean[3]	std. dev.
private	7.81	1.63	7.67	1.63
public	6.51	1.44	6.52	1.33
confidence (pub. sig.)	5.93	1.32	5.86	1.44
confidence (avg. confidence)	0.47	0.37	0.47	0.38

[1] The perfect cutoff is the median of the highest signal for which a subject did not invest and the lowest signal for which a subject invested.
[2] The almost perfect cutoff is estimated using a logistic regression.
[3] The mean is calculated by weighting the estimated cutoff with the share of subjects that follows this kind of cutoff strategy with respect to all subjects that follow some cutoff strategy (see Table 6).

The mean and standard deviation of the estimated cutoffs used by subjects that follow a perfect or almost perfect cutoff strategy are displayed in Table 7 (for the distribution of estimated cutoffs see Figures A.3 and A.4 in the Appendix). In the *private* condition, the average cutoff employed by subjects that follow a perfect or almost perfect cutoff strategy is

7.67, which is very close to the predicted value of 8.00 in the global game equilibrium. In the *public* condition the average cutoffs is 6.52, which is lower than the one in the *private* condition. One can also see this difference in the distribution of estimated cutoffs, see Figure A.3 and A.4 in the Appendix. The mass of estimated cutoff signals in the *public* condition is more to the left than in the *private* condition for both kinds of strategies.

In the *confidence* condition we estimate two cutoffs, one is based on the average response to the confidence question, which is observed by subjects prior to making investment decisions. The other, based on the public signal as in the *public* condition, is not feasible since subjects never directly observe the average of all the private signals, but allows us to make comparisons across conditions in terms of the states for which subjects tend to invest. Using the public signal yields an average cutoff of 5.86, which is below the cutoffs in either the *private* or *public* conditions.

The average cutoff estimated using average confidence is 0.47. If we assume that the cutoff is a pure linear information aggregation device, in which confidence reports are based on equal-sized intervals of the possible private signals, an answer of 0 ("neither good nor bad") indicates a private signal between 7.2 and 10.8 and an answer of 1 ("somewhat good") indicates a private signal between 10.9 and 14.5. Comparing the estimated cutoffs and their distributions (see Panels (c) and (d) of Figures A.3 and A.4 in the Appendix) shows that subjects answer more positively, i.e., use higher scores, than expected from their signal.

Result 3 *The majority of subjects follows either a perfect or an almost perfect cutoff strategy in each condition. The average estimated cutoff is highest in the* private *condition and lowest in the* confidence *condition, with the* public *condition in between.*

Summarizing, so far we have shown that subjects in the *confidence* condition earn the same as in the *public* condition and that these earnings are significantly higher than in the *private* condition. This difference in payoffs arises because the number of subjects choosing to invest is significantly lower in the *private* condition than in the other two conditions for intermediate values of the underlying state. In line with this observation, the estimated cutoff signals are lower in the *public* and *confidence* conditions than in the *private* condition. However, we have not yet addressed why investment behavior in the *confidence* condition is so similar to the *public* condition. Therefore we will turn our focus on investment behavior in this condition in the next section.

5.4 Investment in the confidence condition

Recall that subjects in both the *public* and *confidence* conditions receive some sort of public information in addition to their private signals. While in the *public* condition subjects receive the average of their group's private signals as public information, subjects in the *confidence* condition have to create the public information themselves. That is, subjects privately answer the confidence question after receiving their private signal and the average answer is then made public. *Ex ante*, it is unclear what will be the difference between these two pieces of information. In this section we will therefore focus on how subjects use the public information to make their investment decision and how they create the public information, i.e., whether the average answer contains information about their private signals, their intended investment decision, or both.

To analyze how subjects investment decision in the *confidence* condition responds to signals, average confidence, and the variance of confidence, we run several linear regression models (see Table 8 for the results). Models 1 to 4 indicate that investment outcomes in a group are significantly determined by both the average of the private signals and the average answer to the confidence question. Model 3 is a two-stage linear regression where average confidence is instrumented by the average signal. The results are very similar when compared to the standard regression Model 2. In Model 4 we include average signal and average confidence as independent variables. Even though the variables are highly correlated (see Model 5), both remain significant suggesting that they explain different parts of the variance.[14] This is a first indication that there is a difference in the content of the public information produced in the *confidence* condition and the average signal in the *public* condition and that the average answer of the confidence question not only aggregates information about subjects' private signals, but also possesses additional informational content.

If subjects' responses to the confidence question only provide information about the average private signal, the average answer should resemble a direct mapping from the the private signal to the confidence question. That is, if we divide the signal range into five equally sized intervals, then any signal in an interval should map into the corresponding answer of the confidence question (e.g., any signal in the interval of [0,3.6] is mapped to an answer of

[14]The correlation between average confidence and the underlying state is positive and highly significant $\rho = 0.790$ (p<0.01) as well as the correlation between average confidence and the average signal $\rho = 0.813$ ($p < 0.01$).

Table 8: Average signal, confidence, and investment decisions, period 11 -30

	avg. # of investors				avg. conf.	avg. # of investors
	(1)	(2)	(3)	(4)	(5)	(6)
avg. signal	0.368***			-0.082**	0.205***	0.284***
	(0.030)			(0.034)	(0.012)	(0.042)
avg. confidence		1.892***	1.794***	2.194***		
		(0.063)	(0.053)	(0.129)		
std.dev. confidence						-0.607***
						(0.159)
Constant	0.629**	1.688***	1.802***	2.064***	-0.654***	1.856***
	(0.265)	(0.074)	(0.071)	(0.186)	(0.109)	(0.476)
N	560	560	560	560	560	560
R^2	0.52	0.76	0.77	0.77	0.75	0.53

Linear regressions with group fixed effects. Robust standard errors in parentheses.
Model 3 is a linear two-stage regression with group fixed effects, standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

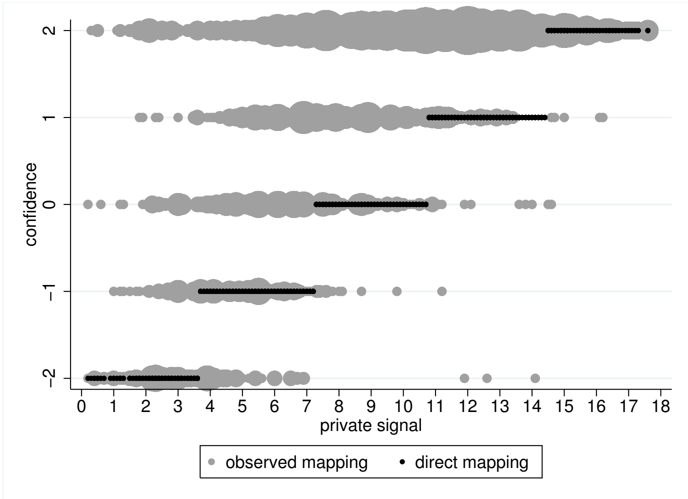
"-2"). Figure 3 compares this direct mapping with the observed mapping and clearly shows that subjects do not follow such direct mapping. In particular, responses of 0 to 2, indicating higher levels of confidence, are often provided in response to low signals. That is, subjects appear to inflate their reported confidence.[15]

Result 4 *Investment decisions in the confidence condition are based on the average answer given to the confidence question. This sentiment index partly reflects information on the average private signal, but its influence on investment seems to go beyond this informational content.*

The next question is whether all groups apply a similar kind of mapping or whether there is heterogeneity among groups and, if so, does this heterogeneity explain differences in aggregate performance such as profits, efficiency, and investment. Figure 4 depicts the distribution of the average answer to the confidence question given by each group, across different realizations of the underlying state—using the same categories as in Figure 2. Especially for low values of X, groups seem to differ in the way they answer the confidence question. If the state is high, the mapping is much more homogenous: all 28 group averages are between 1.63 and 2 with an outlier of 1.2, indicating that the majority of subjects answered the question with "good"

[15] The degree of inflation does not change much over time and, if anything, is slightly increasing from 1.06 points in period 11 to 1.4 points in period 30.

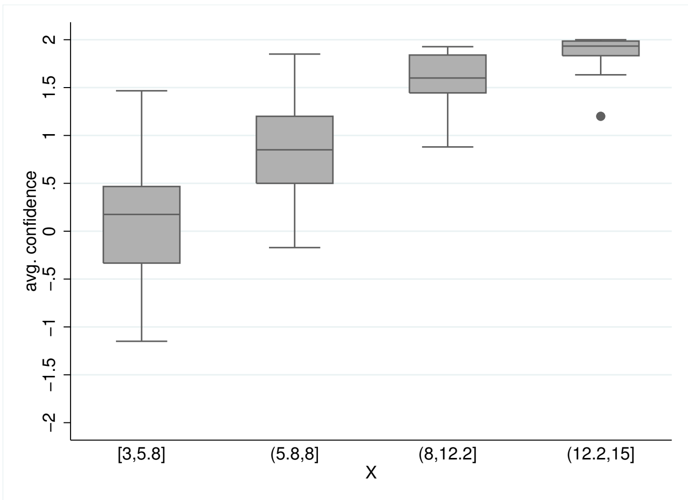
Figure 3: Mapping of the private signal to the confidence question, period 11-30



Note: The size of the markers depicting the observed mapping indicates the frequency of signals in category of the confidence question.

in this situation. But, for lower states and collections of signals, groups varied dramatically in how they responded.

Figure 4: Average confidence across states, period 11-30



Since we have two groups for each of the 14 unique sequences, we can compare their responses to the confidence question, holding the sequence of signals constant. Figure A.5 in the Appendix provides Figure 4 separately for each sequence. It becomes evident that response patterns are very similar for some sequences and quite different for others. However, comparing aggregate outcomes from the two sets of groups suggest that they are not significantly different (pairwise Wilcoxon signed rank tests: average number of investors: 3.77 vs. 4.01, p=0.510; average confidence: 1.14 vs. 1.19, p=0.975; average profits: 18.36 vs. 18.54, p=0.246).

Result 5 *Average confidence contains more information than just the private signal. Groups differ in how they map the average signal to the average confidence. The degree of heterogeneity is particularly high if the value of the state is in the lower range.*

To answer the question of whether this heterogeneity also leads to heterogeneity in profits across groups, we first estimate the relationship between the state and the average confidence for each group and then try to predict groups' realized profits by characteristics of the estimated relationship. More precisely, the estimation is done by means of linear regressions using the state as the dependent variable and average confidence as the independent variable. The idea behind this specification is that it characterizes what subjects can infer about the state from average confidence when making their investment decision. For each group, Table 9 provides the estimated intercept, slope, and explained variance. Using these estimates, we can identify relationships between the "rule" a group is using for aggregating information and the group's realized profits. For instance, the correlation between the explained variance (R^2) and the average number of investors is $\rho = -0.460$ ($p = 0.014$) and for average realized profits it is $\rho = -0.336$ ($p = 0.081$). Hence, groups that use less informative mappings from signals into confidence reports generally invest more frequently and earn more. That is, the inflation of confidence reports that we observed earlier appears to be somewhat profitable.

Finally, we can also test whether the degree of disagreement with respect to the confidence question has an effect on subjects' investment decisions. The intuition is that disagreement reflects heterogeneity in the mapping of private signals into confidence reports. We measure this disagreement as the standard deviation of responses to the confidence question among group members in a period, and add it as an explanatory variable in Model 6 of Table 8. The results show that a higher degree of disagreement within a group does, indeed, lead to a lower average number of investors. Hence, we observe heterogeneity both in how groups map signals into confidence reports, as well as in the level of agreement regarding such mapping.

Table 9: Estimation results of $X_{g,t} = \alpha + \beta * \text{avg. confidence}_{g,t} + \epsilon_{g,t}$, periods 11 - 30

sequence	group ID	α	β	R^2	avg. real. profits	avg. # investors
6	2503	6.671	1.384	0.047	0.995	4.65
6	603	-4.864	7.432	0.408	0.995	4.75
4	1803	0.789	5.135	0.654	0.981	4.65
3	303	4.509	3.623	0.667	0.986	4.45
3	1703	5.178	3.847	0.673	0.984	4.25
10	1003	5.210	3.198	0.681	0.993	4.00
2	203	4.715	3.094	0.687	0.954	3.80
11	1103	6.146	3.210	0.699	0.960	3.95
7	2603	-0.616	5.952	0.705	0.976	4.50
9	903	3.976	3.220	0.740	0.959	4.15
13	2303	4.429	4.125	0.745	0.947	3.35
13	1303	3.784	4.425	0.756	0.914	3.00
9	2803	6.175	2.170	0.765	0.986	2.75
12	2203	3.234	4.532	0.770	0.990	4.45
14	2403	4.493	3.752	0.775	0.981	4.10
8	2703	-0.171	6.118	0.781	0.981	4.55
11	2103	3.305	4.803	0.823	0.991	4.30
12	1203	3.134	4.799	0.824	0.963	4.00
1	1503	-3.082	7.563	0.829	0.985	4.75
2	1603	6.999	2.385	0.839	0.932	2.95
5	503	5.076	4.036	0.857	0.989	4.10
8	803	5.384	3.842	0.861	0.972	3.30
10	2003	6.585	3.237	0.866	0.976	3.55
14	1403	3.760	4.027	0.869	0.986	4.35
5	1903	5.642	4.265	0.872	0.937	3.40
4	403	7.076	3.327	0.874	0.878	2.35
7	703	4.727	3.481	0.896	0.964	3.60
1	103	5.850	3.437	0.900	0.965	3.00

6 Conclusion

We examined the roles of both private and public information in an investment game with strategic complementarities. When players only have private signals about the underlying state, behavior is largely consistent with the global games prediction of a unique cutoff strategy based on individuals' private information. This result is consistent with other experimental results on global games that show that subject tend to follow cutoff strategies (Heinemann, Nagel, and Ockenfels, 2004). We add to this literature by showing that this result holds even when the level of strategic complementarity is fixed across states and in a simpler environment that is likely more accessible to subjects. Moreoever, the actual cutoffs employed by subjects are similar to those predicted by the theory.

Our more surprising results pertain to the two treatments with public information signals. In the *public* condition where subjects observe the average signal of all players in addition to their own private signal, subjects are able to use this information to coordinate on more efficient outcomes of coordinated investment whenever it is profitable to do so. While subjects still seem to use the public signal to decide on whether they invest, this result is consistent with previous theoretical work that suggests that multiplicity of equilibria can be restored when there is a sufficiently precise public signal—behavior shifts toward an efficient equilibrium with high levels of investment.

Behavior in the *confidence* condition is even more remarkable. In this treatment, subjects observe an endogenously generated public signal via an answer to a survey question regarding players expectations of the outcome in the game. The question was designed to closely parallel standard questions from common consumer sentiment indices in practice. Despite the coarse nature of the survey answers (players could only select one of five scores) and the fact that the answer is merely cheap talk, the outcomes of the *confidence* condition yield, if anything, increased investment and earnings relative to the *public* condition. In trying to disentangle what makes the confidence treatment work so well, we find that the confidence question appears to both contain information about the underlying state (just as the public signal does, though the confidence report is by construction less informative) but also provides expectational information about intended actions of players. For example, players tend to inflate their confidence score, perhaps indicating their willingness to invest and encouraging others to invest as well.

While the experiment is a vast simplification from real-world macroeconomic settings in which sentiment indices are used, we believe the results provide intriguing clues about the relationship between such indices and behavior. While previous experiments such as (Heinemann, Nagel, and Ockenfels, 2004) have shown that cheap talk signals can improve coordination, our experiment shows that a similar result obtains with more natural real world sentiment indices. The empirical literature is largely divided on whether the apparent correlation between sentiment indices and microeconomic activity is due to an informational ("news") component or to an "animal spirits" component–e.g. indices yield self-confirming correlation devices for subsequent economic activity. Our experiment demonstrates that both elements appear to be at work.

Finally, in this experiment the animal spirits component of the consumer confidence questions appears to have a largely positive effect by encouraging increased investment. A natural concern of any such device is that such expectations can also result in less efficient actions as well; animal spirits can lead to both non-fundamental booms and busts. We believe an intriguing avenue of future research concerns the features of endogenous public information devices that either encourage or discourage more or less efficient activity. For example, earlier related research demonstrated that the signals produced by a two-sided asset market could guide activity to a highly inefficient equilibrium outcome (Kogan, Kwasnica, and Weber, 2011) (i.e., the signals tended to exacerbate the prevalence of non-fundamental busts). This raises the naturally important question of what makes some endogenous public signals work well while others do not, which we highlight as a valuable topic for future research.

References

Acemoglu, D., and A. Scott (1994): "Consumer confidence and rational expectations: are agents' beliefs consistent with the theory?," *The Economic Journal*, 104, 1–19.

Angeletos, G.-M., and I. Werning (2006): "Crises and Prices: Information Aggregation, Multiplicity, and Volatility," *American Economic Review*, 96(5), 1720–1736.

Ball, L., and D. Romer (1991): "Sticky Prices as Coordination Failure," *American Economic Review*, 81(3), 539–52.

Barsky, R., and E. Sims (2012): "Information, Animal Spirits, and the Meaning of Innovations in Consumer Confidence," *American Economic Review*, 102(4), 1343–77.

Blanchard, O. (1993): "Consumption and the Recession of 1990-1991," *The American Economic Review*, 83(2), pp. 270–274.

Bock, O., A. Nicklisch, and I. Baetge (2012): "hroot: Hamburg Registration and Organization Online Tool," *H-Lab Working Paper*, 1.

Bryant, J. (1983): "A Simple Keynes-Type Model," *Quarterly Journal of Economics*, 98(3), 525–28.

Carlsson, H., and E. van Damme (1993): "Global games and equilibrium selection," *Econometrica*, 61(5), 989–1018.

Cass, D., and K. Shell (1983): "Do Sunspots Matter?," *Journal of Political Economy*, 91(2), 525–28.

Cooper, R., and A. John (1988): "Coordinating Coordination Failures in Keynesian Models," *Quarterly Journal of Economics*, 103(3), 441–63.

Cornand, C. (2006): "Speculative attacks and informational structure: a experimental study," *Review of International Economics*, 14, 797–817.

Cornand, C., and F. Heinemann (2014): "Measuring Agents' Reaction to Private and Public Information in Games with Strategic Complementarities," *Experimental Economics*, 17(61-77).

Dohmen, T., A. Falk, D. Huffman, U. Sunde, J. Schupp, and G. G. Wagner (2011): "Individual Risk Attitudes: Measurement, Determinants, and Behavioral Consequences," *Journal of the European Economic Association*, 9(3), 522–550.

Fischbacher, U. (2007): "z-Tree: Zurich toolbox for ready-made economic experiments," *Experimental Economics*, 10, 171–178.

Goldstein, I., and A. Pauzner (2005): "Demand–Deposit Contracts and the Probability of Bank Runs," *The Journal of Finance*, 60(3), 1293–1327.

Hall, R. (1993): "Macro Theory and the Recession of 1990-1991," *American Economic Review*, 83(2), 275–79.

Harrison, S., and M. Weder (2006): "Did Sunspot Forces Cause the Great Depression?," *Journal of Monetary Economics*, 53, 1327–1339.

Heinemann, F., R. Nagel, and P. Ockenfels (2004): "The Theory of Global Games on Test: Experimental Analysis of Coordination Games with Public and Private Information," *Econometrica*, 72(5), 1583–1599.

Hellwig, C. (2002): "Public Information, Private Information, and the Multiplicity of Equilibria in Coordination Games," *Journal of Economic Theory*, 107(2), 191 – 222.

Kiyotaki, N. (1988): "Multiple Expectational Equilibria under Monopolistic Competition," *Quarterly Journal of Economics*, 103(4), 695–713.

Kogan, S., A. M. Kwasnica, and R. Weber (2011): "Coordination in the Presence of Asset Markets," *American Economic Review*, 101(2), 927–947.

Lemmon, M., and E. Portniaguina (2006): "Consumer Confidence and Asset Prices: Some Empirical Evidence," *Review of Financial Studies*, 19(4), 1499–1529.

Lorenzoni, G. (2009): "A Theory of Demand Shocks," *American Economic Review*, 99(5), 2050–84.

Ludvigson, S. C. (2004): "Consumer Confidence and Consumer Spending," *Journal of Economic Perspectives*, 18(2), 29–50.

Matsusaka, J., and A. Sbordone (1995): “Consumer Confidence and Economic Fluctuations,” *Economic Inquiry*, 33(2), 296–318.

Milgrom, P., and J. Roberts (1990): “Rationalizability, Learning, and Equilibrium in Games with Strategic Complementarities,” *Econometrica*, 58(6), 129–56.

Morris, S., and H. S. Shin (1998): “Unique Equilibrium in a Model of Self-Fulfilling Currency Attacks,” *American Economic Review*, 88(3), 587–97.

——— (2002): “Social Value of Public Information,” *American Economic Review*, 92, 1522–1534.

——— (2006): “Endogenous public signals and coordination,” *Working Paper*.

Murphy, K., A. Shleifer, and R. W. Vishney (1989): “Industrialization and the Big Push,” *Journal of Political Economy*, 97(5), 1003–26.

Qu, H. (2013): “How Do Market Prices and Cheap Talk Affect Coordination?,” *Journal of Accounting Research*, 51(5), 1221–60.

Roberts, J. (1987): “An Equilibrium Model with Involuntary Unemployment at Flexible, Competitive Prices and Wages,” *American Economic Review*, 77(5), 856–74.

Shleifer, A. (1986): “Implementation Cycles,” *Journal of Political Economy*, 94(6), 1163–90.

Szkup, M., and I. Trevino (2013): “Costly Information Aquisition in a Speculative Attack: Theory and Experiments,” *Working Paper*.

VanHuyck, J. B., R. C. Battalio, and R. O. Beil (1990): “Tacit Coordination Games, Strategic Uncertainty, and Coordination Failure,” *American Economic Review*, 80(1), 234–48.

——— (1991): “Strategic Uncertainty, Equilibrium Selection, and Coordination Failure in Average Opinion Games,” *Quarterly Journal of Economics*, 106(3), 885–910.

Weil, P. (1989): “Increasing Returns and Animal Spirits,” *American Economic Review*, 79(4), 889–94.

A Data Supplement

Table A.1: Investment behavior across conditions and sequences, periods 1 - 30

	average			avg. # of investors			avg. median invest.			avg. profit		
seq.	state	sig.	conf.	*priv*	*pub*	*conf*	*priv*	*pub*	*conf*	*priv*	*pub*	*conf*
1	8.26	8.18	1.07	2.60	3.07	3.92	0.50	0.63	0.80	17.01	17.78	17.93
2	8.99	9.09	1.04	3.97	4.10	3.60	0.80	0.80	0.70	18.16	18.59	18.27
3	9.12	9.17	1.03	2.87	4.40	3.98	0.57	0.87	0.82	17.60	18.83	18.82
4	9.27	9.26	1.07	4.27	4.67	3.78	0.93	0.97	0.75	18.76	19.11	18.28
5	9.18	9.27	0.93	3.50	4.87	3.37	0.73	1.00	0.70	18.25	19.15	18.34
6	8.81	8.89	1.63	2.67	3.83	4.58	0.53	0.73	0.95	16.35	17.58	18.61
7	8.53	8.44	1.22	2.10	2.17	4.05	0.43	0.43	0.83	17.07	17.09	18.13
8	9.63	9.34	1.27	3.10	3.73	3.90	0.67	0.73	0.78	18.53	18.99	18.90
9	7.83	7.94	0.80	4.00	3.23	3.62	0.83	0.67	0.72	17.18	17.50	17.38
10	8.92	8.89	0.95	3.33	3.33	3.83	0.70	0.70	0.77	18.14	18.41	18.56
11	9.79	9.59	1.05	3.17	3.70	3.83	0.70	0.73	0.75	18.43	18.80	18.99
12	9.10	8.97	1.19	2.70	2.70	3.85	0.57	0.50	0.77	17.40	17.54	18.58
13	8.41	8.45	0.91	4.33	3.30	3.33	0.97	0.63	0.65	18.08	17.58	17.29
14	8.58	8.38	0.96	2.10	2.57	3.72	0.37	0.50	0.77	16.45	17.34	18.15
Avg.	8.89	8.85	1.08	3.19	3.55	3.81	0.66	0.71	0.77	17.67	18.16	18.30

Table A.2: Summary statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
Private					
age	23.34	3.31	18	35	70
male	0.59	0.50	0	1	70
economics major	0.17	0.38	0	1	70
swiss	0.46	0.50	0	1	70
general trust [1]	0.63	0.49	0	1	70
risk attitude [2]	4.97	2.21	0	10	70
political orientation [3]	3.47	1.26	1	7	70
yearly donation in CHF (left/right)	276.36	1787.93	0	15000	70
number of siblings	1.24	1.07	0	4	70
Public					
age	23.43	3.60	18	34	70
male	0.53	0.50	0	1	70
economics major	0.19	0.39	0	1	70
swiss	0.57	0.50	0	1	70
general trust	0.63	0.49	0	1	70
risk attitude	5.76	2.26	0	10	70
political orientation (left/right)	3.49	1.46	1	6	70
yearly donation in CHF	534.47	3579.53	0	30000	70
number of siblings	1.66	1.28	0	7	70
Confidence					
age	23.26	3.31	18	38	140
male	0.48	0.50	0	1	140
economics major	0.13	0.34	0	1	140
swiss	0.53	0.50	0	1	139
general trust	0.68	0.47	0	1	140
risk attitude	5.43	2.57	0	10	140
political orientation (left/right)	3.49	1.43	1	7	140
yearly donation in CHF	111.63	197.53	0	1000	139
number of siblings	1.33	0.99	0	6	140

[1] The question on trust was “Generally speaking, would you say that most people be trusted, or that you can’t be too careful in dealing with people?” with two answers “you can’t be too careful” (=0) “most people can be trusted” (=1).

[2] The question on risk was “How do you see yourself: Are you generally a person who is fully prepared to take risks or do you try to avoid taking risks?” with the possibility to answer on an 11-point scale with “try to avoid risks” (=0) and “fully prepared to take risks” (=10).

[3] The question on political orientation was “Where would you classify yourself on the left/right political spectrum?” with the possibility to answer on a 7-point scale with “left” (=1) and “right” (=7).

Figure A.1: Number of investors across conditions and states, periods 11 - 30

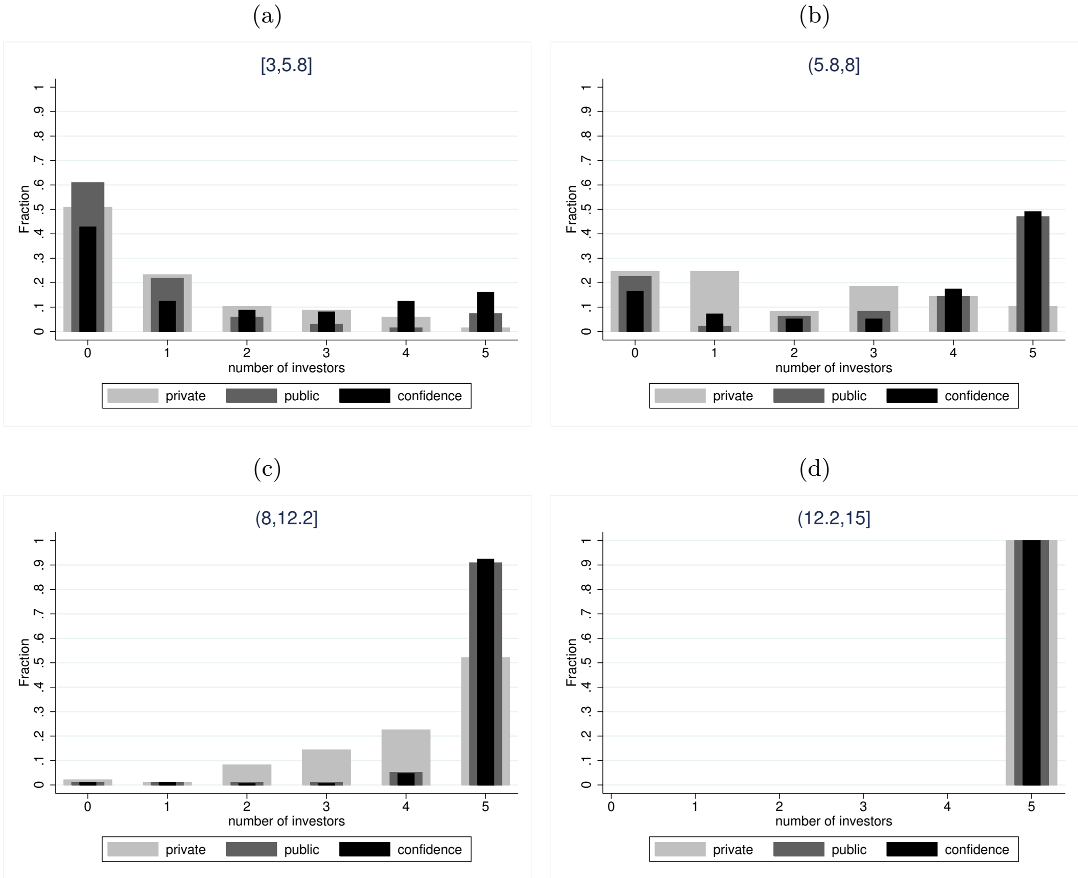
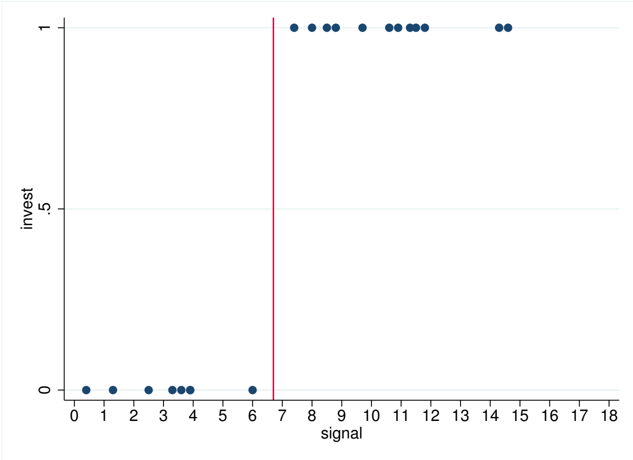


Figure A.2: Classification of investment behavior, periods 11 - 30

(a) perfect cutoff strategy



(b) almost perfect cutoff strategy

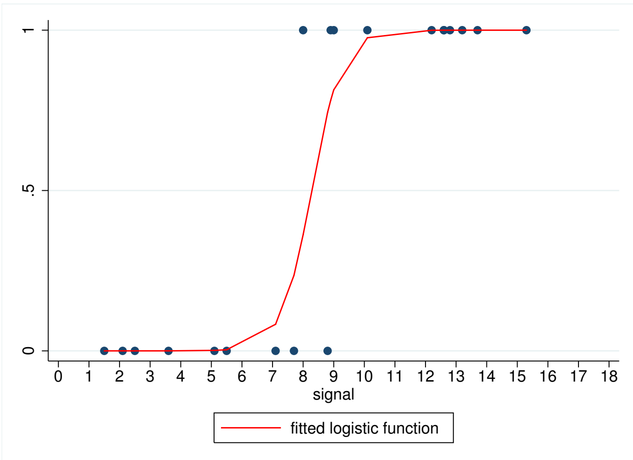
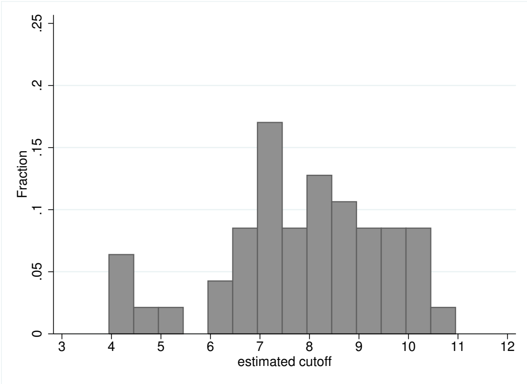
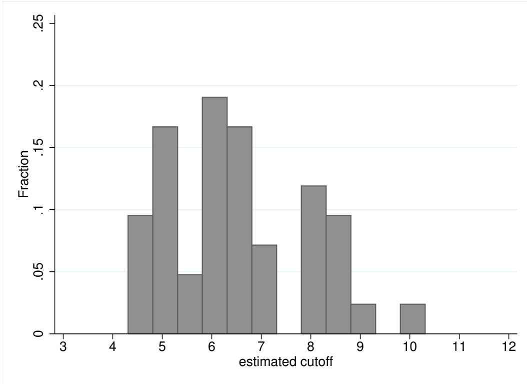


Figure A.3: Subjects following a perfect cutoff strategy, periods 11 - 30

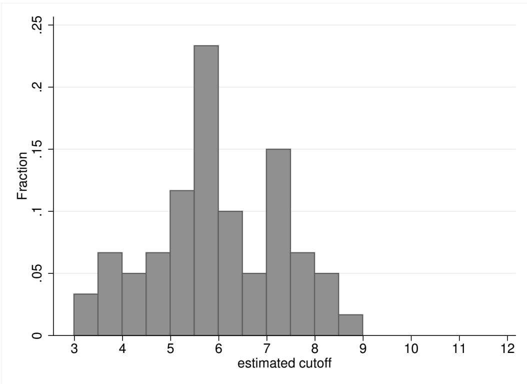
(a) *private* condition



(b) *public* condition



(c) *confidence* condition (pub. sig.)



(d) *confidence* condition (avg. confidence)

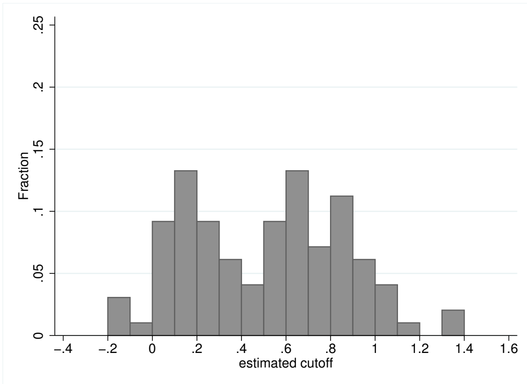
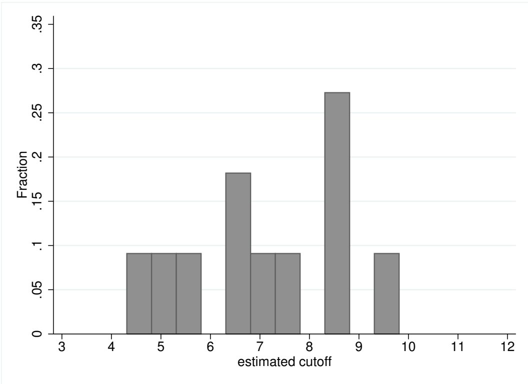
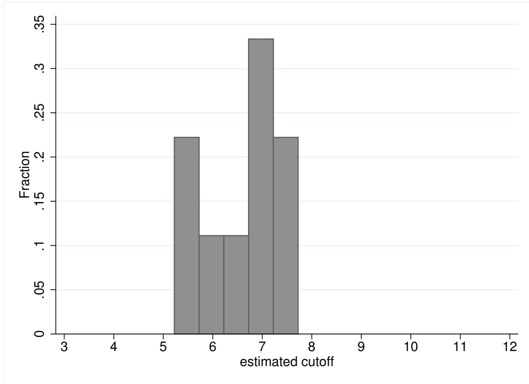


Figure A.4: Subjects following an almost perfect cutoff strategy, periods 11 - 30

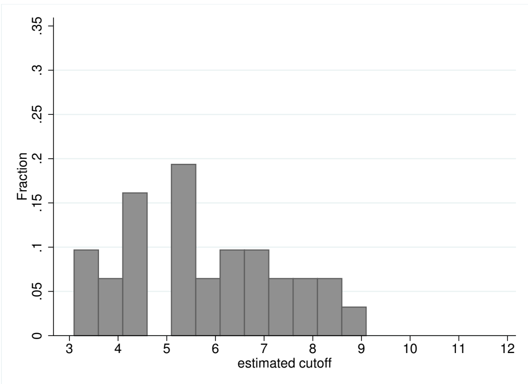
(a) *private* condition



(b) *public* condition



(c) *confidence* condition (pub. sig.)



(d) *confidence* condition (avg. confidence)

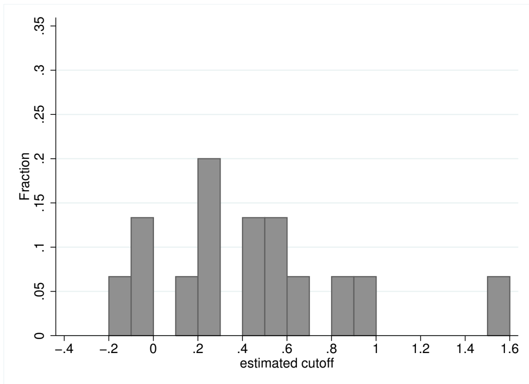


Figure A.5: Average confidence by sequence, period 11-30

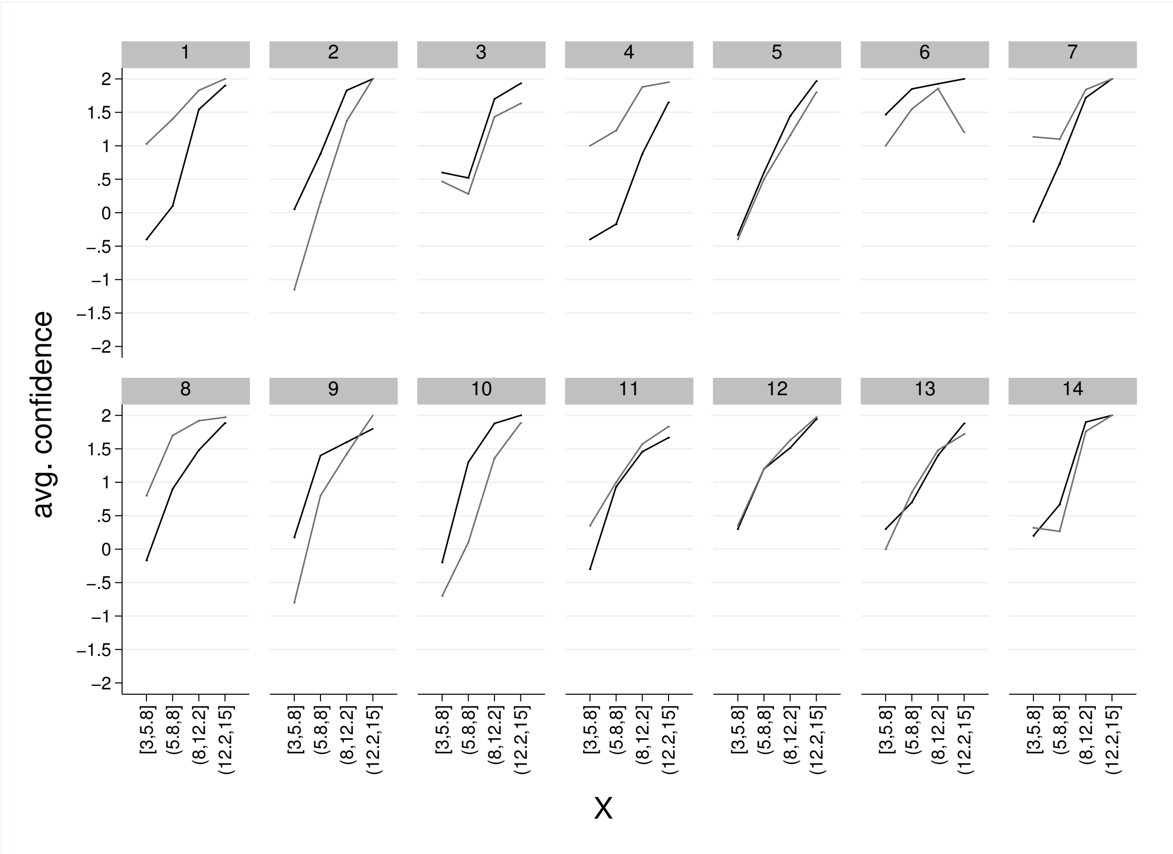
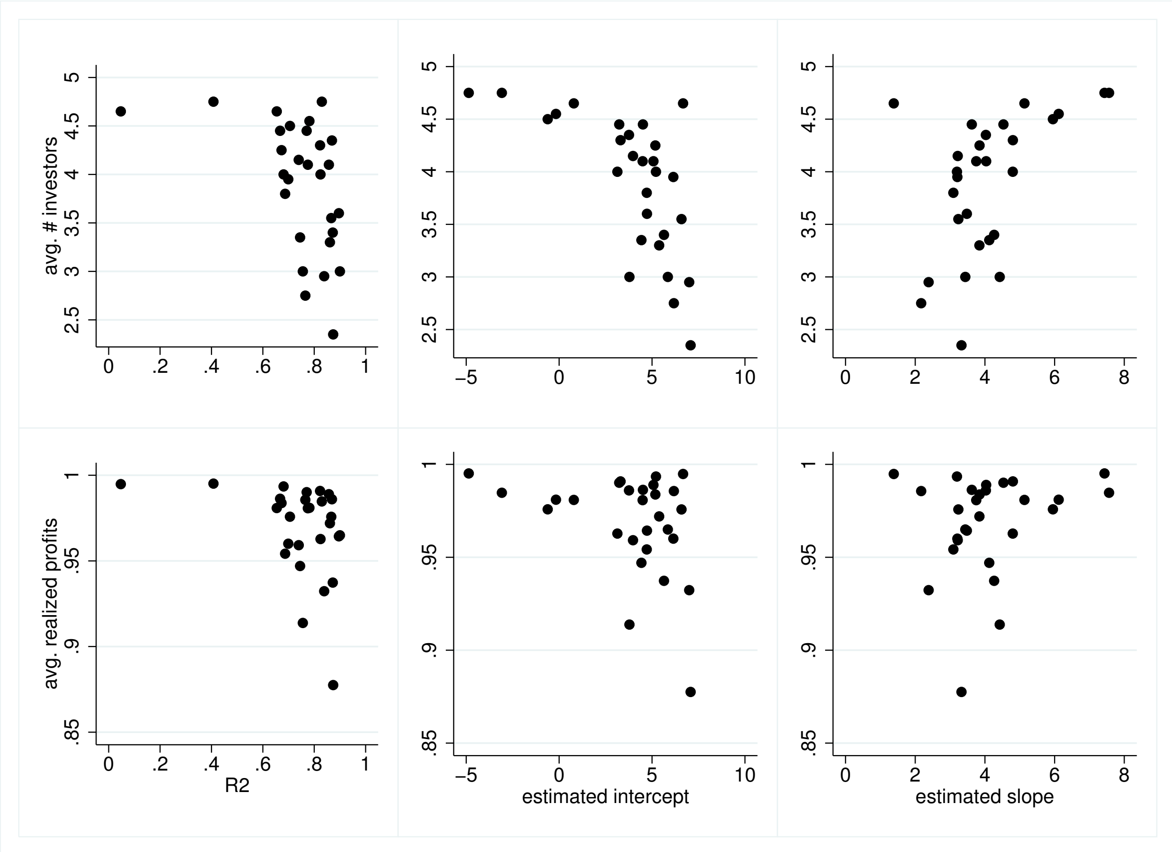


Figure A.6: Estimated variables and aggregate outcomes, period 11-30



B Conditions for multiple equilibria

Consider the *public* game where players observe both their own signal s_i as as well as the mean of the other players' signals $\overline{s}$ where signals are distributed uniformly about X as before. We identify sufficient condition for there to exist multiple equilibria for a particular average signal $\overline{s}$.[16]

For all invest to be an equilibrium it must be that a player with the most pessimistic feasible signal given $\overline{s}$ still wants to invest knowing that everyone else is investing, or

$$\min_{s_i} E(X|s_i, \overline{s}) \geq T - P. \tag{3}$$

Similarly, for all not invest to be an equilibrium it must be that the most optimistic feasible signal will want to also to not invest, or

$$\max_{s_i} E(X|s_i, \overline{s}) \leq T. \tag{4}$$

Directly characterizing these lower and upper bounds for the expectation is non-trivial since it requires characterizing the joint distribution of s_i and $\overline{s}$. We take an alternative approach by directly identifying the most pessimistic (optimistic) feasible signal. Let s_i be player i's signal without loss of generality and let $\overline{s}_{-i}$ be the mean of the other $N-1$ signals. If $\overline{s}_{-i} = s_i + 2\epsilon$, then player i knows for certain that $X = s_i + \epsilon$. While this may seem like this player's expectations are positive, note that we are considering expectations about X for a *particular* $\overline{s}$. We know that the support of $\overline{s}$ is $[X - \epsilon, X + \epsilon]$ and the support of s_i is the same so that $E(X|s_i) \in [s_i - \epsilon, s_i + \epsilon]$ and $E(X|\overline{s}) \in [\overline{s} - \epsilon, \overline{s} + \epsilon]$ so that if $s_i < \overline{s}$ then $E(X|s_i, \overline{s}) \in [\overline{s} - \epsilon, s_i + \epsilon]$. Let us find the $\overline{s}$ that is consistent with this condition on $\overline{s}_{-i}$. It must be that

$$\overline{s} = \frac{(N-1)(s_i + 2\epsilon) + s_i}{N}$$

or

$$\overline{s} = s_i + \frac{N-1}{N} 2\epsilon.$$

[16]Note that since we have assumed that $\underline{X} < T - P$ and $\overline{X} > T$ in order to rule out multiple equilibria in the private information case we know that there will be some average signals such that multiple equilibria will not necessarily exist. For example, any average signal $\overline{s}$ where $s_i = \underline{X} - \epsilon$ is feasible (as we will see later this rapidly converges to any $\overline{s} \leq \underline{X} + 2\epsilon$) will mean that there cannot exist an "all invest" equilibrium for all possible draws of s_i that generated $\overline{s}$.

Therefore, solving for the most pessimistic signal given the mean signal we obtain,

$$s_i = \overline{s} - \frac{N-1}{N} 2\epsilon$$

and the expectation of a person with this signal is given by

$$\begin{aligned} E(X|s_i = \overline{s} - \frac{N-1}{N} 2\epsilon, \overline{s}) &= s_i + \epsilon \\ &= \overline{s} - \frac{N-1}{N} 2\epsilon + \epsilon \\ &= \overline{s} - \frac{N-2}{N} \epsilon. \end{aligned}$$

Note that this rapidly approaches $\overline{s} - \epsilon$ as N increases which seems to make sense since this is the smallest feasible signal and as n gets large any one signal has negligible impact on the average. Similar logic implies hat $E(X|s_i = \overline{s} + \frac{n-1}{n} 2\epsilon, \overline{s}) = \overline{s} + \frac{N-2}{N}\epsilon$ is the most optimistic expectation for a given $\overline{s}$.

C Instructions

All subjects received the instructions for the condition, in which they have been randomly selected. For the *private* condition, the instructions consisted of six pages (see Figure C.1 - C.6). For the *public* condition, the instructions also consisted of six pages (see Figure C.1 - C.3 and C.7 - C.9). For the *confidence* condition, the instructions consisted of seven pages (see Figure C.1 - C.3 and C.10 - C.13).

The instructions were read aloud and were followed by quiz questions to make sure that subjects understood how payoffs are calculated. After all subjects had correctly answered the quiz questions, the experiment began.

Figure C.1: Page 1 of the instructions in all conditions

General Information

This is an experiment in decision making. Several sources have provided funds for this research. In addition to a CHF 10 participation payment, you will be paid the money you accumulate from a decision task that will be described to you in a moment. The exact amount you receive will be determined during the experiment and will depend on your decisions and the decisions of others.

In today's experiment you will participate in a group decision task for **30 periods**. Upon the completion of the experiment, one period out of the 30 will be randomly selected. You will be paid only for your earnings from this randomly selected period, in addition to the CHF 10 participation payment. Since all periods are equally likely to be selected, and since you do not know which period will count, you should treat each period as if it could be the only one that determines your earnings.

From this point forward all units of account will be in **experimental currency units**, or **ECU**. At the end of the experiment, ECU will be converted to CHF at the rate of **1 ECU for 2 CHF**.

If you have any questions during the experiment, please raise your hand and wait for an experimenter to come to you. Please do not talk, exclaim, or try to communicate with other participants during the experiment. Participants intentionally violating the rules may be asked to leave the experiment and may not be paid anything beyond their participation payment.

Group Decision Task

The experiment will have **30 periods**, during which you will perform the group decision task.

Throughout the experiment, you will each be in a **5-person group**. This means that you will be in a group with 4 other participants. Each of you will be in only one group. The other participants with whom you are grouped will be **the same in all periods**. You will never know the identity of these participants and they will never know your identity.

In each period, every one of you will make a choice: **Invest** or **Not Invest**. You will make this choice using the computer interface, by clicking on one of two options.

Figure C.2: Page 2 of the instructions in all conditions

Your Payment in a Period

In each period of the experiment, you will receive a payment, based on your choice and the choice of others in your group. This payment will be determined by three things:

- **your choice** to Invest or Not Invest in that period,
- **the most common choice in your group in** that period (the choice made by at least 3 of the 5 group members) and
- the level of **investment productivity in your group in that period**.

The level of investment productivity will change from one period to the next. Each period, the level of **investment productivity is determined by drawing a random number**. This means that the level of investment productivity is not determined by choices you or others in your group make.

At the beginning of every period, the computer will draw a random number for each group. We will call this random number the **Group Productivity Number** for that period. Each period, the computer will draw a new Group Productivity Number from a **uniform distribution ranging from 3.0 to 15.0**. That is, each number between 3.0 and 15.0, in increments of 0.1, is equally likely to be drawn. (You can think of all possible numbers, from 3.0 to 15.0, being placed in a bag, and each period one of these numbers is drawn, with replacement, to determine the Group Productivity Number for your group in that period.)

The computer will **draw a new Group Productivity Number in each period from all the numbers between 3.0 and 15.0**, and **each draw is unaffected by draws that come either earlier or later**. For example, if the Group Productivity Number drawn in Period 1 is high, the Group Productivity Number drawn in Period 2 is no more or less likely to be high, but will again be drawn from all the numbers between 3.0 and 15.0, with each number equally likely.

Figure C.3: Page 3 of the instructions in all conditions

The table below shows you the possible payments that you will receive. These are based on:

- **Your choice** in a period (Invest or Not Invest).
- **The most common choice in your 5-person group** in that period.
- The **Group Productivity Number for that period, denoted by X**.

		Most Common Choice in Your Group	
		Not Invest	Invest
Your Choice	Not Invest	14.0	14.0
	Invest	X	10 + X

X = Group Productivity Number

Note the following properties of the payoffs in a period:

- If you choose to Not Invest, your payoff will be equal to 14.0 ECUs, regardless of the Group Productivity Number for that period or of the choices made by others in your group.
- If you choose to Invest and the most common choice in your group is “Not Invest”, then your payoff will be equal to the Group Productivity Number (X ECUs), which can be any number from 3.0 to 15.0.
- If you choose to Invest and the most common choice in your group is “Invest”, then your payoff will be equal to 10 plus the Group Productivity Number (X ECUs), which can be any number from 13.0 to 25.0.

Notice that if you choose to Not Invest, your payoffs are not affected by the choices of others in your group or by the Group Productivity Number. If you choose to Invest, you may receive higher or lower payoffs than if you choose to Not Invest, depending on the most common choice in your group and the Group Productivity Number. Also notice that if you choose to Invest, your payoffs will always be higher when the most common choice in the group is also to Invest than when it is to Not Invest.

Figure C.4: Page 4 of the instructions in the *private* condition

Your Clue about the Group Productivity Number in a Period

When you make your choice in a period, **you will not know the Group Productivity Number drawn by the computer** for your group in that period.

However, prior to making a choice of whether to Invest or Not Invest, you will receive a **Clue about the Group Productivity Number drawn in that period**.

To determine your **Clue** in a period, **the computer will draw a Private Number** at the beginning of **each period, one for every group member**. The Private Number will also be drawn from a uniform distribution, this time ranging from **-3.0 to 3.0.** That is, each number between -3.0 and 3.0, in increments of 0.1, is equally likely to be drawn. (You can think of all possible numbers, from -3.0 to 3.0, being placed in a bag, and for each person in your group one number is drawn, with replacement, to determine that person's Private Number in that period). **Your Clue will equal the Group Productivity Number** for that period **plus your Private Number** for that period. Note that each of the five people in your group will receive a **Clue**, and that all five **Clues** will be determined separately, by drawing separate numbers from -3.0 to 3.0.

To summarize:

- The computer will first draw a **Group Productivity Number**, from 3.0 to 15.0, for the entire group. This number will correspond to the value "X" for that period in the payoff table you saw earlier.
- The computer will then draw a new **Private Number**, from -3.0 to 3.0, **for each member of the group**, or five Private Numbers in total.
- **Your Clue** in a period will then be the **sum of the Group Productivity Number**, which is the same for the entire group, and **your Private Number**, which is unique for each group member.

That is,

Your Clue = Group Productivity Number (3.0, …, 15.0) **+ Your Private Number (-3.0, …, 3.0)**

Note that your Clue in a period can be any value between 0.0 and 18.0.

The **Private Numbers** and therefore the **Clues** will be **different for all of the five members of your group**. Since the Clues are obtained by adding the **Private Numbers** to the **Group Productivity Number**, your **Clue can give you an idea of the Group Productivity Number** for your group in that period.

Figure C.5: Page 5 of the instructions in the *private* condition

Example

Suppose that the computer draws a Group Productivity Number for the period equal to 7.4. It will then draw five new Private Numbers, one for each member of the group: for example, 1.2, -2.7, -0.6, 2.2, and 1.8. As you can see in the illustration below, the Group Productivity Number will be added to these five numbers to create the five Clues (8.6, 4.7, 6.8, 9.6, 9.2), and each group member will receive one of these Clues.

Note that the Clues are related to the Group Productivity Number – they will tend to be around the Group Productivity Number.

Note also that **the five Private Numbers** used to determine the Clues **are all drawn independently**, meaning that one draw does not affect the other draws. However, the five Clues in a group are related, since they all include the original Group Productivity Number for that group.

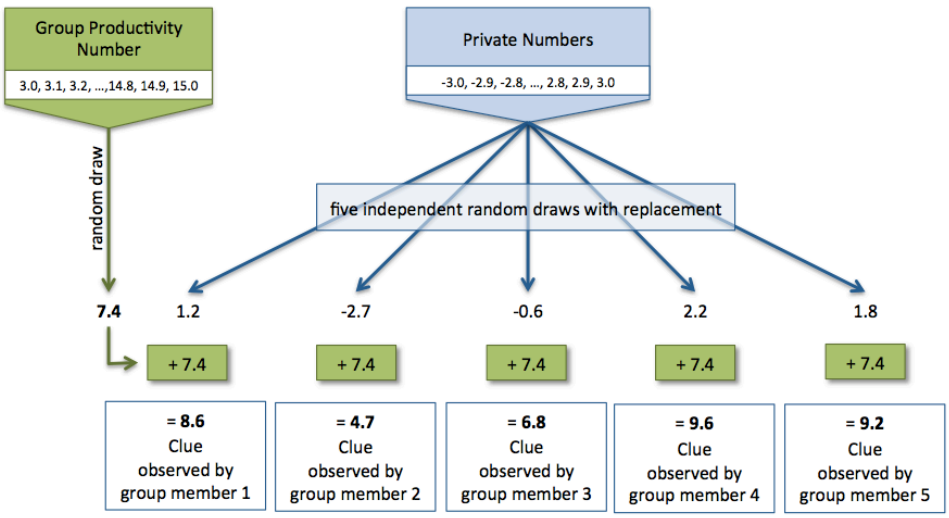


Figure C.6: Page 6 of the instructions in the *private* condition

Making a Choice in a Period

At the beginning of each period, you will each see your Clue for that period. Remember that your Clue gives you an idea of the Group Productivity Number for that period. You **will not** see the Group Productivity Number for that period before making your choice.

You will then choose whether to Invest or Not Invest by clicking on one of the buttons that will appear on the right of your screen. You may change your choice as often as you like, but once you click on "OK" your choice for that period is final.

Note that **when you are making your choice, you will not know the choices of the other people in your group**. Also, remember that you will never know the identity of anyone else in your group, meaning that all choices are confidential and that no one will ever know what choices you make.

Once everyone has made a choice for that period, your screen will display the following information:

- your choice of whether to Invest or Not Invest in that period,
- the total number of Invest and Not Invest choices made in your group in that period,
- the most common choice in your group in that period,
- the Group Productivity Number for that period, and
- your payoffs from the current period.

You will also be able to observe this information for all previous periods. This will be displayed in a table at the bottom of your screen.

At the end of the experiment, we will randomly select one period out of the 30 completed periods, and you will be paid only for this period, plus your CHF 10 participation payment. This amount will be paid to you privately and in cash, meaning that no one will ever know your choices or how much money you made.

Figure C.7: Page 4 of the instructions in the *public* condition

Your Clue about the Group Productivity Number in a Period

When you make your choice in a period, **you will not know the Group Productivity Number drawn by the computer** for your group in that period.

However, prior to making a choice of whether to Invest or Not Invest, you will receive two **Clues about the Group Productivity Number drawn in that period: A Private Clue and a Public Clue.**

To determine your **Private Clue** in a period, **the computer will draw a Private Number** at the beginning of **each period**, **one for every group member**. The Private Number will also be drawn from a uniform distribution, this time ranging from **-3.0 to 3.0.** That is, each number between -3.0 and 3.0, in increments of 0.1, is equally likely to be drawn. (You can think of all possible numbers, from -3.0 to 3.0, being placed in a bag, and for each person in your group one number is drawn, with replacement, to determine that person's Private Number in that period). **Your Private Clue will equal the Group Productivity Number** for that period **plus your Private Number** for that period. Note that each of the five people in your group will receive a **Private Clue**, and that all five **Private Clues** will be determined separately, by drawing separate numbers from -3.0 to 3.0.

All five people in your group will also receive a **Public Clue**, which will be the same for everyone in the group. To determine the **Public Clue** for a group in a period, the computer will **average all five of the Private Clues** in that group in that period.

To summarize:

- The computer will first draw a **Group Productivity Number**, from 3.0 to 15.0, for the entire group. This number will correspond to the value "X" for that period in the payoff table you saw earlier.
- The computer will then draw a new **Private Number**, from -3.0 to 3.0, **for each member of the group**, or five Private Numbers in total.
- **Your Private Clue** in a period will then be the **sum of the Group Productivity Number**, which is the same for the entire group, **and your Private Number**, which is unique for each group member.
- **The Public Clue** in a period will then be the **average of the five Private Clues**.

That is,

Your Private Clue = Group Productivity Number (3.0, …, 15.0)
+ Your Private Number (-3.0, …, 3.0)

The Public Clue = Average of the five Private Clues (0.0, …, 18.0)

Note that your Private and Public Clue in a period can be any value between 0.0 and 18.0.

Figure C.8: Page 5 of the instructions in the *public* condition

Example

Suppose that the computer draws a Group Productivity Number for the period equal to 7.4. It will then draw five new Private Numbers, one for each member of the group: for example, 1.2, -2.7, -0.6, 2.2, and 1.8. As you can see in the illustration below, the Group Productivity Number will be added to these five numbers to create the five Clues (8.6, 4.7, 6.8, 9.6, 9.2), and each group member will receive one of these Clues.

Note that the Clues are related to the Group Productivity Number – they will tend to be around the Group Productivity Number.

Note also that **the five Private Numbers** used to determine the Clues **are all drawn independently**, meaning that one draw does not affect the other draws. However, the five Clues in a group are related, since they all include the original Group Productivity Number for that group.

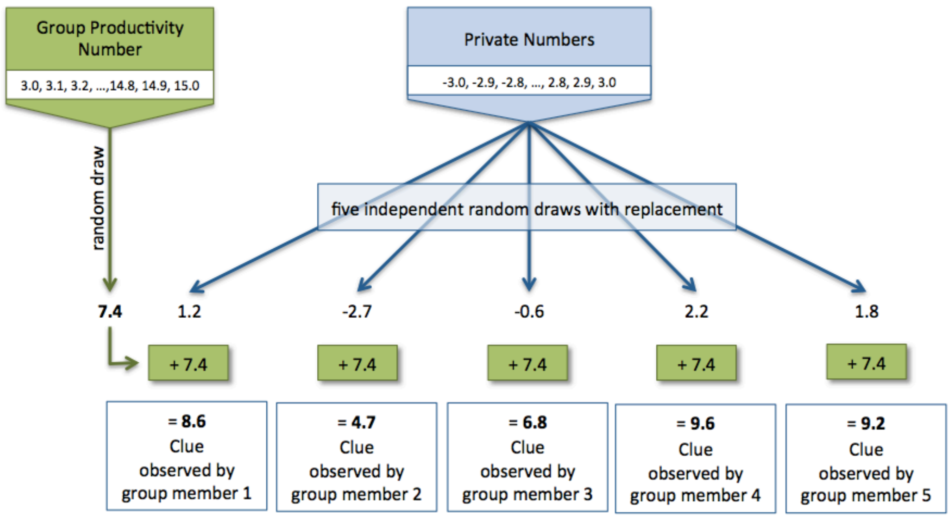


Figure C.9: Page 6 of the instructions in the *public* condition

Making a Choice in a Period

At the beginning of each period, you will each see your Private Clue and the Public Clue for that period. Remember that both Clues give you an idea of the Group Productivity Number for that period. You **will not** see the Group Productivity Number for that period before making your choice.

You will then choose whether to Invest or Not Invest by clicking on one of the buttons that will appear on the right of your screen. You may change your choice as often as you like, but once you click on "OK" your choice for that period is final.

Note that **when you are making your choice, you will not know the choices of the other people in your group**. Also, remember that you will never know the identity of anyone else in your group, meaning that all choices are confidential and that no one will ever know what choices you make.

Once everyone has made a choice for that period, your screen will display the following information:

- your choice of whether to Invest or Not Invest in that period,
- the total number of Invest and Not Invest choices made in your group in that period,
- the most common choice in your group in that period,
- the Group Productivity Number for that period, and
- your payoffs from the current period.

You will also be able to observe this information for all previous periods. This will be displayed in a table at the bottom of your screen.

At the end of the experiment, we will randomly select one period out of the 30 completed periods, and you will be paid only for this period, plus your CHF 10 participation payment. This amount will be paid to you privately and in cash, meaning that no one will ever know your choices or how much money you made.

Figure C.10: Page 4 of the instructions in the *confidence* condition

Your Clue about the Group Productivity Number in a Period

When you make your choice in a period, **you will not know the Group Productivity Number drawn by the computer** for your group in that period.

However, prior to making a choice of whether to Invest or Not Invest, you will receive a **Clue about the Group Productivity Number drawn in that period**.

To determine your Clue in a period, **the computer will draw a Private Number** at the beginning of **each period, one for every group member**. The Private Number will also be drawn from a uniform distribution, this time ranging from **-3.0 to 3.0.** That is, each number between -3.0 and 3.0, in increments of 0.1, is equally likely to be drawn. (You can think of all possible numbers, from -3.0 to 3.0, being placed in a bag, and for each person in your group one number is drawn, with replacement, to determine that person's Private Number in that period). **Your Clue will equal the Group Productivity Number** for that period **plus your Private Number** for that period. Note that each of the five people in your group will receive a **Clue**, and that all five **Clues** will be determined separately, by drawing separate numbers from -3.0 to 3.0.

To summarize:

- The computer will first draw a **Group Productivity Number**, from 3.0 to 15.0, for the entire group. This number will correspond to the value "X" for that period in the payoff table you saw earlier.
- The computer will then draw a new **Private Number**, from -3.0 to 3.0, **for each member of the group**, or five Private Numbers in total.
- **Your Clue** in a period will then be the **sum of the Group Productivity Number**, which is the same for the entire group, and **your Private Number**, which is unique for each group member.

That is,

Your Clue = Group Productivity Number (3.0, …, 15.0)
+ Your Private Number (-3.0, …, 3.0)

Note that your Clue in a period can be any value between 0.0 and 18.0.

The Private Numbers and therefore the **Clues** will be **different for all of the five members of your group**. Since the **Clues** are obtained by adding the **Private Numbers** to the **Group Productivity Number**, the **Clues can give you an idea of the Group Productivity Number** for your group in that period.

Figure C.11: Page 5 of the instructions in the *confidence* condition

After you and all other members in your group have received their Clue, all of you will be asked to the following question:

"Do you think that during this period your group will have good earnings, bad earnings or what?"

-2	-1	0	1	2
bad	somewhat bad	neither bad nor good	somewhat good	Good

You give your answer by clicking on one of five buttons that correspond to the above options and will be displayed on your computer screen. You will then be asked whether you want to submit your answer. If you click on "Yes" you submit it, if you click on "No" you go back to the question screen and you may change your answer. Your answer to this question will not directly affect how much you earn in a period.

When all members of your group have answered the question, the computer will display the **average answer given in your group**.

The **average answer** is calculated by using the values (-2, -1, 0, 1, 2) associated with the respective answers ("bad," "somewhat bad," "neither bad nor good," "somewhat good," "good"). Therefore a negative average answer indicates that your group generally believes earnings will be somewhere between "bad" and "neither bad nor good" and a positive average answer indicates that your group generally believes earnings will be somewhere between "neither bad nor good" and "good."

Figure C.12: Page 6 of the instructions in the *confidence* condition

Example

Suppose that the computer draws a Group Productivity Number for the period equal to 7.4. It will then draw five new Private Numbers, one for each member of the group: for example, 1.2, -2.7, -0.6, 2.2, and 1.8. As you can see in the illustration below, the Group Productivity Number will be added to these five numbers to create the five Clues (8.6, 4.7, 6.8, 9.6, 9.2), and each group member will receive one of these Clues.

Note that the Clues are related to the Group Productivity Number – they will tend to be around the Group Productivity Number.

Note also that **the five Private Numbers** used to determine the Clue **are all drawn independently**, meaning that one draw does not affect the other draws. However, the five Clues in a group are related, since they all include the original Group Productivity Number for that group.

Further suppose that the **average answer** given by the group members is 0.2 indicating that the group, on average, generally believes earnings will be between "neither bad nor good" and "somewhat good" during this period. In addition to their Clue all group members will also receive the group's **average answer**.

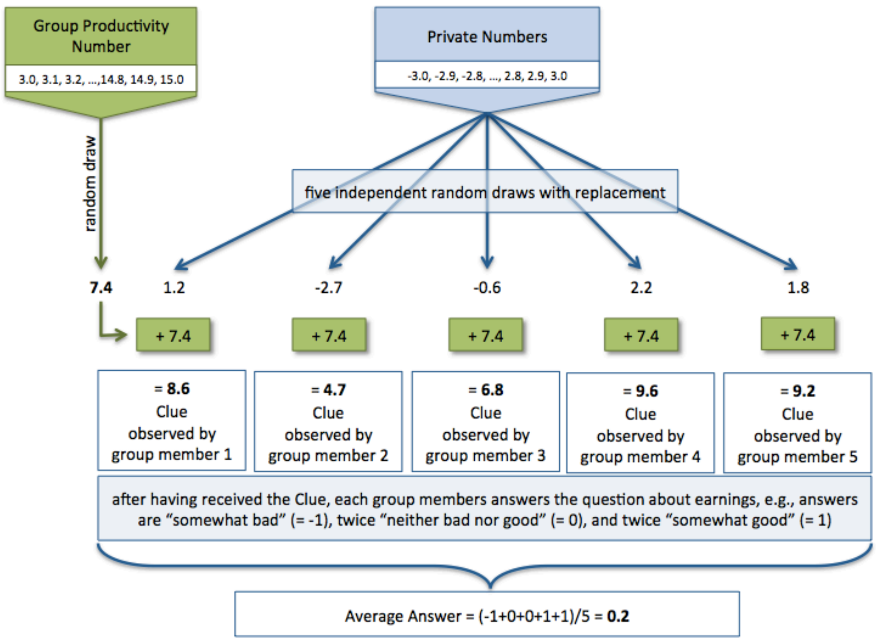


Figure C.13: Page 7 of the instructions in the *confidence* condition

Making a Choice in a Period

At the beginning of each period, you will each see your Clue for that period. Remember that your Clue gives you an idea of the Group Productivity Number for that period. You **will not** see the Group Productivity Number for that period before making your choice.

Before you choose whether to Invest or Not Invest in that period, you will **answer the question** about earnings and **then you will all observe the average answer** given in your group.

You will then choose whether to Invest or Not Invest by clicking on one of the buttons that will appear on the right of your screen. You may change your choice as often as you like, but once you click on "OK" your choice for that period is final.

Note that **when you are making your choice, you will not know the choices of the other people in your group**. Also, remember that you will never know the identity of anyone else in your group, meaning that all choices are confidential and that no one will ever know what choices you make.

Once everyone has made a choice for that period, your screen will display the following information:

- your choice of whether to Invest or Not Invest in that period,
- the total number of Invest and Not Invest choices made in your group in that period,
- the most common choice in your group in that period,
- the Group Productivity Number for that period, and
- your payoffs from the current period.

You will also be able to observe this information for all previous periods. This will be displayed in a table at the bottom of your screen.

At the end of the experiment, we will randomly select one period out of the 30 completed periods, and you will be paid only for this period, plus your CHF 10 participation payment. This amount will be paid to you privately and in cash, meaning that no one will ever know your choices or how much money you made.