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ABSTRACT

Job Market Signaling and Screening: An Experimental Comparison*

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 competing employers from two to three. In all treatments, more efficient workers invest more often in education and employers offer higher wages for workers who have invested. However, separation is incomplete, e.g., investment does not pay on average for efficient worker types. Increased competition leads to higher wages in the signaling sessions, not with screening. In the signaling version, we observe significantly more separating outcomes than in the screening version of the game.

JEL Classification: C35, I2, J24, P3, P52

Keywords: job-market signaling, job-market screening, sorting, Bayesian games, experiments

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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. He studies investments in education which have no productive value and no intrinsic value either in a labor-market context. The reason workers may nevertheless invest in 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. 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.[1]

Another treatment of asymmetric information is screening. In contrast to the signaling model, the screening model assumes that the uninformed party moves first and offers a menu of contracts from which the informed party can choose and thereby reveal its type. In the screening variant of the Spence game (e.g., Rasmusen, 1994), the employers move first by offering wages contingent on the investment decision. Moving second, the workers then decide on their investment in education.[2]

We use Spence's education game both in its original signaling version as well as in a setup with screening by the employer in order to analyze experimentally whether institutional changes cause differences in results, i.e. how outcomes are affected by the order of moves. We design markets such that education has no direct value for the workers nor the employers. Investing in education is socially inefficient. In the signaling treatments of the experiment, we study whether or not signaling occurs and which factors facilitate it. In particular, we look at a situation with one pooling and

[1] 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 (1979), 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.

[2] This model captures for example the situation of job candidates who know what salary they get with and without college education and then decide whether or not to go to college.

one separating equilibrium, where only the separating equilibrium satisfies Cho and Kreps' (1987) intuitive criterion. In contrast to the signaling environment where multiple equilibria exist, the screening game has only one equilibrium with full separation of types. This screening equilibrium leads to identical wages and investments as the separating equilibrium of the signaling game.

For both signaling and screening games, we analyze the impact of competition on the market outcome. Employer competition is an essential part of the Spence model—in contrast to many signaling models with a single responder. In our experiments, we implement competition with two or three employers who bid for the worker in wage competition à la Bertrand. This oligopoly setting predicts the same outcome as a market with many employers. And as a result of competition, employers (receivers) get the same expected profits across different equilibrium outcomes. Theoretically, increasing the number of employers from two to three has no impact on the market outcome, but this may not hold empirically (Fouraker and Siegel, 1963; Dufwenberg and Gneezy, 2000). For example, the study of Dufwenberg and Gneezy (2000) shows that the Bertrand solution does not predict well with two firms, but predicts well when the number of firms is three or four. We check whether their result remains valid in situations with asymmetric information.[3]

Our main findings are as follows. Efficient workers (*high* ability types) invest more frequently than inefficient workers (*low* ability types) and employers make higher wage bids when workers invest. However, the data do not conform fully to the theoretical predictions of the separating equilibrium. In particular, not all *high* types invest in education. And we observe that it does not pay for *high* types of workers to invest as wages are too low. Increasing the number of employers from two to three leads to higher wages in the signaling sessions but not in the screening sessions. Investment behavior does not differ across the four treatments. When focusing on outcomes as combinations of wages and investments, we find significantly more separating behavior with signaling than with screening. It will be shown below that these observations are mutually consistent and can be explained with path-dependent behavior and loss aversion.

Previous experiments on signaling games suggest that the equilibrium concept has some explanatory power, but that refinements cannot reliably predict which equilibrium players coordinate on.[4] None of the experiments is based on Spence's education game, so we present the first study

[3]There are two other signaling experiments (Cadsby, Frank, and Maksimovic, 1998, and Miller and Plott, 1985) with receiver competition, but neither of them systematically varies the number of receivers.

[4]Signaling experiments include Miller and Plott (1985), Cadsby, Frank and Maksimovic (1990, 1998), Brandts and Holt (1992, 1993), Cooper, Garvin and Kagel (1997a,b), Potters and van Winden (1996), as well as Cooper and Kagel (2001a,b). Cooper, Garvin and Kagel. (1997b, p. 553) conclude that the "[e]xperiments have raised serious

focusing on this widely used model.[5] Also, screening has not yet received much attention by experimentalists, therefore the screening treatments are of some stand-alone interest.[6] But our main focus is the comparison of signaling and screening in a unified experiment. We use two different competitive environments to study the interaction between separation of types and competition.

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 present the simple model underlying the experiments and derive the game-theoretic predictions. We provide the results for the model with one worker and two employers—this is the standard textbook variant of the Spence model. 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.

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

4. The employer who offered the higher wage hires the worker. If there is a tie, a fair random draw decides which employer hires the worker.

5. Payoffs are as follows:

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

doubts about the validity of equilibrium refinements."

[5] The sender-receiver game with two messages and and two actions used in Brandts and Holt (1992) can be given a labor market interpretataion although strategies and equilibrium outcomes differ from the standard Spence game.

[6] Screening has been studied experimentally in various setups different from ours by Berg, Dickhaut and Senkow (1987) as well as Shapira and Venezia (1999) and Posey and Yavas (2004). While the first two papers find relatively little support for the screening model, the third paper observes strong separation of types in the screening context.

where w equals the higher of the two wage offers.

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

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 flat payment plus the difference between the worker's ability and the wage. The non-hiring employer receives the flat payment only.[7] The cost of education is $450/10 = 45$ for the *low* type and $450/50 = 9$ for the *high* type of the worker. Note 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.[8] Let us start with the

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

In this equilibrium, both types of 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

[7] 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.

[8] In the appendix, we show that no other equilibria exist. The pooling equilibrium is only unique on the equilibrium path but there can be many out-of-equilibrium beliefs supporting the equilibrium of course.

who chooses $s = 1$ has *high* ability with the prior probability 0.5. In this equilibrium, both types of worker earn a payoff 30 whereas both employers earn an expected payoff consisting only of the fixed payment of 25 (for a proof of the equilibrium, see 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

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

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 the 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 (for the 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 the two contingencies. In the 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 (Cho and Kreps, 1987), the pooling equilibrium can be eliminated. The screening model, both with two and three employers, has a unique separating equilibrium outcome that coincides with the one in the signaling model. Thus, both signaling and screening are predicted to lead to the same wages, investment choices and profits if the intuitive criterion is applied.

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

We applied role switching in the experiment, that is, participants were both in the role of the worker and in the role of the employer. This was done for two reasons. First, role switching enhances learning. Subjects better understand the decision problem of the other players and therefore the overall game if they play in both roles. Second, role switching emphasizes the one-shot nature of interaction and therefore strengthens the effects of the random matching scheme.[9]

All sessions lasted 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. We informed only the workers about their individual types but not the employers. In the signaling game, workers then had to decide whether or not they wanted to make an investment.[10] 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 highest wage offer (possibly after a random computer draw if there was a tie).[11] 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. Workers were informed only about the higher wage for each of the two cases only. Then the worker made her investment decision. Finally, the worker was hired by the employer with the highest wage bid given the investment decision.

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

[9] Most signaling experiments employ role switiching in order to speed up learning. See Brandts and Holt (1992, 1993), Cooper *et al.* (1997a,b), Potters and van Winden (1996). In a non-signaling context, Sloof *et al.* (2003) use role switching.

[10] Post-experimental questionnaires reveal that subjects understood that the investment per se had no value.

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

round and own accumulated profit.

Experiments were computerized[12] 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, leading to an average hourly wage above local student wages.

4 Results

4.1 Aggregated data

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 (that is, averages of all wage offers observed) as well as average wages paid (that is, averages of winning wage bids).

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.[13] We use White (1980) robust standard errors which are adjusted for possible non-independence of observations within sessions.[14] For the regressions, we restrict attention to decisions from the *last*

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

[13] For example, to test whether employers in a signaling 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 σ_i^2.

[14] Observations might not be independent because of the random matching of subjects within sessions. We account

Treatment	Rounds	Investment rate if worker's type is		Employers' wages paid for the case of	
		low	*high*	*no investment*	*investment*
Sig2	First Block	.14	.38	21.24	27.53
		(0.10)	(0.06)	(0.64)	(2.83)
	Last Block	**.00**	**.65**	**13.57**	**29.38**
		(0.00)	(0.19)	(0.26)	(5.52)
Sig3	First Block	.12	.72	34.41	35.81
		(0.02)	(0.14)	(5.62)	(3.58)
	Last Block	**.08**	**.83**	**19.84**	**40.89**
		(0.08)	(0.12)	(5.44)	(0.96)
Scr2	First Block	.22	.59	37.96	40.51
		(0.12)	(0.10)	(7.22)	(3.18)
	Last Block	**.15**	**.92**	**22.27**	**41.3**
		(0.10)	(0.05)	(4.92)	(2.18)
Scr3	First Block	.05	.34	36.09	31.03
		(0.06)	(0.28)	(3.54)	(10.74)
	Last Block	**.00**	**.62**	**27.31**	**43.04**
		(0.00)	(0.26)	(6.24)	(4.08)

Note: Averages of session averages. Standard errors of the mean 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*.

Table 1: Summary of experimental results: Average investment rates and average wages paid.

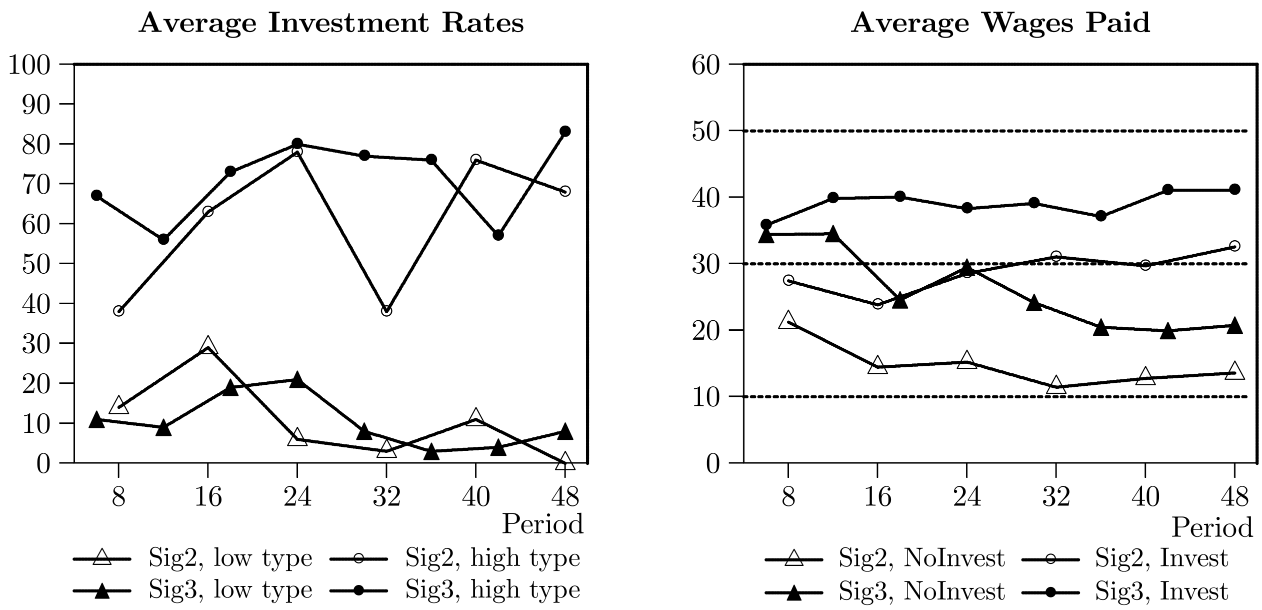

Figure 1: Evolution of investment rates and wages paid in treatments SIG2 and SIG3

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.[15] We will comment on the results of the first rounds of play in section 4.3.In Appendix C we provide details on the regression specifications for each of the results stated and the exact p-values.

First we present a number of general results which hold across all four treatments (Results 1 to 3) and for three of the four treatments (Results 4 and 5). Here, we test the comparative static implications of the theory (tests of point predictions will be reported in Subsections 4.4 and 4.5).

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 5% level. Table 1 indicates that theses differences are also quantitatively substantial. *Low* types invest less often in education, and their investment rate is close to zero towards the end of the experiment. This indicates that the two different types tend to separate themselves by their investment choice. This can be seen in Figures 1 and 2. Figure 1 shows the evolution of the average investment

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).

[15]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.

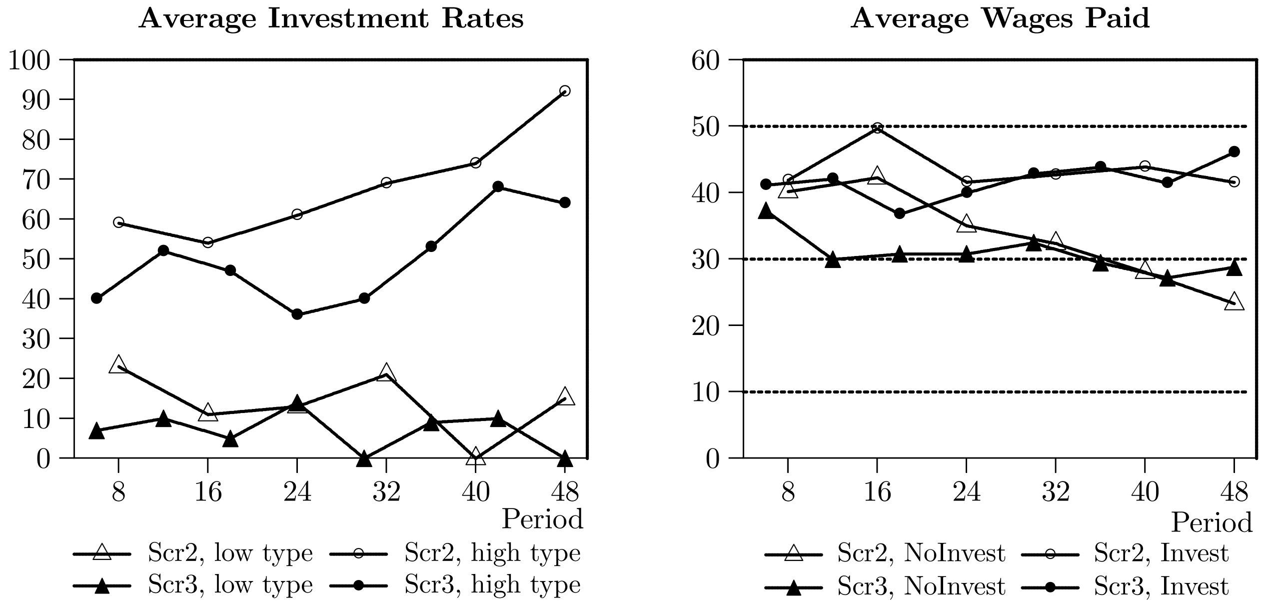

Figure 2: Evolution of investment rates and wages paid in treatments Scr2 and Scr3

rates over time for *high* 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. This effect becomes more pronounced over time. The *low* types' investment rate is negatively correlated with 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 explained by the fact that *low* types face a simpler task as they should never invest, independently 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 with time while earnings of workers who did not invest are negatively correlated with time.[16] 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 do not earn significantly higher payoffs than low types.*

For workers' payoffs, 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 on average *high* types earn more than *low* types as predicted, but this result is generally not significant, except in SIG2 (10% level). The differences fail to be significant because the separation of *high* and *low* types is not complete. In particular, many *high* types earn low wages because they do not invest (we will elaborate on this below). Moreover, the spread between wages paid to a worker who invested and a worker who did not invest is much lower than predicted by the separating equilibrium (see Table 1). Complementary to Result 3 we also find

Result 4 *High types of workers do not earn significantly more when investing compared to not investing.*

Result 4 is true with the exception of treatment SIG3 where *high*-type workers earn significantly higher wages than *low*-type workers. Notice that as stated before for the screening treatments, investment decisions of *high* types are optimal most of the time. And the net payoffs reported in Table 2 are always higher for *high* types than for *low* types. The result only establishes that the payoff differences are not significant.

Turning to employers' profits we find

[16] An exception occurs for SCR2 where earnings following an investment are slightly negatively correlated over time ($\rho = -0.075$).

Treatment	Rounds	Workers' payoff if the type is		Hiring employers' profit after employing a worker who did	
		low	*high*	*not invest*	*invest*
SIG2	First Block	14.62	21.63	6.31	12.95
		(5.87)	(1.89)	(2.31)	(4.83)
	Last Block	**12.92**	**20.52**	**4.42**	**20.62**
		(0.31)	(3.27)	(3.78)	(5.52)
SIG3	First Block	31.39	28.13	−13.50	8.47
		(5.80)	(4.24)	(3.20)	(3.58)
	Last Block	**18.39**	**29.73**	**−3.18**	**5.78**
		(6.07)	(2.71)	(7.09)	(2.76)
SCR2	First Block	30.14	36.74	−11.85	2.04
		(10.45)	(2.77)	(5.25)	(6.90)
	Last Block	**18.74**	**32.37**	**−9.01**	**4.48**
		(6.08)	(1.98)	(3.35)	(3.15)
SCR3	First Block	33.71	35.79	−13.33	5.64
		(3.52)	(1.60)	(0.926)	(19.56)
	Last Block	**25.50**	**37.49**	**−9.60**	**6.96**
		(5.20)	(3.86)	(4.70)	(4.08)

Note: Averages of session averages. Standard errors of the mean in parentheses. Predictions: in the pooling equilibrium both types earn 30; in the separating equilibrium *high* types earn 41, *low* types earn 10; employers earn zero throughout.

Table 2: Average payoffs of workers and average net profits of hiring employers.

Result 5 *Hiring employers' net profits are significantly higher when employing an investing worker than when employing a worker who has not invested.*

For the profits of employers who hired a worker, refer to Table 2. Employers are predicted to compete in a Bertrand fashion, leading to zero expected profits both in the pooling and the separating equilibrium independent of workers' type and investment decision. Table 2 indicates that, with the exception of treatment SIG2, hiring employers' profits are negative[17] when employing an non-investing worker whereas they are positive when employing an investing worker. Result 5 says that the difference in profits is usually (weakly) significant, except in treatment SIG3. This means that employer competition is softer after observing investment by a worker. We elaborate on the possible reasons for this finding in section 4.3. But we note already that Result 5 can provide an explanation for Results 3 and 4 in that investing workers receive relatively low wages, which implies lower profits for *high* types than predicted and sometimes even a disincentive to invest.

4.2 Session-level data

In this section we take a closer look at behavior at the session level. Using these data, we characterize behavior based on the point predictions of the theoretical analysis, i.e., we look at outcomes consisting of wages *and* investment behavior. Each of the four figures in Appendix D (Figures 5 to 8) illustrates behavior in one of the four treatments. Each row in a figure visualizes behavior in one of the three sessions for a given treatment. The first panel in a row shows average investment rates for *low* and *high* type workers; the second panel shows average wages paid, and the third panel traces the evolution of outcomes in a given session. In order to categorize outcomes we employ the following classification scheme. For this purpose recall that the investment decision is either $s = 0$ or $s = 1$ and that w denotes the wage paid to the worker.

"Sepa 0" (Separating by *low* type of worker): If worker's type = *low* & $s = 0$ & $w \leq 20$.

"Sepa 1" (Separating by *high* type of worker): If worker's type = *high* & $s = 1$ & $w \geq 40$.

"Pool 0" (Pooling by *low* type of worker): If worker's type = *low* & $s = 0$ & $20 < w < 40$.

"Pool 1" (Pooling by *high* type of worker): If worker's type = *high* & $s = 0$ & $20 < w < 40$.

[17] Recall that employers received a fixed payment of 25 in every period, but we report *net* earnings here. Negative profits may be due to the presentation of *total* earnings after each round on the screen, including the fixed payment of 25. Thus, employers did not see a negative number even if they made moderate losses.

"Other" All other outcomes.

Recall that the screening versions of the game have a unique separating equilibrium. Thus, in a strict sense outcomes in the screening version that resemble pooling should be labeled "Other." Nevertheless, also for the screening games we classify outcomes, if applicable, according to the above scheme that includes pooling outcomes. We do this for two reasons. First, as will become clear soon, many outcomes in the screening versions fall into this category. Second, it enables us to better compare results across the two versions of the game.

We devote some space to illustrate behavior on the session level. This is called for in the signaling game because averaging across different sessions possibly conceals outcomes consistent with either one of the two equilibria. For screening in experimental markets there is almost no data available in the literature such that it might be instructive to look at the evolution of behavior on the session-level in greater depth. Table 4 in Appendix D shows the shares of outcomes in the last block of the experiments separately for each session. In this table, a more detailed classification for the category "Other" is provided.

Consider first the behavior in the Sig2 sessions (Figure 5). We make some observations: (1) In all sessions there is a clear investment spread with 0% investment by low types in the last block. (2) In session 3 we observe 100% separating of the workers in the last block. (3) In all three sessions there is a clear wage spread. (4) After an adjustment phase, wages after no investment by workers are slightly above the separating wage of 10. (5) However, wages paid after the investment signal are closer to the pooling wage of 30 and thus distinctly below the separating wage of 50 . This behavior translates into a clear-cut result regarding outcomes: in all three sessions we mainly observe two outcomes: *low*-type separating outcomes (due to observations 1 and 4) and outcomes classified as "Other." The latter are mainly outcomes in which investing *high*-type workers are paid too low wages and—to a lesser extent—non-investing *high*-type workers are paid a *low*-type separating wage of about 10.

Next we study the behavior in the Sig3 sessions (Figure 6). We make the following observations: (1) With the exception of session 1 (where the spread in the investment rates shrinks in the second half) there is a clear trend towards (complete) separation of workers in the other two sessions. (2) In all three sessions wages start out to be identical for both investment levels. However, at the end of the sessions there is separation of wages. This is most pronounced in session 2 and less pronounced in session 3. (Note that in session 3 we observe the separation of workers at an increasing rate although the investment of the *high*-type worker hardly pays.) (3) In session

2 there is a clear trend towards complete separating. In fact, we observe about 90% separating outcomes in the last block. (4) In general, as compared to treatment Sig2 employers pay higher wages in treatment Sig3 after both signals.

Consider the behavior in the Scr2 sessions (Figure 7). Sessions 1 and 2 are quite similar. In both of these sessions there is an investment spread (with quite some investment by *low*-type workers) and a spread in wages paid. Session 3 is different. Here we also see a clear investment spread by workers from the beginning with *low* types usually not investing. This, however, is surprising as wages paid after no investment are initially higher than wages paid after investment. But after a number of rounds, the wage spread disappears. Only in the last two blocks, investing workers earn higher wages than non-investing workers with the result that the spread in investment rates increases to about 80%.

Finally, consider behavior in the Scr3 sessions (Figure 8). The sessions are very different from each other. In session 2 we observe clear convergence to pooling (with 90% pooling outcomes in the last block) despite the unique equilibrium prediction of separation. This comes out clearest in wages paid which converge towards the pooling wage of 30. But also the investment rate by *high*-type workers is usually below 30%. In contrast, in session 3 we see a clear convergence to the separating equilibrium (with about 85% separating outcomes in the last block.) Session 1 is somewhat in-between the other two sessions with a lot of *low*-type pooling and *high*-type separating outcomes.

4.3 Discussion of session-level data

To summarize, there is a fair amount of separating in almost all of the sessions. But separation occurs with varying degrees of completeness. There is full separation of worker types in the last block in three sessions (S3 in Sig2, S2 in Sig3, S3 in Scr3). Furthermore, there is almost complete separation of worker types (about 90%) in the last block in two sessions (S3 in Sig3 and S2 in Scr2). There is also separation in wages paid in all sessions, with the exception of session 2 in treatment Scr3.

However, a number of observations are not consistent with the separating equilibrium: (A) Investment rates of *high* types of workers are below 100%, and it is fairly evident that separation of *high* and *low* types is incomplete. (B) In no session do we observe wages converging to the levels predicted by the separating equilibrium. (Convergence to separating wage levels of 10 and 50 is closest in S2 in Sig3 and S3 in Scr3). (C) Result 5 shows that employers earn higher profits when employing workers who invested. This is neither in line with the separating equilibrium, nor with the pooling equilibrium of the signaling game.

In general, the observation of separating behavior that does not fully converge to the separating equilibrium is consistent with results of other signaling experiments.[18] But how can our specific results be explained? Note first that observations (A) and (B) are mutually consistent. Given that some *high* types do not invest, a wage higher than the predicted wage of 10 following no investment seems plausible. The fear of missing a "good catch" after observing non-investment leads employers to compete more fiercely in this case. On the other hand, given that some *low* types invested early in the game (and a few even towards the end), it seems reasonable that employers offer less than the separating equilibrium wage of 50. In turn, *high*-type workers often experience that their investment does not pay (see Result 4 above) which induces some of them to refrain from investing. Thus, path dependence is able to explain the persistence of *high* types who do not always invest. By contrast, the investment never pays for a *low* type, which explains why the *low* types' investment rates are close to the predicted level of zero in the last periods of the experiment.

Let us turn to observation (C). Why do employers make higher profits when hiring investing workers? *Loss aversion* can explain this finding. To see this, let us first calculate employers' expected profits. Let us assume that employers have a reasonably good idea about the likelihood of either type investing after some periods of play. Given these beliefs, employers essentially play lotteries. Imagine an employer observing some signal $s \in \{0, 1\}$ in SIG2. From previous average investment rates, the employer can calculate the posterior belief via Bayesian updating. Denote $p = prob(type = low \mid s = 0)$ and $q = prob(type = low \mid s = 1)$. Assume for simplicity that players are in the last block of the experiment and that the belief about the probability of a type investing is given by workers' average play in the second-to-last block. In SIG2, $prob(s = 0 \mid type = low) = 0.89$ and $prob(s = 0 \mid type = high) = 0.24$. Thus, Bayes' rule implies $p = 0.79$ and $q = 0.13$. Hence, when $s = 0$, the expected payoff for the employer is $0.79 \cdot 10 + 0.21 \cdot 50 - w = 18.4 - w$. The average wage paid in the last block is 13.57 (see Table 1), so the expected payoff is 4.83. Compare this to the lottery after $s = 1$. The lottery now reads $0.87 \cdot 50 + 0.13 \cdot 10 - w$. The expected payoff is 44.8 minus the actual average wage paid, 29.38, that is, 15.42.[19]

[18] See Miller and Plott, 1985, Potters and van Winden, 1996, Cooper, Garvin, and Kagel, 1997b.

[19] Qualitatively similar results hold for the other treatments. In SIG3, we have $p = 0.69$ and $q = 0.07$. Expected gains minus actual average wages paid are $0.69 \cdot 10 + 0.31 \cdot 50 - 19.84 = 2.53$ ($s = 0$) and $0.07 \cdot 10 + 0.93 \cdot 50 - 40.89 = 6.49$ ($s = 1$). In SCR2, $p = 0.79$ and $q = 0.0$ yielding expected payoffs of $0.79 \cdot 10 + 0.21 \cdot 50 - 22.27 = -4.02$ ($s = 0$) and $1.00 \cdot 50.0 - 41.3 = 8.7$ ($s = 1$). Finally, in SCR3, $p = 0.74$ and $q = 0.13$ imply expected payoffs of

Loss aversion can explain why employers bid more fiercely when $s = 0$ (or, as stated in Result 5, earn higher payoffs when $s = 1$). Loss aversion occurs when subjects are more sensitive to losses than to gains. In the above example, when employing a worker after $s = 0$, employers typically make a small loss but in 21% of the cases make a big profit of 26.43. When $s = 1$, firms make a moderate gain in 87% of the cases but they face the risk of making a substantial loss of -19.38 if they come across a *low*-type worker. The higher sensitivity to losses than to gains in prospect theory (Kahneman and Tversky, 1979) predicts that employers will bid relatively less for the $s = 1$ lottery, which is what we observe. (In terms of the utility, rather than the payoff, employers get from these lotteries, employers presumably bid equally competitively in both cases.) Another key element of prospect theory is based on the observation that small probabilities are often overweighted. In our experiment, this can explain why employers are reluctant to make bids close to 50 even though the probability of a *low* type choosing $s = 1$ is rather small or even zero towards the end of the experiment.

Given the relatively small difference in wages paid to investing and non-investing workers, it is somewhat surprising to observe so much signaling of *high*-type workers in many of the sessions. Already in the first block (see Table 1) there is a clear difference in the investment rate of *low*- and *high*-type workers. This difference ranges from 24% in treatment SIG2 to 60% in treatment SIG3. But the difference in wages paid for workers who invest and those who do not invest during the first block is on average very small (SIG2: 6.29; SIG3: 1.40; SCR2: 2.55) and in case of treatment SCR3 even negative (-5.06).[20] On the session level we observe that the difference in wages paid is virtually zero or even negative in 7 of the 12 sessions in the first block (see Figures 5 to 8 in Appendix D). So it seems that employer behavior in the early rounds of the signaling experiments is based on beliefs that support pooling rather than separating. In the screening games, employers might at first not understand the possibility to use wages as a means to induce separation of types. Only over time, they learn to differentiate wages in most sessions. Path dependence and myopia on the part of the employers can explain the slow and incomplete convergence to the separating equilibrium in most sessions—despite the persistent and growing efforts of *high*-type workers to reveal their identity.

$0.74 \cdot 10 + 0.26 \cdot 50 - 27.31 = -6.82$ ($s = 0$) and $0.13 \cdot 10 + 0.87 \cdot 50 - 43.04 = 1.83$ ($s = 1$).

[20] The negative average of wages paid in the first block of treatment is SCR3 is due to behavior in session 2 of this treatment (see Figure 8 in the Appendix D).

4.4 The Effect of Increased Employer Competition

In this subsection and the next, 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.

Figure 1 displays the aggregated results of treatments Sig2 and Sig3. Regarding investment decisions there is no significant difference between the signaling treatments with two and three employers.[21] In the left panel of Figure 1 there are no apparent differences. But both wages paid in treatment Sig3 are shifted upwards compared to Sig2. Workers who did not invest received on average 6 points less in Sig2 compared to Sig3. A worker who invested received 29.38 points in Sig2 whereas he received 40.98 points with three employers. 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).

Table 3 provides information on outcomes in the last block of the experiment. Compared to the tables displaying outcomes on the session level (third panels of Figures 5 to 8, Appendix D), we now show aggregate numbers of outcomes for every treatment. The upper part of this Table shows the share of outcomes according to a rough classification whereas information given in the lower part uses a finer classification. For the rough classification, we add the number of "Sepa 0" and "Sepa 1" outcomes to obtain the variable "Sepa", and similarly for "Pool" and "Other". In the following we perform all statistical tests on the rough classification as this is sufficient to organize behavior according to the theory.

First of all, note that almost all separating outcomes in treatment Sig2 are due to *low*-type separating and that there are virtually no pooling outcomes. As noted above, increasing competition in the signaling version leaves investment behavior unchanged but increases wages after both investment decisions. The increase in wages paid after no investment in Sig3 means that many non-investing *low* types receive higher wages which leads to an increase in *low*-type pooling and a decrease of *low*-type separating in Sig3, according to the classification used in Table 3. The increase in wages paid after investment in Sig3 implies that many investing *high* types also receive higher wages which leads to an increase in *high*-type separating. Finally, the increase in wages in Sig3 reduces the share of "Other" outcomes, which is mainly due to the fact that investing *high* types now receive separating wages. Thus we see a reduction in outcomes classified as "Other

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

Outcome	Description	SIG2	SIG3	SCR2	SCR3
		Rough classification			
Sepa	Separating outcomes	53	54	43	39
Pool	Pooling outcomes	4	18	25	50
Other	All other outcomes	43	28	32	11
		Fine classification			
Sepa 0	Low type doesn't invest and earns $w \leq 20$	50	22	19	13
Sepa 1	High type invests and earns $w \geq 40$	3	32	24	26
Pool 0	Low type doesn't invest and earns $20 < w < 40$	3	17	21	37
Pool 1	High type doesn't invest and earns $20 < w < 40$	1	2	4	13
Other 1	Noninvesting types earn $w \geq 40$	1	2	–	8
Other 2	Low type invests	–	4	7	–
Other 3	High type doesn't invest and earns $w \leq 20$	12	7	–	–
Other 4	High type invests and earns $w \leq 40$	29	15	25	4

Table 3: Shares of outcomes in the last block

4" in Table 3. The difference in (rough) outcomes between treatments SIG2 and SIG3 is significant at $p = 0.01$ (chi-square test, $d.f.$=2, $\chi^2 = 12.09$).

Summarizing the comparison of SIG2 vs. SIG3, we get

Result 6 [SIG2 *vs.* SIG3] *Increased employer competition (i) does not significantly change investment behavior; (ii) significantly increases wages paid to workers who invest; (iii) makes workers who invest benefit significantly and employers hiring those workers earn less; (iv) causes a decrease of low-type separating and an increase in high-type separating and low-type pooling; (v) causes a decrease in non-equilibrium behavior.*

The result of higher wages with three compared to two employers is not predicted by the theory, but confirms the results in Fouraker and Siegel (1963) and Dufwenberg and Gneezy (2000). Note that wages after *both* investment decisions increase. Thus, the incentive to invest remains almost unchanged, and unsurprisingly, this wage increase has no effect on investment decisions. Thus, it is not the case that more or less competition leads to more or less separation of types. Rather, pooling outcomes become more frequent with tougher competition, and there is a decrease in disequilibrium outcomes.

Now consider the screening sessions of the experiment and refer to Figure 2, which shows the aggregated data from Scr2 and Scr3. At first sight, competition of three versus two employers appears to increase the investment rate of *high* types. However, this effect is not significant, which is also reflected by the almost constant number of separating outcomes of *high* types ("Sepa 1") shown in Table 3. And as in the signaling versions, adding a third employer increases the pooling outcomes and decreases outcomes labeled "Other" (again a clear reduction in category "Other 4"). The proportions of (rough) outcomes differ significantly between treatments Scr2 and Scr3 at $p = 0.001$ (chi-square test, $d.f.$=2, $\chi^2 = 18.78$).

Result 7 [Scr2 *vs.* Scr3] *Increased employer competition (i) has no significant effect on workers' investment behavior or payoffs; (ii) does not affect employers' wages paid or profits; (iii) leads to an increase in high- and low-type pooling outcomes; (iv)causes a decrease in non-equilibrium behavior.*

While there is no difference between screening with two and three employers when focusing only on single decision variables (investment, wages), we find some significant effects on outcomes, i.e., combinations of wage offers and investment decisions. Analogous to the signaling game, adding a third employer leads to more pooling and to a decrease of cases denoted by "Other 4" where investing *high* types get wages below 40.

It is noteworthy that employers who offer menus of wages (in the screening games) instead of single wages (in the signaling games) compete as fiercely when there are two competitors as when there are three. Possibly, implicit collusion among two employers is more difficult to achieve when the strategy space has two dimensions rather than one as in standard Bertrand competition or in the signaling treatments. We will elaborate on this again in the next section where the focus is on differences between the signaling and screening games.

4.5 Signaling vs. Screening

Finally, we compare behavior in the signaling and the screening experiments. Figure 3 shows aggregated data in the signaling and screening sessions with two employers while Figure 4 displays the aggregated data 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, the observed (significant) wage difference between signaling and screening for workers who do not invest with two competing employers disappears when competition is increased to three employers. But we still find higher wages of

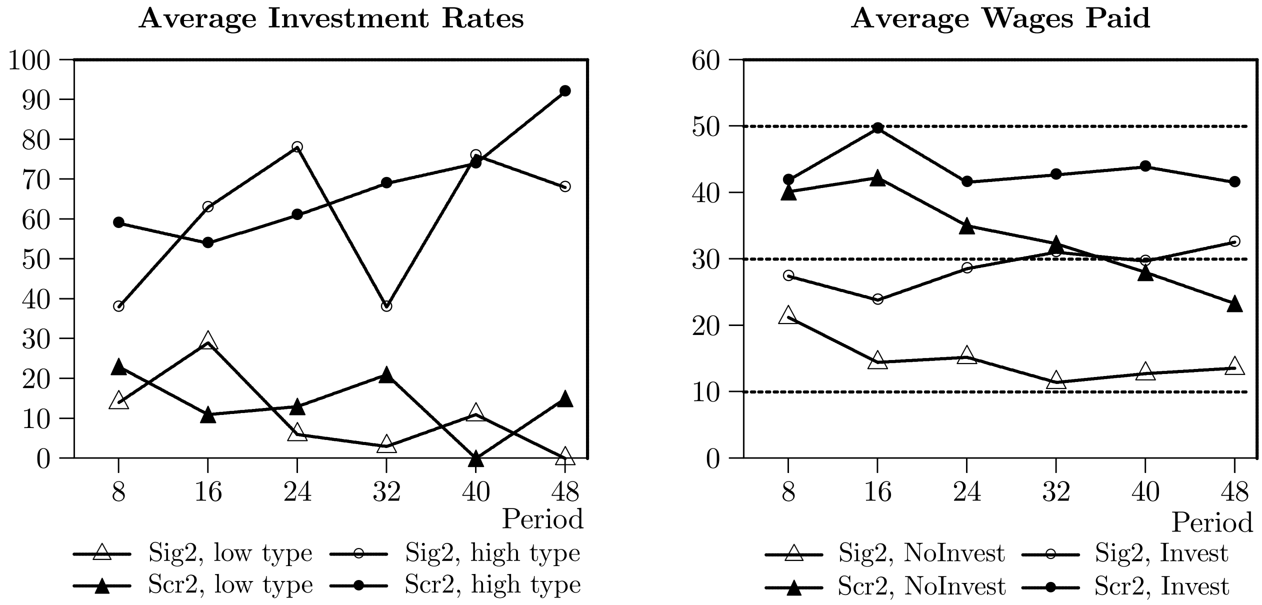

Figure 3: Evolution of investment rates and wages paid in treatments Sig2 and Scr2

investing workers with three employers in screening than in signaling. This is consistent with the higher frequency of investment choices by *high* types of workers.[22]

Statistical tests on the basis of the last block of the experiment yield:

Result 8 [Sig2 *vs.* Scr2] *Moving from signaling to screening with two employers (i) does not change workers' investment behavior; (ii) significantly increases the payoff of investing workers; (iii) significantly increases wages paid after both investment decisions, and (iv) significantly decreases profits of employers hiring investing or non-investing workers.*

Result 9 [Sig3 *vs.* Scr3] *Moving from signaling to screening with three employers has no significant effects except for a significant increase in wages paid to workers who invest.*

The aggregation of data as shown in Figures 3 and 4 masks clear effects regarding outcomes. Comparing outcomes in the signaling and the screening version in Table 3, we note an interesting effect: screening *reduces* the share of separating outcomes (53% in Sig2 vs. 43% in Scr2; 54% in Sig3 vs. 39% in Scr3) and *increases* the share of pooling outcomes (4% in Sig2 vs. 25% in

[22] Figure 4 indicates that there is a difference in investment behavior of *high*-type workers in treatment Sig3 and Scr3 in many blocks during the experiments. However, also tests based on all rounds or only on the second half of the experiment indicate that these differences are not significant at any conventional level.

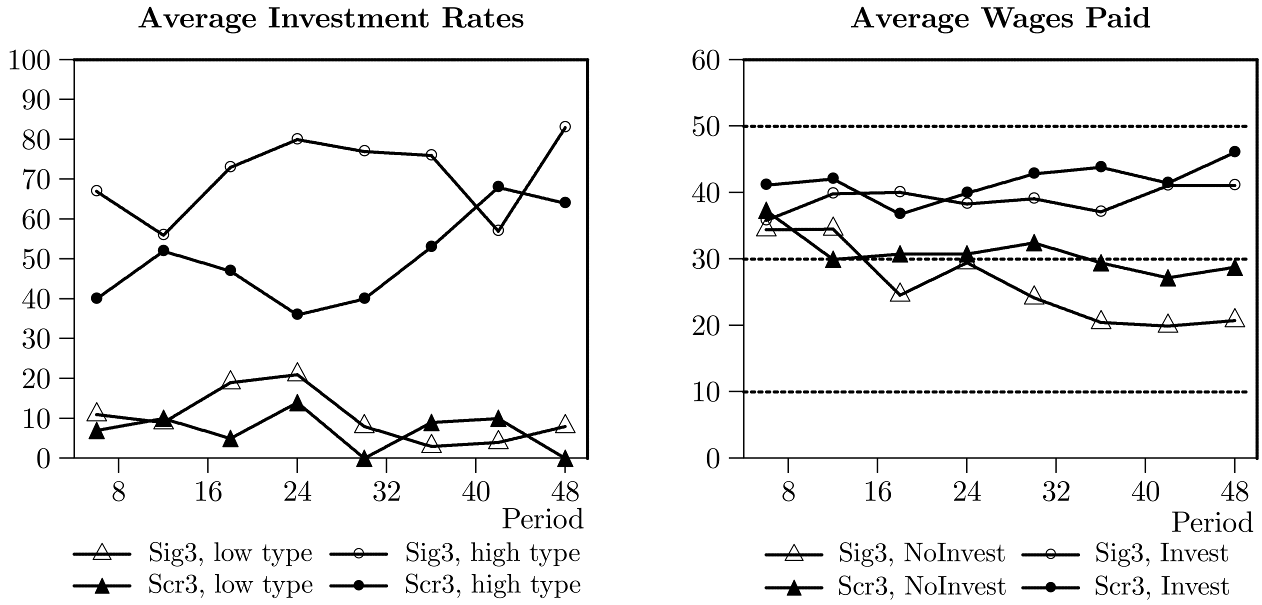

Figure 4: Evolution of investment rates and wages paid in treatments SIG3 and SCR3

SCR2; 18% in SIG3 vs. 50% in SCR3).[23] If anything, we should have observed the opposite as the screening game has a unique separating equilibrium. The data also show that screening reduces the number of outcomes that are neither separating nor pooling outcomes. Chi-square tests reveal that the differences in (rough) outcomes are significant at $p < 0.001$, $d.f.$=2, $\chi^2 = 17.86$ in SIG2 vs. SCR2; and $p < 0.001$ ($d.f.$=2, $\chi^2 = 24.89$) in SIG3 vs. SCR3. Summarizing we state

Result 10 *Screening reduces the share of separating outcomes and increases the share of pooling outcomes.*

Why do we observe more pooling in the screening than in the signaling game? Table 3 shows that an important reason for this finding is the higher wage level of *low* types in screening, leading to a reduction of "Sepa 0" and an increase in "Pool 0". This happens both for treatments with two and with three employers. On the other hand, screening leads to an increase in "Sepa 1" with two employers compared to signaling due to higher wages for investing types, but this effect is much smaller than the increase in pooling of *low* types. Thus, the nature of wage competition has a decisive impact on the prevalence of pooling or separating outcomes.

[23] These results do not depend on the selection of the last block. If instead all rounds of the second half of the experiment are selected the results are unchanged.

When comparing the four treatments, the signaling version with two employers stands out due to the low wages paid in this variant. One explanation for the low wages 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 thus similar to the task in sequential-move experiments where the so-called strategy method is employed. Previous experimental findings suggest that the strategy method leads to less cooperation between players, which is consistent with the results described here.[24]

5 Conclusions

We analyze both a signaling and a screening variant of the Spence education game, and investigate the effect of increasing the number of employers from two to three. In all four treatments of the experiment, we find that less efficient types of workers only rarely choose the costly investment while the more efficient types often do. Consistent with this finding, there is a significant wage spread, and workers who invest get significantly higher wages 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. However, when testing for the point predictions of the separating equilibrium, the results become less favorable for separating. The separation of types is not complete in our data, as in most other signaling experiments before. Wages for investing workers are too low such that their payoffs are not significantly higher than those of non-investing workers. And wages for non-investing workers are too high compared to the theoretical prediction. Finally, employers earn higher profits when hiring a worker who invested than when hiring a worker who has not invested.

As in previous signaling experiments, path dependence is an important aspect of behavior, given the prominent role of beliefs about other players. Investment behavior in early rounds establishes the employer's beliefs. In particular, efficient types of workers invest more often than inefficient types. But investment behavior does not signal a worker's type perfectly and the wage spread is smaller than predicted. 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. However, the finding

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

that profits of employers who hire investing workers are higher than predicted cannot be accounted for by incomplete separation of types. Rather, loss aversion of employers is consistent with the observed wage pattern.

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 three employers, the two institutions yield the same results with respect to wages and investment behavior when looking at these two variables separately. Though signaling sessions with two employers are less competitive in terms of wages than screening sessions with two employers, we find no evidence that adding a third employer leads to more investment in education. Therefore, the amount of costly investments is the same for signaling and screening, independent of the number of competing employers.

When focusing on the point predictions of outcomes as *combinations* of wage levels and investment decisions, we see significant differences between signaling and screening games. Most importantly, the share of separating outcomes is smaller with screening than with signaling. Screening leads to more pooling although it is not an equilibrium of the screening game. We explain this observation by differences in wage setting of employers under signaling and screening institutions. Thus, the nature of competition affects the amount of separation of types taking place. As a future project, it would be useful to elicit the beliefs of the participants to learn directly what their beliefs about worker types and about beliefs of other players are. This would be necessary to pin down exactly whether any of the equilibria is played or not.

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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 $50 - 45 = 5 < 30$ (if an employer offers the highest wage that can be optimal). 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 $50 - 9 = 41$ if he deviates by investing in education. Therefore, the only reasonable belief p of the employer 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: Details for and results of statistical tests

As already mentioned in the text, for all estimations we used White (1980) robust standard errors which adjust for possible non-independence of observations within sessions. All regressions are based on 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. In all regressions, the estimate for β_1 can be directly interpreted as the difference in means. We report as p-levels $P > \mid t \mid$.

Result 1: For each treatment separately the following probit estimation equation was used for workers' investment decisions: $Prob[Invest = 1] = F(\beta_0 + \beta_1 TYPE + \varepsilon_i)$ where $TYPE$ was equal to 1 if the worker was of *high* type and 0 otherwise. Test results: Sig2: $p = n.p.$; Sig3: $p = 0.021$; Scr2: $p = 0.000$; Scr3: $p = n.p.$[25]

Result 2: For each treatment separately the following OLS estimation equation was used for wages paid to workers: $wage = \beta_0 + \beta_1 INVEST + \varepsilon_i$ where $INVEST$ was equal to 1 if the worker invested and 0 otherwise. Test results: Sig2: $p = 0.020$; Sig3: $p = 0.077$; Scr2: $p = 0.028$; Scr3: $p = 0.066$.

[25] All data points are zero; therefore it is not possible to generate a value of p.

Result 3: For each treatment separately the following OLS estimation equation was used for payoffs earned by workers: $payoff = \beta_0 + \beta_1 TYPE + \varepsilon_i$ where $TYPE$ is defined as above. Test results: Sig2: $p = 0.086$; Sig3: $p = 0.250$; Scr2: $p = 0.117$; Scr3: $p = 0.190$.

Result 4: For each treatment separately the following OLS estimation equation was used for payoffs earned by high-type workers: $payoff = \beta_0 + \beta_1 INVEST + \varepsilon_i$ where $INVEST$ is defined as above. Test results: Sig2: $p = 0.144$; Sig3: $p = 0.049$; Scr2: $p = 0.403$; Scr3: $p = 0.893$.

Result 5: For each treatment separately the following OLS estimation equation was used for profits earned by hiring employers: $profit = \beta_0 + \beta_1 INVEST + \varepsilon_i$ where $INVEST$ is defined as above. Test results: Sig2: $p = 0.066$; Sig3: $p = 0.462$; Scr2: $p = 0.099$; Scr3: $p = 0.059$.

Results 6–9:

Comparison between	Workers				Employers			
	investment[a]		payoffs[b]		wages paid[c]		profits[d]	
	low	high	low	high	no invest	invest	no invest	invest
Sig2 and Sig3	n.p.	0.418	0.323	0.062	0.196	0.025	0.303	0.019
Scr2 and Sig3	n.p.	0.125	0.349	0.274	0.387	0.125	0.960	0.856
Sig2 and Scr2	n.p.	0.075	0.375	0.016	0.045	0.041	0.010	0.009
Sig3 and Scr3	n.p.	0.424	0.403	0.129	0.276	0.024	0.503	0.471

Notes:

[a] For each worker type separately the following probit estimation equation was used for workers' investment decisions: $Prob[Invest = 1] = F(\beta_0 + \beta_1 TREATM + \varepsilon_i)$ where $TREATM$ is a dummy used to code the treatments included in the regression.

[b] For each worker type separately the following OLS estimation equation was used for workers' payoffs: $payoff = \beta_0 + \beta_1 TREATM + \varepsilon_i$ where $TREATM$ is defined as above.

[c] For each investment decision separately the following OLS estimation equation was used for wages paid to workers: $wage = \beta_0 + \beta_1 TREATM + \varepsilon_i$ where $TREATM$ is defined as above.

[d] For each investment decision separately the following OLS estimation equation was used for profits earned by employers: $profit = \beta_0 + \beta_1 TREATM + \varepsilon_i$ where $TREATM$ is defined as above.

Appendix D: Additional data and figures

Outcome	Description	SIG2				SIG3				SCR2				SCR3			
		S1	S2	S3	**All**	S1	S2	S3	**All**	S1	S2	S3	**All**	S1	S2	S3	**All**
									Rough classification								
Sepa	Separating outcomes	63	46	50	**53**	39	89	34	**54**	50	50	29	**43**	33	—	83	**39**
Pool	Pooling outcomes	4	4	4	**4**	11	—	45	**18**	4	29	42	**25**	50	89	11	**50**
Other	All other outcomes	33	50	46	**43**	50	11	23	**28**	46	21	29	**32**	17	11	6	**11**
									Fine classification								
Sepa 0	low type doesn't invest and earns $w \leq 20$	63	42	46	**50**	22	39	6	**22**	29	8	21	**19**	—	—	39	**13**
Sepa 1	high type invests and earns $w \geq 40$	—	4	4	**3**	17	50	28	**31**	21	42	8	**24**	33	—	44	**26**
Pool 0	low type doesn't invest and earns $20 < w < 40$	—	4	4	**3**	11	—	39	**17**	4	25	33	**21**	50	50	11	**37**
Pool 1	high type invests and earns $20 < w < 40$	4	—	—	**1**	—	—	6	**2**	—	4	8	**4**	—	39	—	**13**
Other 1	Noninvesting types earn $w \geq 40$	—	4	—	1	—	—	6	**2**	—	—	—	—	17	6	—	**8**
Other 2	low type invests	—	—	—	—	11	—	—	**4**	17	4	—	**7**	—	—	—	**—**
Other 3	high type doesn't invest and earns $w \leq 20$	21	17	—	**12**	22	—	—	**7**	—	—	—	—	—	—	—	**—**
Other 4	high type invests and earns $w \leq 40$	12	29	46	**29**	17	11	17	**15**	29	17	29	**25**	—	6	6	**4**

Table 4: Shares of outcomes in the last block for each session separately

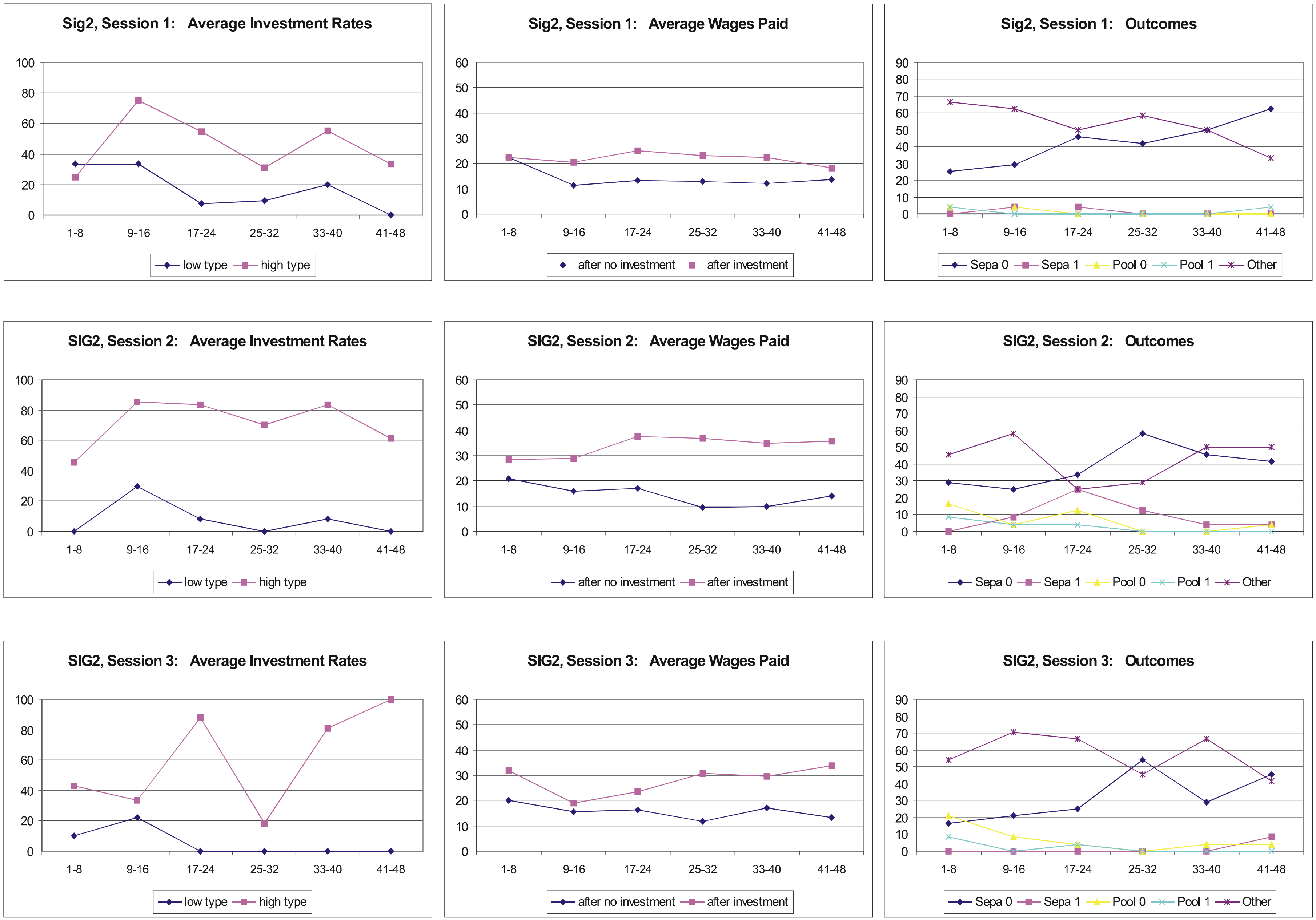

Figure 5: Results in the signaling sessions with two employers.

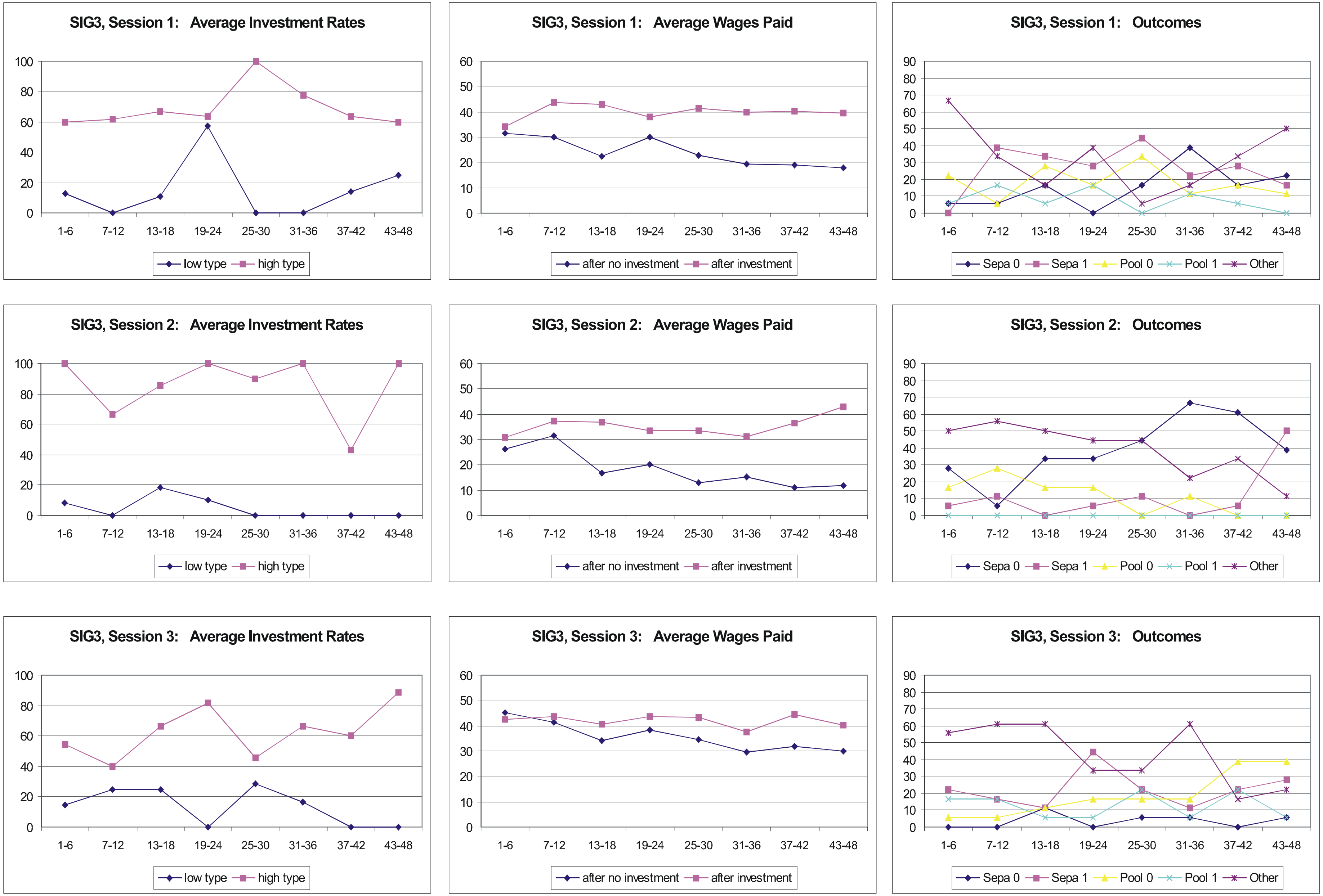

Figure 6: Results in the signaling sessions with three employers.

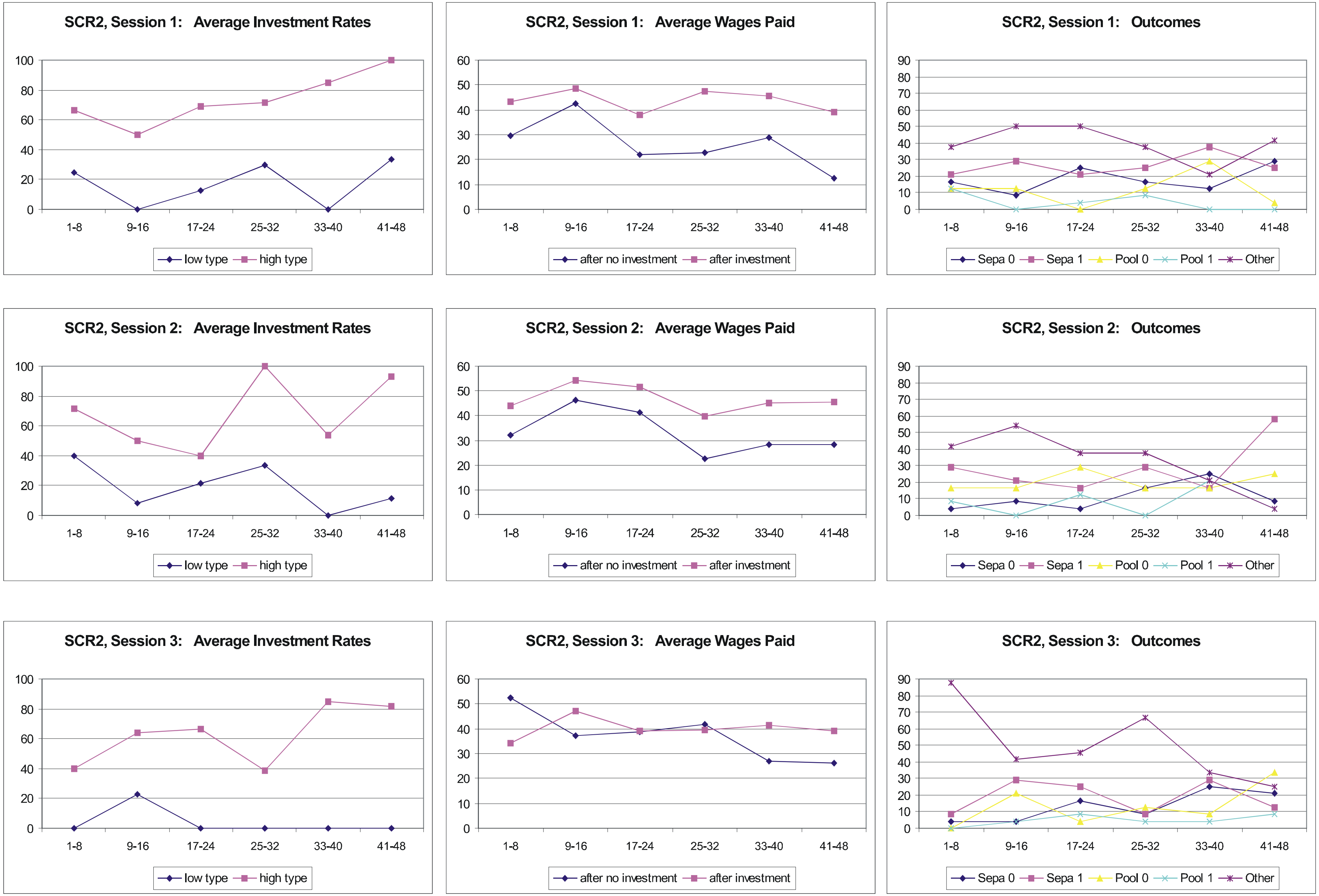

Figure 7: Results in the screening sessions with two employers.

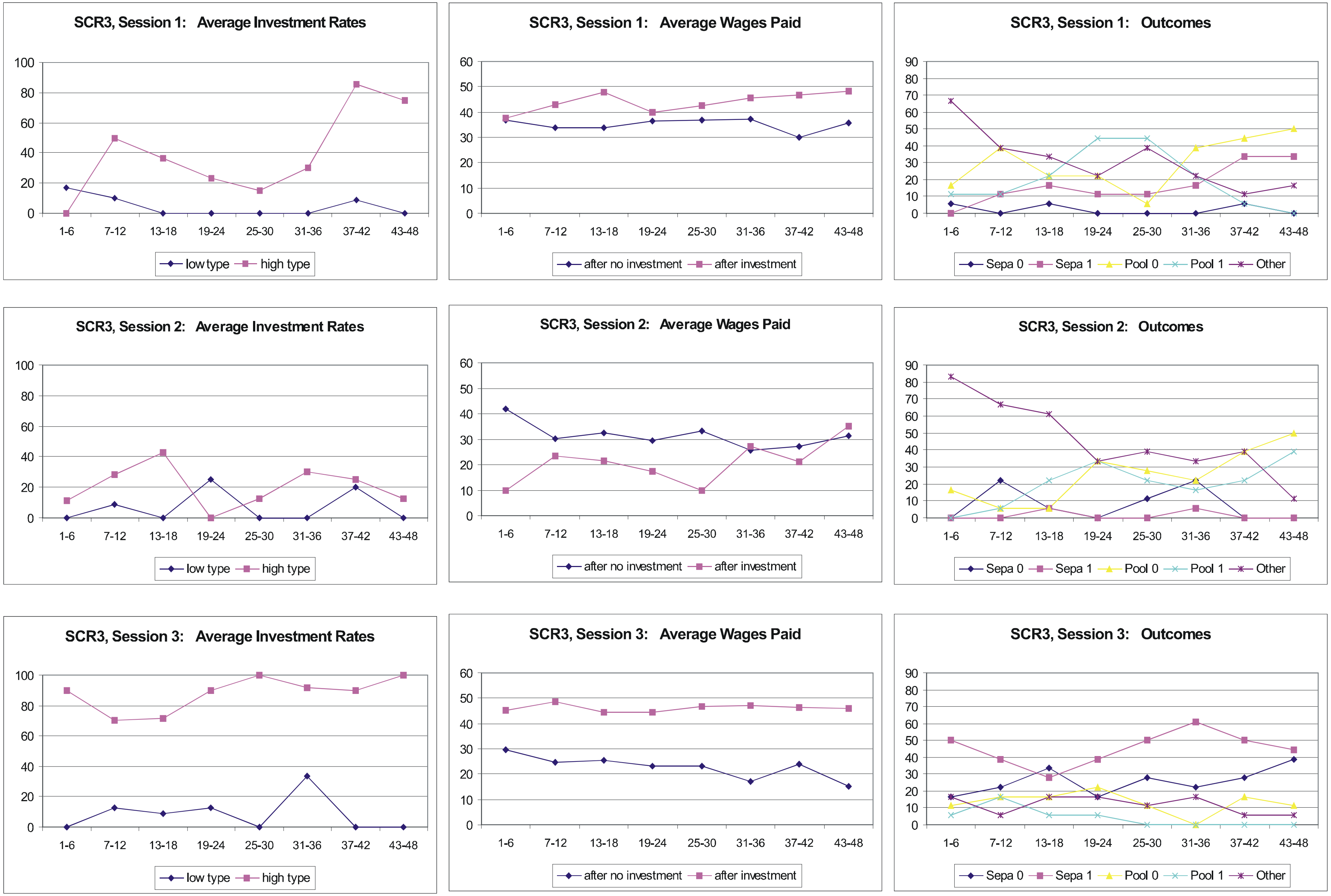

Figure 8: Results in the screening sessions with three employers.