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JOB MARKET SIGNALING AND SCREENING: AN EXPERIMENTAL COMPARISON

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Job market signaling and screening: An experimental comparison[*]

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Abstract

We analyze the Spence education game in experimental markets. We compare a signaling and a screening variant, and we analyze the effect of increasing the number of employers from two to three. In all treatments, there is a strong tendency to separate. More efficient workers invest more often and employers bid higher for workers who have invested. More efficient workers also earn higher wages. Employers' profits are usually not different from zero. Increased competition leads to higher wages only in the signaling sessions. We find that workers in the screening sessions invest more often and earn higher wages when there are two employers.

Keywords: job-market signaling; job-market screening; sorting; Bayesian games; experiments.

JEL classification numbers: C72; C73; C91; D82.

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1   Introduction

Spence's (1973, 1974) work on "market signaling" is a seminal contribution to economics. It is one of the first treatments of incomplete information and has led to a large body of theoretical and empirical papers. Spence's idea is simple. In a labor-market context, he studies investments in education which have no productive value and no intrinsic value either. The reason workers may nevertheless invest in such apparently superfluous education is that it may serve as a signal to potential employers. By choosing to invest in education, highly productive workers distinguish themselves from less productive workers. The potential employers cannot observe the ability of the workers, but they know that investing in education is cheaper for highly able workers. Therefore, education serves as a credible signal of unobserved productivity, and it is rewarded with a higher wage. As education is correlated with productivity, it has a sorting effect.

The Spence game had an enormous influence on game theory itself as it triggered the literature on signaling games and equilibrium refinements. Many of the theoretical contributions have focussed on the emergence of separating equilibria. In a separating equilibrium, workers who have different unobserved productivity levels choose different levels of education. Among others, Riley (1979a), Cho and Kreps (1987), Banks and Sobel (1987), Cho and Sobel (1990) and Mailath *et al.* (1993) analyzed conditions and criteria under which the separating equilibrium is likely to occur. The main implication of this literature is that, even though other equilibria with pooling of types exist, often only separating equilibria survive the application of equilibrium refinements. In this sense, the sorting effect is theoretically robust.

In this paper, we report on experiments designed to analyze Spence's (1973, 1974) model. Our main question is to what extent and under which conditions wasteful signaling occurs. Previous experiments on signaling games suggest that equilibrium refinements cannot reliably predict behavior.[1] Rather, the success of refinements depends on "inconsequential" changes of the payoff structure as outcomes are path dependent (Brandts and Holt, 1992, 1994; Cooper et al., 1997a,b). Cooper et al. (1997b, p. 553) conclude that these "[e]xperiments have raised serious doubts about the validity of equilibrium refinements." Thus, one goal of this study is to investigate the role of path dependence and refinements in the Spence education game which has not been studied in experiments before. We design markets such that education has no direct value for either workers or

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[1]Signaling experiments include Miller and Plott (1985), Cadsby, Frank and Maksimovic (1990, 1998), Potters and van Winden (1996), Cooper and Kagel (2001a,b).

employers, and we control for workers' actual ability to ensure that there are no productivity effects of sorting. In our setup, investing in education is entirely wasteful, and workers pooling on a zero level of education would be an ex-ante Pareto improvement. In this "pure" Spence environment, we investigate whether or not signaling occurs and which factors facilitate it.

We focus on two features of the game that may affect signaling. Firstly, we analyze the education game both in its original signaling version as well as in a setup with screening by the employers. In the screening variant of the Spence game (e.g., Rasmusen, 1994), the sequence of moves is reversed. The employers move first by offering two wages, contingent on the investment decision. Then, moving second, the workers decide whether or not to invest in education. This model captures for example the situation of job candidates first receiving information about salaries for jobs that require college education and those that do not and then deciding whether or not to go to college. The motivation for running the screening variant is to analyze whether institutional changes cause differences in results. One institution may turn out to be better suited for job-market separating of types than the other. As screening in an incomplete information experiment has not been studied before, our screening treatments should be of some stand-alone interest.

Our second treatment variable analyzes the impact of competition in the markets. Employer competition is an essential part of the Spence model—in contrast to many signaling models with a single responder. Two or more employers bid for the worker in wage competition à la Bertrand. As a result, employers (receivers) get the same expected profits across different equilibrium outcomes. Theoretically, increasing the number of employers has no impact on the prediction but it may nevertheless affect the outcome in experiments (Fouraker and Siegel, 1963; Dufwenberg and Gneezy, 2000). For example, Dufwenberg and Gneezy (2000) have analyzed Bertrand oligopolies with two, three and four firms. They show that the Bertrand solution does not predict well with two firms, but predicts well when the number of firms is three or four. If wages get more competitive with three employers, this might affect investments in education positively. Or, put differently, if employers successfully collude on low wages, signaling might not be profitable for workers any more as the wage may be insufficient to cover the cost of education. Hence, the separating equilibrium may lose predictive power. We analyze this issue by employing treatments with two and three competing employers.[2]

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[2]There are two other studies with receiver competition, but they do not systematically vary the number of receivers. Cadsby, Frank, and Maksimovic (1998) test a signaling model with a large number of competing investors. Miller and Plott (1985) investigate an open offer market where six buyers and six sellers can make bids. In this study, there

There are some interesting and influential field-data studies on this topic which provide evidence in favor of the Spence hypothesis.[3] Basically, these papers found evidence that is consistent with the signaling model but inconsistent with a pure human-capital model of education (Becker, 1964). We believe that our experiments nicely complement these studies. Note, for example, that (wasteful) investments in education can still be second-best in the field. The first-best outcome in which ability or productivity is observable is not feasible. However, compared to pooling of types, and therefore a purely random allocation of types to jobs, sorting might have productive effects as it might help employers to allocate workers according to their comparative advantage. In our experiments, there are no such productive effects of education, that is, we test the theory in an environment in which education is purely dissipative. Furthermore, we are not aware of field data evidence on the effects of our treatment variables (signaling vs. screening and two vs. three employers). Here, experimental data might help to assess the behavioral relevance of the different variants of the model.

The next section presents the model underlying our experiments. Section 3 describes the experimental design. Section 4 reports the results, and Section 5 concludes.

2 Theory

In this section, we lay out the simple model underlying our experiments and derive the game-theoretic predictions. We provide the results for the model with one worker and two employers. We ran experimental treatments with two and three employers, but it will be obvious that the theoretical results are not affected by adding a third employer. We start with the predictions for the signaling treatments and then add those for the screening variant.

The timing of the signaling game is as follows:

1. Nature chooses the worker's ability $a \in \{10, 50\}$ where *low* ($a = 10$) and *high* ($a = 50$) ability are equally likely. Workers know a but employers do not.

2. The worker chooses an education level $s \in \{0, 1\}$ which is observed by the employers.

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is asymmetric information about the quality of the good, but a costly signal is available to the seller. By varying the cost of the signal, they find that with relatively costly signals, more separating occurs than pooling compared to the case of relatively cheap signals.

[3]Early empirical findings, e.g. Layard and Psacharopoulos (1974), were against the Spence hypothesis but later studies provided evidence in favor it. These papers include Wolpin (1997), Riley (1979b), Lang and Kropp (1986) and Bedard (2001).

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3. The employers each offer a wage $w(s) \in [0, 60]$.

4. The employer who offered the higher wage hires the worker. In case of a tie, a fair random draw decides which employer hires the worker.

5. Payoffs are as follows:

$$\pi_{\text{worker}} = w - 450s/a \tag{1}$$

where w equals the higher of the two wage offers.

$$\pi_{\text{employer}} = \begin{cases} 25 + a - w, & \text{for the employer who hired the worker} \\ 25, & \text{for the other employer.} \end{cases} \tag{2}$$

The payoffs in (1) and (2) indicate that the worker gets the wage minus his cost of education, whereas the hiring employer's payoff is a fixed payment plus the difference between the worker's ability and the wage. The non-hiring employer receives the fixed payment only.[4] Note that the cost of education is $450/10 = 45$ for the *low* type and $450/50 = 9$ for the *high* type of the worker. Note also that a worker's strategy is to specify an investment decision (a signal) given his type realization whereas an employer's strategy is to specify a wage offer for each of the two signals she might receive.

The appropriate solution concept is perfect Bayesian Nash equilibrium, comprising a strategy profile and a system of beliefs. Prior beliefs on the worker's type are common knowledge. Posterior beliefs after the worker has chosen the educational level s are as follows. Let $p = Prob(a = high \mid s = 1)$ denote an employer's belief that the worker has *high* ability after observing that the worker invested in education (and hence $1 - p = Prob(a = low \mid s = 1)$). Likewise, let $q = Prob(a = high \mid s = 0)$ denote an employer's belief that the worker has *high* ability after observing that the worker did not invest in education (and hence $1 - q = Prob(a = low \mid s = 0)$).

The game above has two equilibria—a pooling and a separating equilibrium. Let us start with the

$$\text{pooling equilibrium:} \quad \begin{cases} s(low) = s(high) = 0 \\ w(0) = w(1) = 30 \\ p = 0.5, \ q = 0.5. \end{cases} \tag{3}$$

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[4]We introduced this fixed positive payment since employers earn zero expected payoffs in both equilibria of the game (see below). Like Holt (1985), we prefer employers to earn a strictly positive payoff in equilibrium to avoid frustration which might trigger unreasonable behavior of subjects.

In this equilibrium, both types of the worker do not invest in education, and the two employers offer a wage equal to the expected value of the worker's ability ($0.5 \times 10 + 0.5 \times 50 = 30$). Note that the employers' information sets corresponding to $s = 0$ are on the equilibrium path. Therefore, the belief q is dictated by Bayes' rule and the worker's strategy. In contrast, the employers' information sets corresponding to $s = 1$ are off the equilibrium path. Hence, Bayes' rule does not pin down the employer's beliefs and we are free to choose beliefs p. In (3) employers assume that a worker who chooses $s = 1$ has *high* ability with the prior probability 0.5. In this equilibrium, both types of the worker earn payoff 30 whereas both employers earn an expected payoff consisting only of the fixed payment of 25 (for a proof of the equilibrium, see the Appendix A). While the pooling equilibrium (3) is a perfect Bayesian Nash equilibrium, it can be ruled out by applying Cho and Kreps' (1987) "intuitive criterion" (see Appendix A).

Next consider the

$$\text{separating equilibrium:} \quad \begin{cases} s(low) = 0, \ s(high) = 1 \\ w(0) = 10, \ w(1) = 50 \\ p = 1, \ q = 0. \end{cases} \quad (4)$$

In this equilibrium, the *low*-ability worker does not invest in education whereas the *high*-ability worker does. The employers condition their wage on the signal they receive. They pay a wage which is equal to the *low* type's ability in case of no education whereas they pay a wage which equals the *high* type's ability after the "education" signal. Since both signals can be observed in equilibrium, the beliefs of the employers are determined by Bayes' rule and the worker's strategy, and we have $p = 1$ and $q = 0$. In this equilibrium the *low* type earns profit $10 - 0 = 10$ whereas the *high* type earns $50 - 9 = 41$. Again, the expected payoffs of both employers are equal to the fixed payment of 25 (proof, see Appendix A).

Comparing the equilibria, note that the *high* type is better off in the separating equilibrium than in the pooling equilibrium ($41 > 30$) and vice versa for the *low* type ($10 < 30$). The ex-ante expected payoff for the worker is larger in the pooling equilibrium though ($30 > 0.5 \cdot 41 + 0.5 \cdot 10 = 25.5$). This difference in expected wages is equal to the welfare loss of the separating equilibrium as the expected payoff for the employer is the same in both equilibria. Thus, the pooling equilibrium is both ex-ante payoff dominant for the worker and welfare dominant.

Now consider the screening variant. The timing of the screening game is as follows.

1. Nature chooses the worker's ability $a \in \{10, 50\}$. Workers know a but employers do not.

2. The employers each offer two wages, $w(s) \in [0, 60]$; $s \in \{0, 1\}$, which are conditional on the education decision. The worker learns the higher wage for each contingency. In case of a tie, a fair random draw decides whose wage is displayed.

3. The worker chooses an education level $s \in \{0, 1\}$.

4. The employer who offered the higher wage for the education level chosen by the worker hires the worker.

5. Payoffs are as above in the signaling variant.

There is no pooling equilibrium in this game, and the unique prediction is a separating equilibrium with wage and investment levels as described above (for a proof of both results, see Appendix A).

Let us finally mention that in a model with three employers competing for the worker, the equilibria are exactly the same as with two employers. The arguments to establish these equilibria are identical, so we abstain from reiterating them.

To summarize, the signaling model with either two or three employers has both a separating and a pooling equilibrium. However, based on the "intuitive criterion," a strong case can be made against the pooling equilibrium. The screening model, both with two and three employers, has a unique separating equilibrium outcome that coincides with the one in the signaling model.

3 Experimental design and procedures

We compare two markets, one in which the informed workers move first (signaling markets, henceforth SIG) and one in which the uninformed employers are the first movers (screening markets, called SCR). As a second treatment variable, we study the effect of varying the number of employers (two versus three). Thus, we ran four different treatments resulting from a 2×2 design. The SIG2 and SCR2 sessions involved 9 subjects each whereas the SIG3 and SCR3 sessions involved 12 subjects each.

On the one hand, the design should be as close as possible to a single-period interaction between subjects. On the other hand, there is need for learning in such a complex environment. Therefore, we decided to allow for many repetitions, but we randomly rematched subjects in every period. More precisely, with two (three) competing employers, the 9 (12) participants were ran-

domly matched in every period into groups of three (four) subjects, consisting of one worker and two (three) employers.

To enhance learning we employed role switching. That is, participants played both in the role of the worker and in the role of the employer. All sessions lasted for 48 rounds. In the treatments with two employers, we partitioned the 48 rounds of the experiment into six "blocks" consisting of eight consecutive rounds. Within a block of eight rounds, roles did not change. All subjects played the role of the worker for two blocks and the role of the employer for four blocks. In principle, after being a worker for one block, subjects took on the role of employer for two blocks. (For some subjects this pattern was different at the beginning and at the end of the experiment.) In sessions with three employers, we partitioned the 48 rounds of each session into eight blocks of six rounds. Here, subjects played in the role of the worker for two blocks and in the role of the employer for six blocks. As before, roles did not change within blocks. The usual pattern of role switching was that, after being a worker for one block, subjects were in the employer's role for three blocks. The computer screen indicated the current role of the participant throughout the experiment.

Decision making in each round of the experiment was exactly as described in the theory section above. In both the signaling and the screening game, there was a random move first, selecting the worker's type. Whereas workers were informed about their individual types, employers were not. In the signaling game, workers then had to decide whether or not they wanted to make an "investment."[5] Third, after learning about the investment decision of the worker (but without learning the type of the worker), employers were asked to submit a wage offer. Finally, the worker was hired by the employer who submitted the higher wage offer (possibly after a random computer draw in case of a tie).[6] In the screening treatment, employers first had to submit wage bids for the case that the worker invests and for the case the worker does not invest. Then the worker made her investment decision. Finally, the worker was hired by the employer with the highest wage bid given the investment decision.

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[5]We avoided the term "education" as it might bias decisions. The instructions simply asked the workers to decide whether or not they want to make an "investment." It was not specified what the nature of this investment was. Before the start of our experimental sessions, subjects occasionally asked why they should invest into something which has no value. Also post-experimental questionnaires reveal that subjects understood that the investment per se has no value.

[6]We decided to automatically give the worker the higher wage and not to let workers reject wages in order to simplify the design.

After each round, the computer screen displayed the following feedback information: type and investment decision of the worker, wage offers of both employers (with an indication of which employer hired the worker), own profits as well as the profits of the other group members of that round and own accumulated profit.

Experiments were computerized[7] and were conducted at Royal Holloway, University of London. The experiments were run from October 2001 to October 2002. In total, 126 subjects participated. Upon arrival in the lab, subjects (undergraduate as well as a few graduate students from all over the campus) were assigned a computer and received written instructions. After reading the instructions, subjects were allowed to ask questions privately.

We conducted three sessions for each treatment. Sessions lasted about one and a half hours. Earnings were denoted in a fictitious currency called "points." The fixed exchange rate of £1 for 150 points was commonly known. In addition to their earnings, subjects received a one-off endowment of 200 points at the beginning of the experiment. This was done to cover possible losses that could–and occasionally did–occur in the beginning of a session. Subjects' average monetary earnings were £9.40, including the initial endowment and a show-up fee.

4   Results

4.1   Main Findings

We summarize the data about worker and employer behavior in Table 1. For workers, Table 1 shows investment rates for each type. For employers, it shows average wage offers (i.e., averages of all wage offers observed) as well as average wages paid (i.e., average of wages that have been actually paid in the experiments).

To test for significance of differences in the data, we run regressions for the investment decisions of workers, the wages paid by employers and profits. As independent variables we use the worker's type (*high* vs. *low*), the investment decision of workers (*yes* vs. *no*), or *treatment* as a dummy. We run probit regressions for the investment choice and linear regressions for the wages and profits and test whether the coefficient of the dummy is statistically different from zero.[8] We use

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[7]We used the software tool kit *z-Tree*, developed by Fischbacher (1999).

[8]For example, to test whether employers in a signalling game pay more upon observing investment rather than observing no investment by a worker, we use the estimation equation $wage = \beta_0 + \beta_1 Dummy + \varepsilon_i$ where the variable $Dummy$ is equal to 0 after no investment and equal to 1 after the worker invested. The estimate for β_1 can be directly interpreted as the difference in means. ε_i is a normally distributed error term with mean zero and variance

Treatment	Rounds	Investment rate if worker's type is		Employers' wage offer [wage paid] for the case of			
		low	high	no investment		investment	
SIG2	1–48	.10	.61	11.53	(7.31)	22.87	(11.13)
				[14.83	(8.48)]	[28.41	(10.26)]
	41–48	.00	.68	11.34	(4.68)	27.54	(9.90)
				[13.59	(5.32)]	[32.55	(7.87)]
SIG3	1–48	.11	.71	16.96	(12.51)	29.90	(12.21)
				[26.00	(13.26)]	[39.05	(7.65)]
	43–48	.08	.83	14.46	(8.85)	31.96	(11.53)
				[20.75	(9.78)]	[41.10	(4.12)]
SCR2	1–48	.14	.68	21.29	(14.31)	34.67	(12.37)
				[34.12	(15.45)]	[43.21	(9.04)]
	41–48	.15	.92	15.35	(8.65)	34.24	(10.25)
				[23.31	(9.90)]	[41.55	(5.44)]
SCR3	1–48	.07	.49	18.62	(13.08)	24.89	(15.60)
				[31.00	(11.91)]	[41.79	(11.16)]
	43–48	.00	.64	17.10	(12.44)	27.58	(15.78)
				[28.78	(11.99)]	[46.06	(4.78)]

Table 1: Summary of experimental results: Average investment rates and average wages offered [wages paid]. Standard deviations are in parentheses. Predictions for the pooling equilibrium: no investment, wage = 30; for the separating equilibrium: only type *high* invests; wage = 10 for type *low*, wage = 50 for type *high*.

White (1980) robust standard errors and we adjust for possible non-independence of observations within sessions.[9] For the regressions, we restrict attention to the decisions from the last block in each session, that is, the last eight games in the treatments with two employers and the last six games in the treatments with three employers.[10]

First we will provide a number of general results which hold across all four treatments.

Result 1 *High types of workers invest significantly more often than low types of workers.*

Investment rates of *high* types are significantly higher in all treatments at the 1% level. Table 1 indicates that theses differences are also quantitatively substantial. *Low* types clearly invest less often in education, and their investment rate is practically zero towards the end of the experiment. This indicates that the different types separate themselves by their investment choice. This is clearly displayed by Figures 1 and 2. Figure 1 shows the average investment in every period for high types and low types, both for the signaling game with two and three employers. Figure 2 represents investment decisions in the two screening treatments. In all treatments, the investment rate of high types is always above the investment rate of low types. And this effect becomes more pronounced over time. The *low* types' investment rate is negatively correlated over time while that of *high* types is positively correlated in all treatments. The difference between the investment rates of *high* and *low* types significantly increases over time (SIG2 and SCR2: 1%, SCR3: 5% level) except in treatment SIG3.

Notice that the investment decision in the screening sessions is actually a simple binary choice. Workers know the highest wage for both investment decisions. They only have to choose the option which maximizes their payoff. The data indicate a high proportion of payoff-maximizing decisions as 90% (SCR2) and 91% (SCR3) of all investment decisions over all periods were rational. Moreover, the number of rational decisions is significantly higher in the second half of the experiment, that is, subjects learn to make the right decisions. The few irrational decisions show a certain bias. Taking both treatments together, 70 out of a total of 81 wrong investment decisions were taken in situations where a worker should have invested but decided not to do so. This can be

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σ_i^2.

[9]Observations might not be independent because of the random matching of subjects within sessions. We account for this by forming *clusters* (here a cluster is one session) when running our regressions (see STATA Corp. (1999, vol. 3, pp.156-158 and 178-179) and Martin, Normann and Snyder (2001) for a detailed description of the test.

[10]Although there is some learning within each block, the main trend in behavior occurs across blocks. Thus, restricting attention to aggregate decisions in the last block yields a good measure of mature behavior.
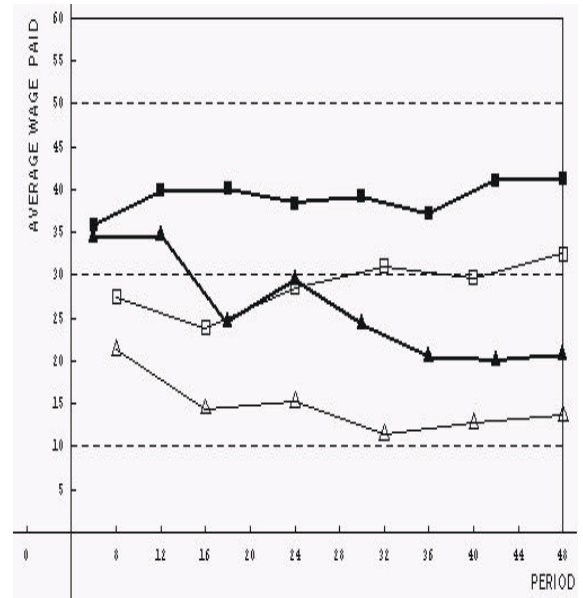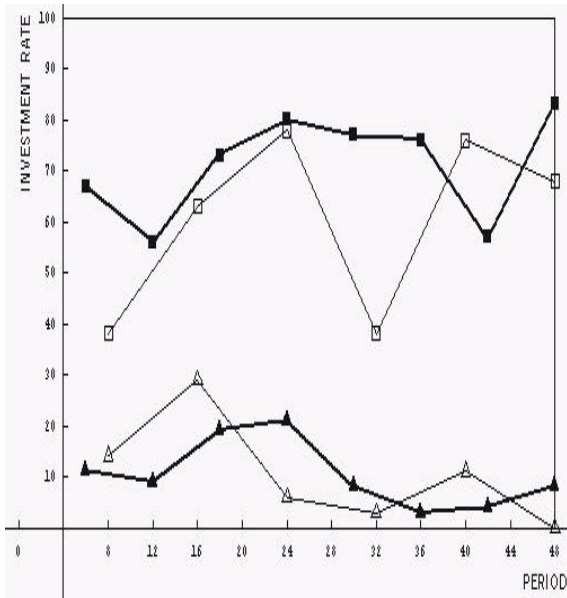
11

Figure 1: SIG2 (normal lines) vs. SIG3 (bold lines). Left panel contains investment rates, triangles indicate *low* types, squares indicate *high* types. Right panel contains average wages paid, triangles indicate wages if $s = 0$, squares indicate wages if $s = 1$.
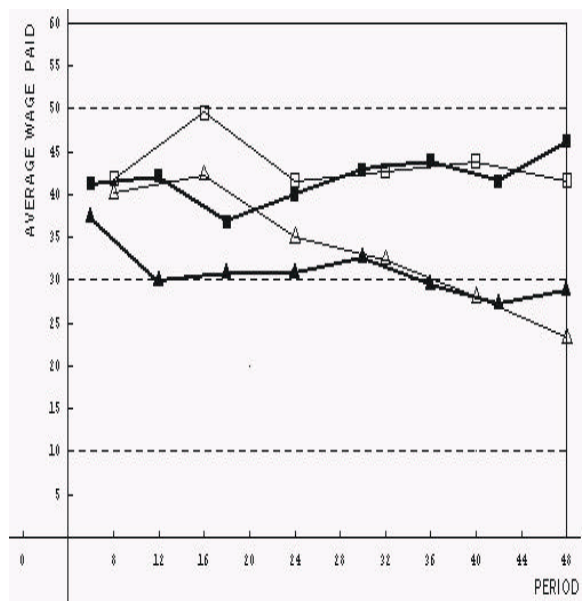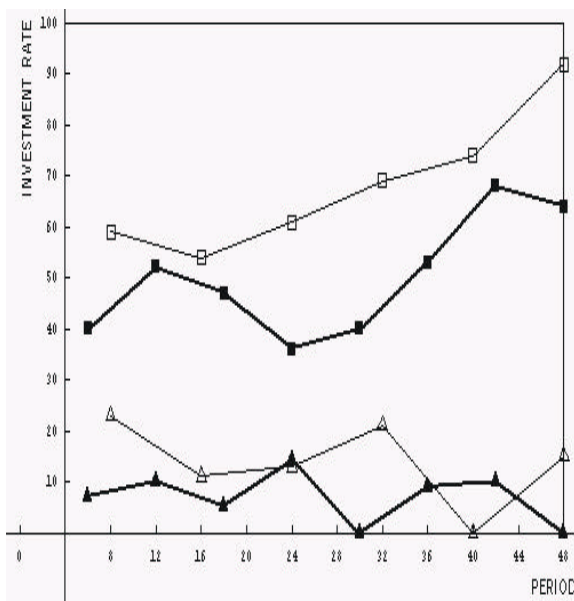

Figure 2: SCR2 (normal lines) vs. SCR3 (bold lines). Left panel contains investment rates, triangles indicate *low* types, squares indicate *high* types. Right panel contains average wages paid, triangles indicate wages if $s = 0$, squares indicate wages if $s = 1$.

explained by the fact that low types face a simpler task as they should never invest, independent of the wage offers, whereas high types must condition their choice on the actual wage offers.

Result 2 *Wages are significantly higher for workers who invest.*

Table 1 shows that average wages paid are higher for workers who invest in education compared to those who do not invest. This is significant for SIG2 and SCR2 at the 5% level and for SIG3 and SCR3 at 10%. As above, the time trend is also in favor of the separating equilibrium (see again Figures 1 and 2). Gross earnings of workers who invested are positively correlated over time while earnings of workers who did not invest are negatively correlated over time.[11] The wage spread significantly increases over time in all treatments (at the 1% level; SCR3: 5% level). Very similar results hold when studying wage offers instead of wages paid. Table 1 shows that wage offers are higher when $s = 1$ and this is significant in SIG2, SIG3 and SCR3 (5% level).

Result 3 *High types of workers earn higher profits.*

For workers' earnings and profits, refer to Table 2. In the pooling equilibrium both types earn the same (30 points) as neither type invests. The separating equilibrium predicts that *high* types earn 41 points while *low* types earn 10 points. The table indicates that *high* types earn more on average as predicted but this result is generally not significant, except in SIG2 (10% level). The differences presumably fail to be significant because the separation of *high* and *low* types is not complete. In particular, a considerable number of high types earn low wages because they do not invest (we will elaborate on this below).

Result 4 *Employers' net profits are not significantly different from zero—except in* SIG2.

Employers are predicted to compete in a Bertrand fashion, leading to zero profits both in the pooling and the separating equilibrium. Employers' net earnings, reported in Table 2, are, by all means, small on average (recall that employers received a fixed payment of 25 in every period, but we report net earnings here). For the case of no investment, they are even negative on average in all treatments but SIG2.[12] We estimated 95% confidence intervals around the profit means, again accounting for possible dependence of observations. Profits are not different from zero, apart from the SIG2 treatment where we observe a small positive profit.

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[11]An exception occurs for SCR2 where earnings following an investment are slightly negatively correlated over time ($\rho = -0.075$) which is due to the behavior in one of the three sessions.

[12]This finding may be due to the presentation of total earnings after each round on the screen, including the fixed payment of 25. Thus, employers never saw a negative number even if they made moderate losses.

Treatment	Rounds	Workers' profit if the type is		Employers' profit for the case of	
		low	*high*	*no investment*	*investment*
SIG2	1–48	11.14	18.11	3.96	8.10
		(12.79)	(10.26)	(14.67)	(14.18)
	41–48	12.87	21.14	2.69	8.72
		(3.27)	(8.96)	(11.80)	(10.40)
SIG3	1–48	22.03	29.42	-1.88	1.94
		(16.13)	(9.28)	(12.41)	(9.05)
	43–48	19.18	29.82	-1.12	1.98
		(12.60)	(6.96)	(11.39)	(6.88)
SCR2	1–48	26.58	36.38	-5.94	0.51
		(17.47)	(11.09)	(14.96)	(12.72)
	41–48	18.38	32.71	-4.78	1.72
		(12.87)	(5.26)	(9.80)	(10.37)
SCR3	1–48	26.92	33.45	-1.99	1.25
		(15.89)	(10.63)	(12.52)	(8.89)
	43–48	25.86	37.46	-3.10	1.31
		(10.27)	(8.34)	(10.19)	(3.29)

Table 2: Average profits of workers and average net profits of employers. Standard deviations are in parentheses. Predictions: in the pooling equilibrium both types receive a wage of 30; in the separating equilibrium *high* types earn 41, *low* types earn 10; employers earn zero throughout.

4.2 Session- and Individual-Level Data

We complement these aggregate results with a view of the data at the session and at the individual level. Figures 5 and 6 in Appendix C provide graphs for each session separately. The general picture emerging from the analysis of aggregated results holds for almost all sessions separately. In the signaling sessions, investment behavior is different for *high* and *low* types from the beginning (except in SIG2, session 1). In 4 out of 6 sessions wages start out to be identical for both investment levels. However, at the end of the sessions there is clear separation of wages and investment levels in all sessions (least in SIG2, session 1). In the screening sessions, there is complete separation of investment decisions right from the beginning in 4 out of 6 sessions. Wages are clearly separated in 3 out of 6 sessions in the beginning (but not in the two sessions without separation of investment decisions). At the end of the screening sessions, separation has occurred in 5 out of 6 sessions. The only session where no clear separation of types emerges is session 2 of SCR3. Thus, behavior conforms more closely to the separating equilibrium in the signaling game where all session lead to a separation of types than in the screening game. This is somewhat surprising from a theoretical point of view as there are multiple equilibria only in the signaling version.

On the left-hand sides of Figures 7 and 8 in Appendix C, the investment behavior at the individual level is shown for each of the four treatments. For each subject the graph shows the investment rate as a *high* type on the vertical axis and the investment rate as a *low* type on the horizontal axis. One subject's combination of two investment rates (averaged over periods 25-48)[13] is represented by a circle. If there is one or more petals in the circle, this indicates that accordingly more individuals have the same pair of investment rates. From the figures it is evident that many subjects invest more often as a *high* than as a *low* type, and a considerable fraction perfectly conforms to the separating prediction. In total, 54 out of 126 subjects always invest when they are the *high* type and they never invest when they are the *low* type. This clear-cut behavior by so many subjects is strong support for the separating equilibrium prediction. A small number of subjects (17 in total) never invest, suggesting pooling behavior. The remaining subjects often do not invest when they are a, *low* type and invest with a probability smaller than one when they are a *high* type.

In the same manner, we graph wage-setting behavior at the individual level on the right-hand sides of Figures 7 and 8 in Appendix C, again separately for the four treatments and using

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[13]Here we report results from the second half of the experiment (rather than the last block) to have data for each subject.

the data from the second half of the experiment. The average wage offered by a subject when $s=1$ is on the vertical axis and the average wage offered when $s=0$ is on the horizontal axis. The vast majority of subjects (93 out of 126) offers a strictly higher wage for investing workers, that is, their circle is above the $45°$-line in Figures 7 and 8. Regarding absolute wage levels, behavior is quite dispersed but an average wage of 10 for non-investing workers appears to be modal. This supports the separating equilibrium prediction while the support for the pooling of wages is weak: only four subjects offer the same average wage regardless of the investment decision. We summarize

Result 5 *Session and individual level data overall indicate the separating of types.*

4.3   Discussion

To summarize, our results roughly support the separating equilibrium prediction. *High* and *low* types of workers clearly behave differently in their investment behavior, and employers reward investing workers with higher wages. Also, there is tough employer competition leading to zero net profits as predicted.

A number of observations are not consistent with the theory. Investment rates of *high* types of workers are below 100%, and it is fairly evident that separation of *high* and *low* types is incomplete. Wages do not perfectly conform to the predicted levels of 10 and 50 either. For this reason, Result 3 concerning profits of *high* and *low* types turned out to be not significant. Furthermore, Table 2 shows that employers earn higher profits when employing workers who invested.[14] This is not in line with the separating equilibrium.

These observations are mutually consistent, and they indicate that a small amount of noisy behavior is present. Given that some *high* types do not invest, a wage higher than the predicted wage of 10 following no investment seems plausible. On the other hand, given that some *low* types invested early in the game (and very few even towards the end), it also seems reasonable that employers offer less than the separating equilibrium bid of 50. In turn, some *high*-type workers experience that their investment does not pay. This might induce them to refrain from investing in later periods.

It seems that path dependence might explain the persistence of *high* types who do not always invest although, ex-post and on average, it pays to do so. By contrast, the investment never pays for a *low* type, which explains why the *low* types' investment rates are close to the predicted

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[14]This is significant in treatments SIG2, SCR2, and SCR3 at the 10% level.

level of zero in the last periods of the experiment. A second explanation for too little investment by *high* types could be that subjects do not only maximize own payoffs. Recall that investment is purely wasteful here. Subjects often exhibit a preference for efficiency (see Charness and Rabin, 2002), which might explain why some of them are reluctant to invest.

In the following, we present the results regarding our treatment variables, that is the number of employers and the order of moves. Let us start with the effect of having three rather than two employers.

4.4   The Effect of Increased Employer Competition

Figure 1 displays the results of treatment SIG2 (normal lines) and SIG3 (bold lines). The two bold lines in the right panel of Figure 1 representing wages paid in treatment SIG3 are both shifted upwards compared to the lines representing treatment SIG2. Workers who did not invest received on average 7 points less in SIG2 compared to SIG3. A worker who invested received 32.55 points in SIG2 whereas he received 41.1 points with three employers. This difference is significant for *high* worker types only. Thus, wages are higher with three employers than with two for both investment decisions. As a result, adding a third employer reduces employer profits in the signaling game (this is significant for *high* worker types).

Regarding investment decisions there is no significant difference between the signaling treatments with two and three employers.[15] In the left panel of Figure 1 there are no apparent differences. Summarizing the comparison of SIG2 vs. SIG3, we find

Result 6 [SIG2 *vs.* SIG3] *Increasing the number of employers significantly increases wage bids for workers who invested but does not significantly change investment behavior. Furthermore, when there are three employers, workers who invested benefit significantly whereas employers hiring those workers earn less.*

The result of increased wages is not predicted, but confirms the results in Fouraker and Siegel (1963) and Dufwenberg and Gneezy (2000). Since wages after both investment decisions increase, it is not surprising that there is no secondary effect on investment decisions.

Now consider the screening sessions of the experiment and refer to Figure 2, which shows both the results from SCR2 (normal lines) and SCR3 (bold lines). Competition of three versus two employers does not seem to influence behavior substantially. Thus, we have

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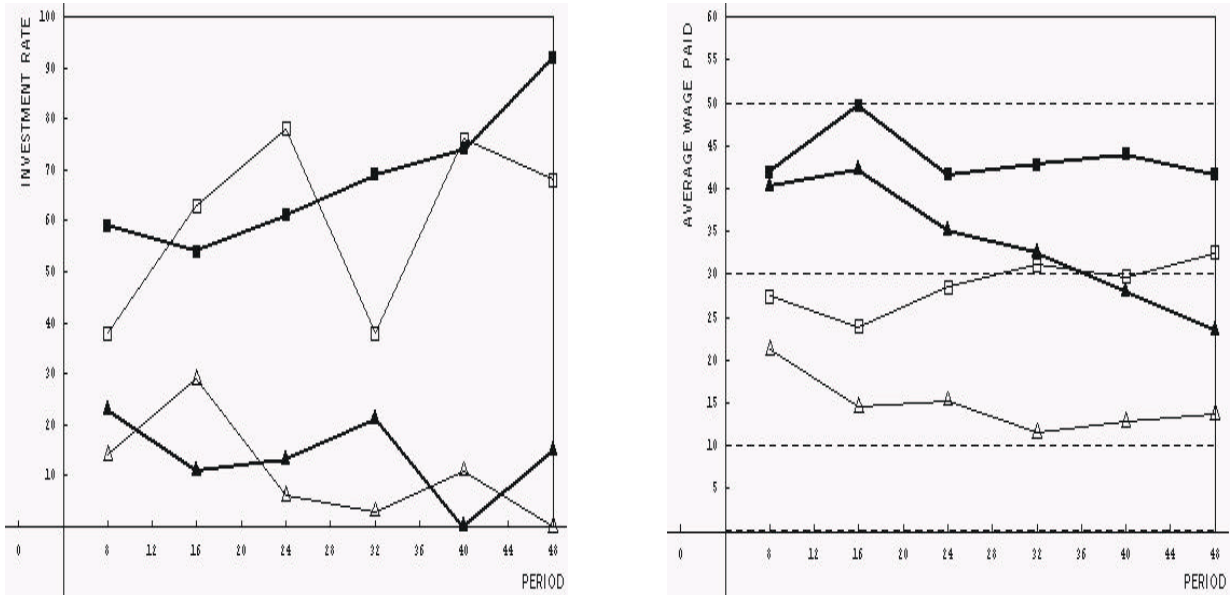[15]For the statistical tests we again use the results of the last block of the experiment.

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Figure 3: SIG2 (normal lines) vs. SCR2 (bold lines). Left panel: investment rates, triangles indicate *low* types, squares indicate *high* types. Right panel: average wages paid, triangles indicate wages if $s=0$, squares indicate wages if $s=1$.

Result 7 [SCR2 *vs.* SCR3] *Increasing the number of employers in the screening game causes no significant effects.*

4.5 Signaling vs. Screening

Finally, we compare behavior in the signaling and the screening experiments. Figure 3 shows the signaling and screening sessions with two employers while Figure 4 displays the results with three employers. It can be taken from Figure 3 that while investment rates in the signaling and screening treatments with two employers are similar, wages of workers are clearly higher in the screening sessions. However, these wage differences disappear when competition is increased to three employers, and Figure 4 does not reveal any differences in investment behavior towards the end of the experiment.

Statistical tests on the basis of the last eight (six) rounds of the experiment yield:

Result 8 [SIG2 *vs.* SCR2] *In the screening treatment, both types of workers earn significantly higher wages, high types of workers earn significantly higher profits, and employers earn significantly lower profits when employing either type of worker. Investment rates do not differ significantly.*
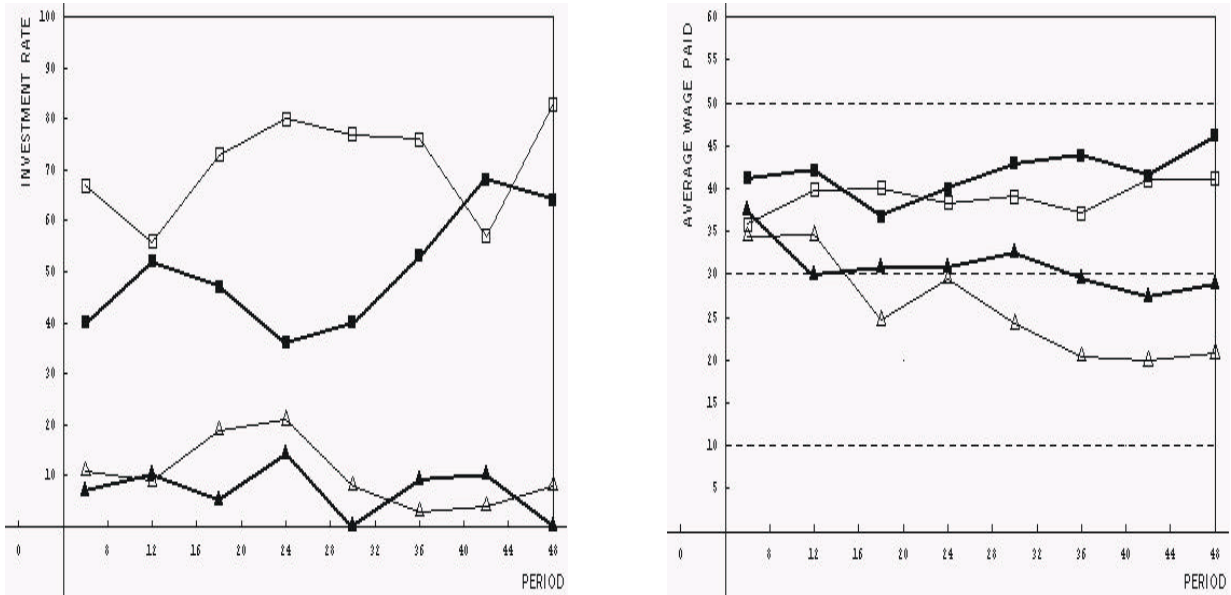
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Figure 4: SIG3 (normal lines) vs. SCR3 (bold lines). Left panel: investment rates, triangles indicate *low* types, squares indicate *high* types. Right panel: average wages paid, triangles indicate wages if $s=0$, squares indicate wages if $s=1$.

Result 9 [SIG3 *vs.* SCR3] *There are no significant differences between signaling and screening with three employers.*

To summarize, adding a third employer only has an effect on the market outcome of the signaling treatments which is driven by the relatively low wage levels in SIG2. One explanation for the low wage in SIG2 is that the signaling game facilitates collusion among two employers compared to the screening game. In the signaling game, employers choose a wage offer *after* observing the investment choice by the worker. In contrast, in the screening game employers offer a menu of wages for *every possible* investment level. The decision task in the screening games is similar to the task in sequential-move experiments where the so-called strategy method is employed. With the strategy method, subjects are asked to specify a response for every possible choice of the first mover—as opposed to responding only to the actual choice of the first mover. Previous experimental findings suggest that the strategy method leads to less cooperation between players, which is consistent with the results described here.[16]

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[16]See Kübler and Müller (2002) who analyze a price-leader/follower game with the strategy method.

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5 Conclusion

We analyze both a signaling and a screening variant of the Spence education game, and we investigate the effect of increasing the number of employers from two to three. In all four treatments of the experiment, we find a strong tendency to separate. Less efficient types of workers only rarely make the costly investment while the more efficient types usually do. Consistent with this finding, there is a significant wage spread, and workers who invest earn significantly more than those who do not invest. These main findings are supported in all four treatments at the aggregate level but also at the session and the individual level. Taken together, these findings strongly support the separating equilibrium prediction. An implication of this is that both signaling and screening can be used by employers as fairly effective sorting devices.

The separation of types is not complete in our data, and this leads to a number of findings inconsistent with the separating equilibrium prediction. In particular, the wage spread is smaller than predicted and investment behavior does not signal a worker's type perfectly. This can be explained with some noisy behavior at the beginning of each session which leads to a persistent pattern of less than full separation. As in previous signaling experiments, path dependence is an important aspect of behavior, given the prominent role of beliefs about other players.

The comparison of signaling and screening with two and three employers suggests that signaling and screening institutions work similarly if there is enough competitive pressure between employers. With two employers, signaling is less competitive than screening. With three employers, the two institutions do not differ and hence welfare and efficiency are statistically the same. Though sessions with two employers are less competitive in terms of wages, we find no evidence that adding a third employer leads to more investment in education.

These results indicate that, with sufficiently intense competition, it does not matter for the outcome whether the informed or the uninformed party moves first. When competition is weak, workers would prefer to be screened while employers would prefer job candidates to move first and signal their type.

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Appendix A: Proofs

This Appendix contains the proofs of the statements in the theory section above. Start with the separating equilibrium. To see that (4) is a perfect Bayesian equilibrium, note that for both worker types it does not pay to mimic the other type's behavior: If the *low* (*high*) type deviates by choosing $s = 1$ ($s = 0$), she earns a payoff of $50 - 45 = 5$ ($10 - 0 = 10$), given the employers' strategy and beliefs. The deviation payoffs are smaller than both types' equilibrium earnings. Now consider the employers' incentive to deviate. Given the other employer's strategy, it does not pay for an employer to offer a smaller wage as she would lose the worker to the other employer for sure, implying an expected payoff of 25. A deviation to a higher wage after observing some signal (say, to $50 + \varepsilon$ after signal $s = 1$) is not optimal either since this yields a payoff of $25 - \varepsilon < 25$. Thus, deviation does not pay for employers either.

To see that the pooling equilibrium (3) is a perfect Bayesian Nash equilibrium, consider first the incentive for the two types of the worker to deviate. If the *low* type of the worker deviates by investing in education, she realizes payoff $30 - 45 = -15$ whereas the *high* type gets $30 - 9 = 21$. For both types, this is smaller than what the worker earns by playing according to (3). Next consider an employer's incentive to deviate. If one employer offers a wage lower than 30, she does not hire the worker in which case her expected payoff is 25, too. If she deviates to a wage $w = 30 + \varepsilon$, $\varepsilon > 0$, she does hire the worker for sure but earns only $0.5 \times [25 + 10 - (30 + \varepsilon)] + 0.5 \times [25 + 50 - (30 + \varepsilon)] = 25 - \varepsilon < 25$. Thus, deviation doesn't pay for employers either and we have a perfect Bayesian Nash equilibrium.

The pooling equilibrium (3) does not survive the application of Cho and Kreps' (1987) "intuitive criterion." Consider the out-of-equilibrium beliefs in this equilibrium, i.e., the belief of the employers after observing an investment ($s = 1$): Employers believe that each type of the worker is equally likely. This belief, however, is not "intuitive". To see this, recall that the *low*-ability type of the worker earns payoff 30 in equilibrium. The highest possible payoff this type could possibly earn by deviating to investing is $60 - 45 = 15 < 30$ (if an employer offers the highest possible wage). Thus, the *low*-ability type of the worker can under no circumstances gain from a deviation. On the other hand, the *high*-ability worker, who earns 30 in equilibrium, can potentially earn up to $60 - 9 = 51$ if he deviates by investing in education. Therefore, the only reasonable belief p of the employers after observing $s = 1$ should be one, i.e., $p = Prob(a = high \mid s = 1) = 1$. This belief, however, destroys the pooling equilibrium (3). The reason is that with this new belief employers

would optimally offer a wage of 50 after the signal $s = 1$ which would cause the *high*-ability type of the worker to deviate.

It is easy to see that no other equilibria exist. Pooling with $s(low) = s(high) = 1$ is not incentive compatible for the *low*-ability type. The pooling wage would be 30 again in this equilibrium which does not cover the *low*-ability type's investment cost of 45. Deviating to no investment yields a non-negative profit no matter how the deviation is interpreted. Similarly, $s(low) = 1$, $s(high) = 0$ cannot be an equilibrium either. Hybrid equilibria where one of the worker types randomizes between investment and no investment can also be ruled out. For the sake of brevity, let us only consider two possible candidates. To see that the *high* type choosing $s = 1$ and the *low* type randomizing between $s = 0$ and $s = 1$ with $r = Prob(s = 1) \in [0, 1]$ is not an equilibrium, note that the equilibrium wage after an investment is $0.5(50 + 10r)$. For the *low* type to be indifferent between investment and no investment, we must have: $10 = 0.5(50 + 10r) - 45$, which leads to a contradiction. Similarly, consider the possibility that the *low* type never invests and the *high* type randomizes between $s = 0$ and $s = 1$ with $z = Prob(s = 0) \in [0, 1]$. The equilibrium wage after no investment is $0.5(10 + 50z)$, and the indifference condition for the *high* type becomes $50 - 9 = 0.5(10 + 50z)$, which cannot be satisfied.

Regarding the separating equilibrium of the screening variant, consider that both employers can directly target *high* and *low* types, and perfect wage competition leads to wage increases up to a level where employers break even: $w(0) = 10$, $w(1) = 50$. The worker simply chooses the payoff-maximizing education level which is $s(low) = 0$ and $s(high) = 1$. Employers' posterior beliefs are irrelevant as they move first. There is no pooling equilibrium here because if one employer tried to offer the pooling wage, the other employer would successfully target the high types by offering them slightly more than that wage.

Appendix B: Instructions (for treatment SIG2)

Please read these instructions closely! Please do not talk to your neighbours and remain quiet during the whole experiment. If you have a question, please raise your hand. We will come up to you to answer it.

In this experiment you can earn varying amounts of money, depending on which decisions you and other participants make. Your earnings in the experiment are denoted by points. In the beginning of the experiment, every participant receives 200 points as an initial endowment. Your total payoff at the end of the experiment is equal to the sum of your own payoffs in each round plus your initial endowment. For every 150 points you will be paid £1.

Description of the experiment

In the experiment, three participants interact with each other: one participant in the role of an employee and two participants in the role of employers. The employee can be of "type 1" or of "type 2". The experiment consists of several rounds, and at the beginning of each round, a random draw determines the employee's type. The random draw is such that both possible types of employee ("type 1" or "type 2") are equally probable to be drawn (50:50). After the random draw, the employee is informed about his/her type. However, the employers are not informed about the type of the employee.

Knowing his or her type, the employee has to decide whether or not he/she wants to make an investment. The costs of the investment depend on the employee's type: The investment cost of an employee of type 1 is 9 points and the investment cost of an employee of type 2 is 45 points. After the employee's investment decision, the employers are informed about whether the employee has made an investment or not. Knowing the investment decision of the employee, the two employers simultaneously decide which wage they want to offer the employee. They can choose a wage between 0 and 60 points (if desired, up to two decimal places).

Given the two wage offers of the employers, the employee is hired by the employer who offered the higher wage. (If both employers make the same wage offer, the computer decides randomly and with equal probability which of the two employers hires the employee.)

It is important to understand that the profit of the employer who hires the employee depends both on the wage offered and on the employee's type, but not on the investment decision. This is explained in the following section.

Payoffs

The payoff of the employee at the end of each round is given as follows:

- If the employee has not invested, he/she is paid the higher wage offer, independently of his/her type.

- If the employee has invested, his/her payoff depends on the type:

  - If the employee is of type 1, his/her payoff is: higher wage offer minus 9 points.
  - If the employee is of type 2, his/her payoff is: higher wage offer minus 45 points.

The payoff of the employer, who hired the employee, depends on the employee's type:

- If the hired employee is of type 1, the employer's payoff is: 50 points minus wage offer.

- If the hired employee is of type 2, the employer's payoff is: 10 points minus wage offer.

In addition, both employers (that is, also the employer who did not hire an employee) receive a payoff of 25 points in every round.

Please note that the employer who has hired the employee makes losses if the wage offer is greater than 50 and the employee is of type 1 or if the wage offer is greater than 10 and the employee is of type 2.

Please note also that the employee makes losses if the cost of investment (in case an investment has been made) is higher than both wage offers. That is, an employee of type 1 makes losses if he/she invests and the higher wage offer is below 9 points, and an employee of type 2 makes losses if he/she invests and the higher wage offer is below 45 points.

To give you a clearer sense of the rules, the timing of events can be summarized as follows:

1. The computer randomly determines the employee's type. With a 50% probability the employee is either of type 1 or of type 2. After the random draw, the employee is informed about his/her type, but the employers are not informed about it.

2. The two employers simultaneously decide on their individual wage offer (a number from the interval of 0 to 60).

3. The employee is automatically hired by the employer who made the higher wage offer. If both employers make the same wage offer, a random draw (50:50) decides which employer hires the employee.

4. The payoffs are given as described above.

Number of rounds and role assignment

The experiment consists of 48 rounds.

You will have to make decisions both as the employer and as the employee, alternating in the following way: The roles of all participants are randomly determined for 8 consecutive rounds. After 8 rounds new roles are assigned to all participants that remain in place for another 8 rounds. For example, a participant who had the role of the employee for the past 8 rounds, will have the role of the employer for the next 16 rounds (if the experiment is not over before this). Your computer screen shows you in every round which role you have in that round. At the end of each round, you are informed about the employee's type, the wage offers, and the payoffs of all three participants.

Please notice that in every round the groups of 3 players are randomly matched from the pool of all participants. We secure that it is always one employee and 2 employers who form one group.

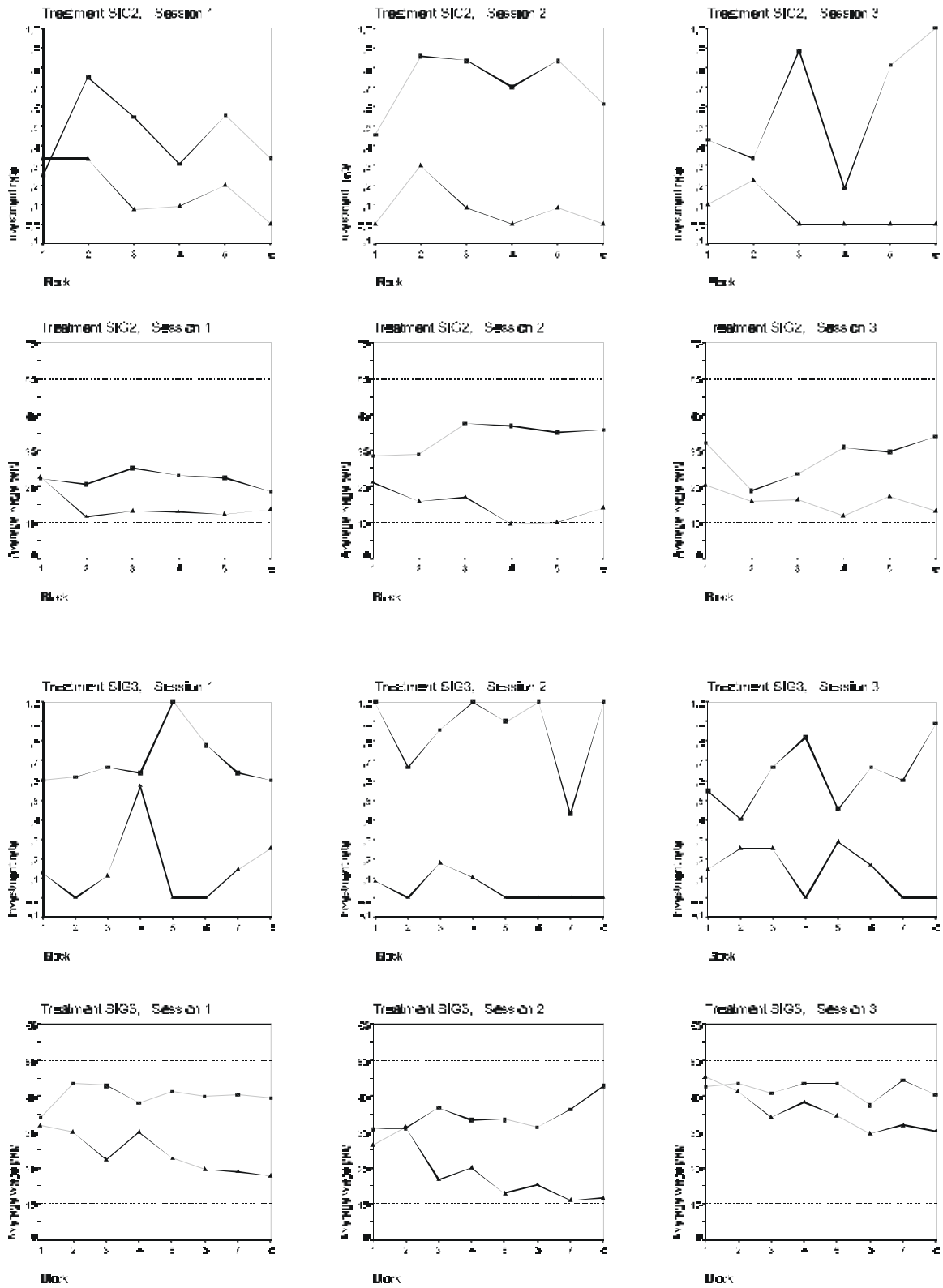# Appendix C: Session and individual data

Figure 5: Results in the signaling sessions. (Investment behavior of high (low) types of workers and employers' wage offers after (not) observing investment are indicated by ■ (▲)).
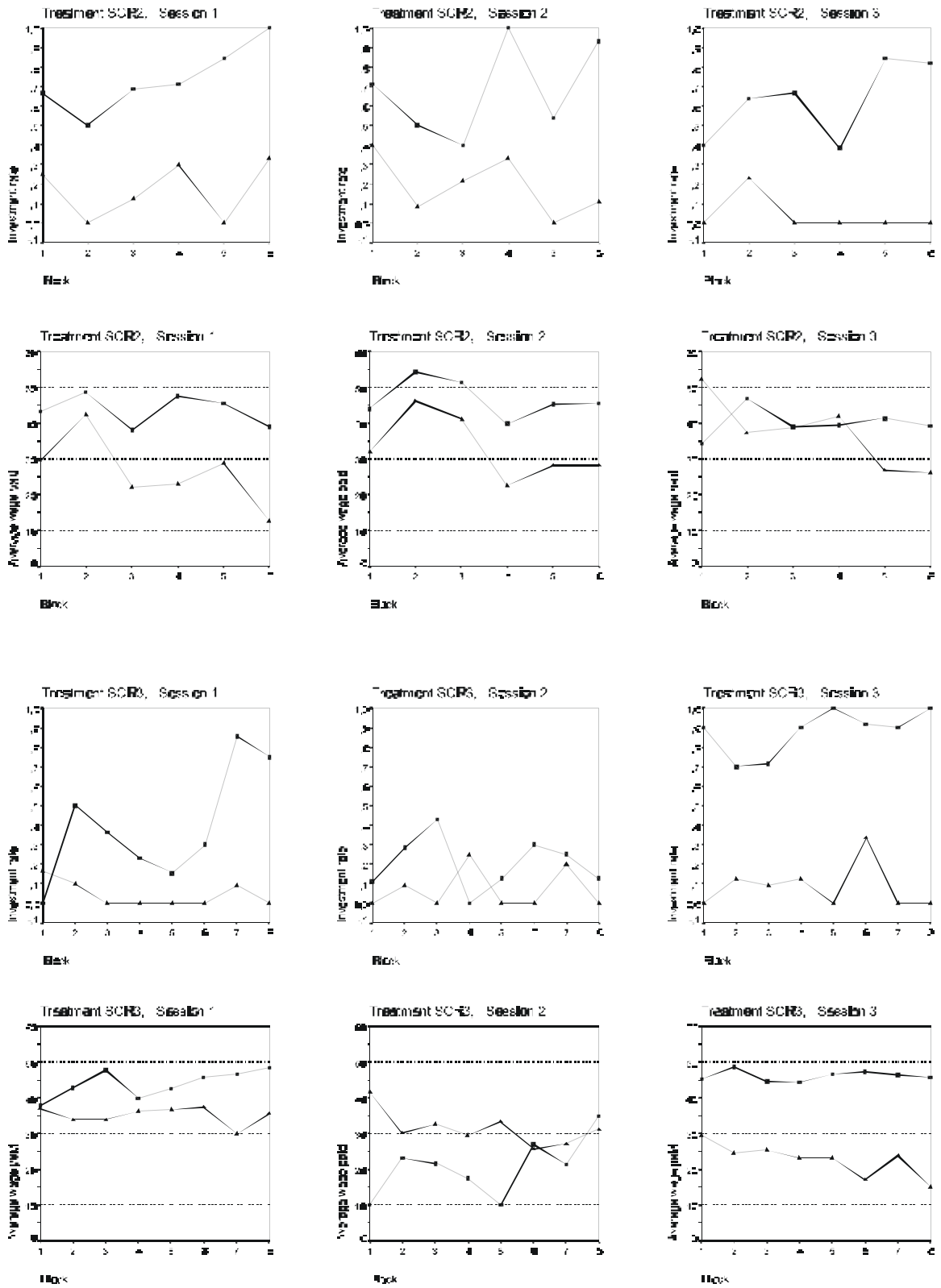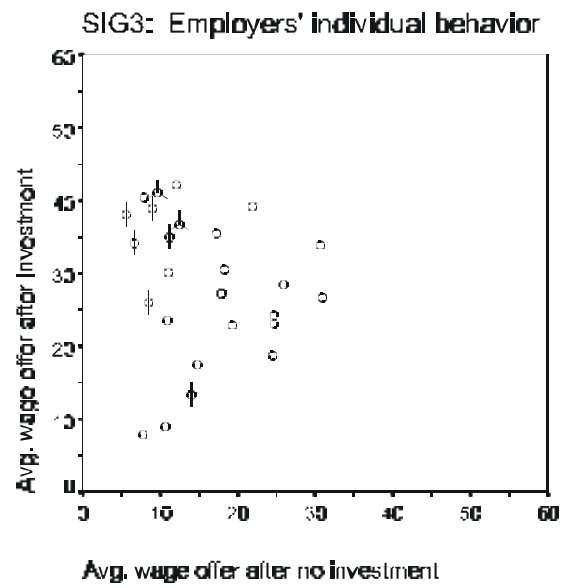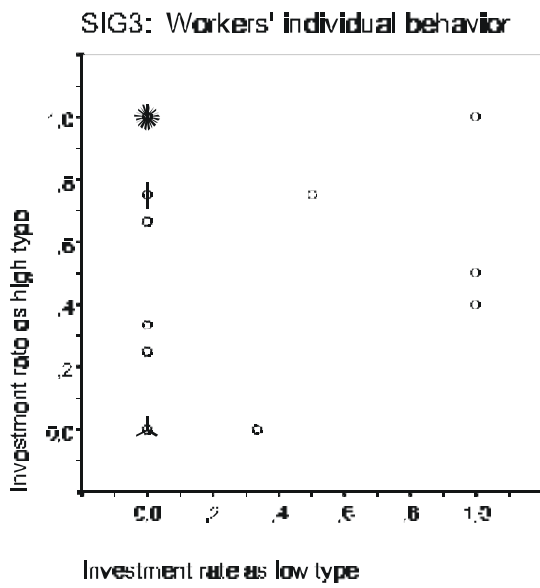
Figure 6: Results in the screening sessions. (Investment behavior of high (low) types of workers and employers' wage offers after (not) observing investment are indicated by ■ (▲)).
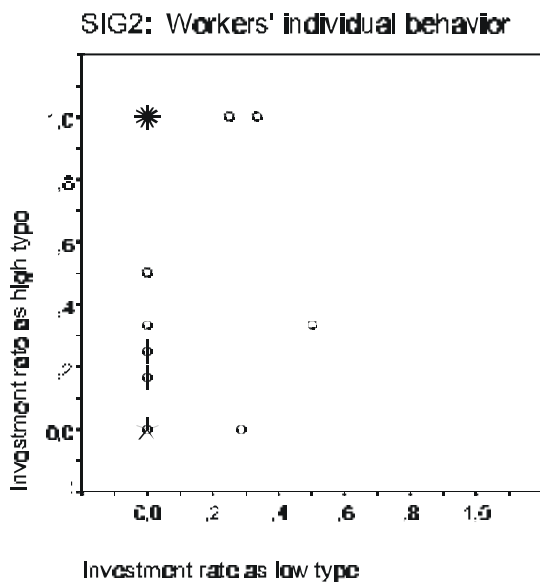
Figure 7: Individual data: Signaling treatments (Note: Number of petals in a sunflower indicates the number of observations.)
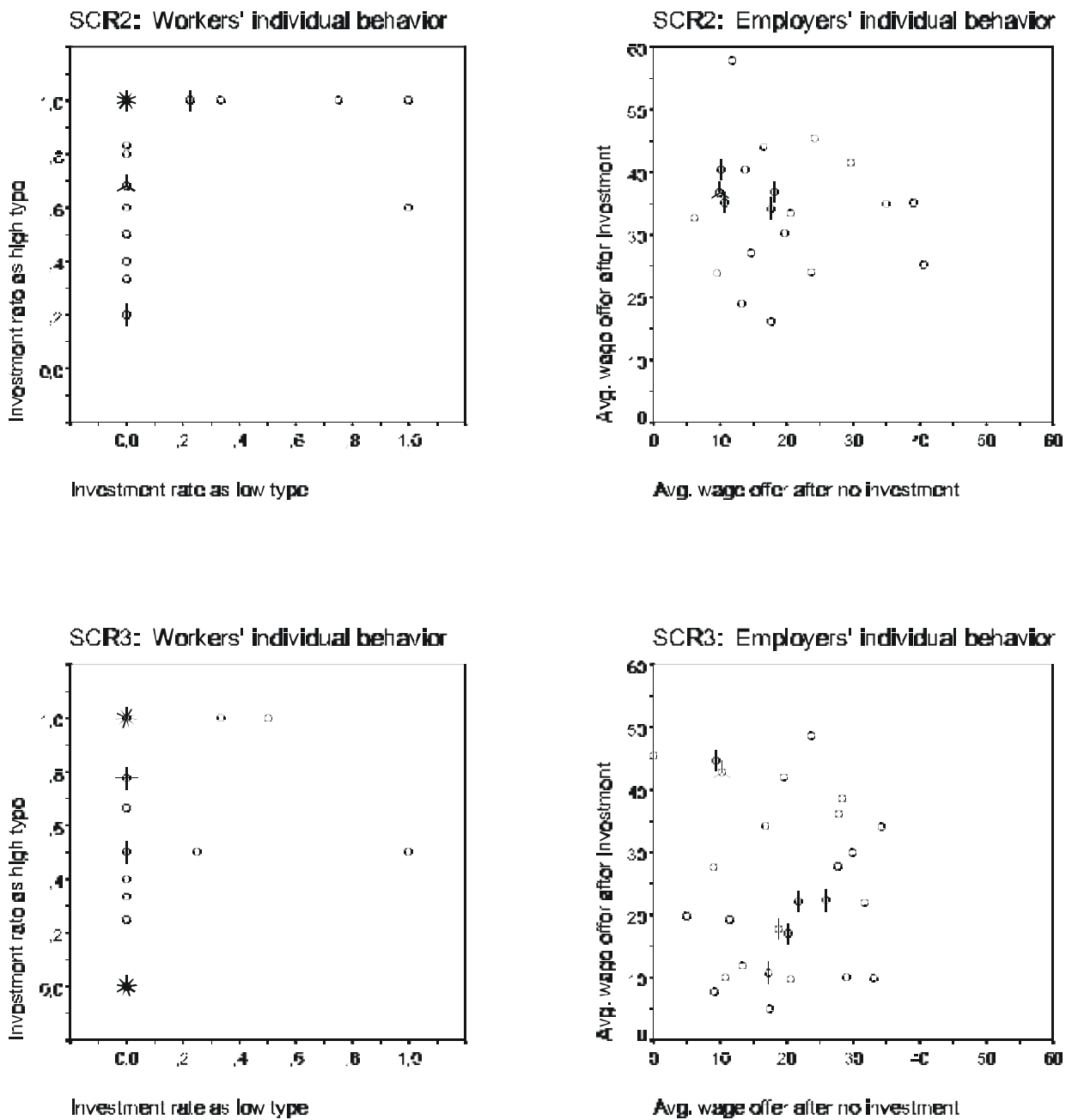
Figure 8: Individual data: Screening treatments (Note: Number of petals in a sunflower indicates the number of observations.)