# The Effect of Production Technology on Trust and Reciprocity in Principal-Agent Relationships with Team Production

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### Abstract

*We study experimentally the impact of varying production technologies and number of workers on trust and reciprocity in a gift-exchange experiment. Our treatments allow examination of trust and reciprocity when we have additional motivations (e.g., free riding, responsibility) and obstacles, (e.g., coordination). The finding of positive relationship between wages and effort holds in our richer environments, although when the production technology intensifies free riding motivations and coordination is more difficult workers reduce effort. Our findings also suggest that firm's behavior, conditioned by the production technology, mainly react to the final relevant outcome, rather than to the team's profile of efforts.*

**JEL Classification:** C91, D01, J3, J41

**Keywords:** labor market, gift exchange-game, production technology, experiment, team of workers.

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## 1. Introduction

Principal-agents relationships, where the principal moves first, are often characterized by the following three features: the principal chooses agents' wages, the principal's profit depends (in part) on agents' efforts, and the agents' performance is often not enforceable. In these situations, agents have a dominant strategy to reduce effort to the minimum level allowed, and anticipating it the principal would have no incentive to pay an above-minimum wage. Nevertheless, gift exchange experiments have regularly shown that there exists a positive relationship between wage and effort. This non-equilibrium result indicates that elements of trust (by the firm) and reciprocity (by the workers) must be an important part of these labor relationships.[1] This robust finding of trust and reciprocity produces *excess* cooperation (relative to the dominant strategy predictions) which is one of the most important vehicles for progress. Therefore, it is useful to understand the scope and limitation of such *excess* cooperation. In other words, what mitigates or enhances it and how?

This paper analyzes experimentally to what extent the trust and reciprocity embedded in the labor relationships are affected when a principal is in charge of a team of agents rather than one-firm-one-worker setting used in most previous studies. We examine two of the main characteristics of team production: the production technology and the size of the team (number of agents). Firms and workers' decisions may depend critically on these two characteristics. Different technologies can induce different motivations and have different effects on firms and workers' decisions. Think of a firm in which the worst performing individual determines the final outcome of the team, as with an assembly line that moves only as fast as the slowest worker. Does this environment lead to the same behavior as one in which the overall productivity is determined by the performance of the best worker?[2] Does the size of the team affect workers and firms' behavior?

[1] See, for instance, Fehr et al. (1993), Fehr and Gächter (1998), Charness (2004), or Charness et al. (2004) for one-shot games and Gächter and Falk (2002) and Brown et al. (2004) for repeated interactions settings.

[2] Examples of environments where the overall productivity is determined by the performance of the best worker are frequent in real life: a team of medical researchers finding a cure for a disease or a group of cops searching for a criminal.

Although the analysis of the principal-agent problem with several workers has generated a recent and growing literature on this topic (we will review this literature in the next section), to our knowledge this is the first experiment that directly examines principal-agent relationships when work-teams are involved by changing the production technology and the size of the team.[3]

With the goal of studying whether and how the production technology affects subjects' behavior, we propose an experimental design similar to the one proposed in the seminal paper by Fehr et al. (1993); in the first stage the firm offers a wage to workers, and in the second stage, workers choose how much effort they will provide. We consider three different production functions to determine the final outcome. In the *Average* (*Minimum/Maximum*) production technology, the average (minimum/maximum) effort level provided by the workers gives the output of the firm.[4] We also vary the number of workers paired with a firm to test how the effect of the production technology on wages and efforts varies with the size of the workforce (2 and 4 workers per firm).

The *Minimum* and the *Maximum* production technologies have been used in the experimental literature to represent both the voluntary private provision of public goods and the notion of team production (Croson et al., 2006). The *Minimum* production technology is similar to the weakest link mechanism (where the minimum contribution determines the team production/public good), and the *Maximum* production technology is similar to the best-shot mechanism (where the maximum contribution determines the team production/public good).[5]

[3] From a theoretical point of view, the principal-agent problem with multiple workers has been largely studied in the literature. See, for instance, Holmstron (1982), Harris and Holmstrom (1982), Frank (1984), Lazear (1989), Akerlof and Yellen (1990), Lawler (1990), Bewley (1999), Danziger and Katz (1997) or Charness and Kuhn (2007).

[4] Throughout the paper, we shall presume that the firm is female and the worker is male.

[5] These production technologies were theoretically analyzed by Hirshleifer (1983) and have been experimentally examined in several papers (for the weakest link game, see for instance, Harrison and Hirshleifer, 1989; van Huyck et al., 1990; Knez and Camerer, 1994; Cachon and Camerer, 1996; Bornstein et al., 2002; Brandts and Cooper, 2006; Croson et al., 2006; Brandts, Cooper and Fatás, 2007; Hamman et al., 2007; Chaudhuri et al., 2009; Kogan et al., 2011; and Riedl, Rohde, and Strobeland, 2011; and for the best-shot mechanism, Harrison and Hirshleifer, 1989; Prasnikar and Roth, 1992; Duffy and Feltovich, 1999; Carpenter, 2002; Croson et al., 2006; and Kroll et al. 2007).

Standard theory predicts the same minimum wage/minimum effort regardless of the production technology and the size of the labor team. However, we conjecture that with the *Maximum* and *Minimum* production technology, workers will provide lower effort levels than with the *Average* production technology. The *Maximum* and *Minimum* production technologies involve coordination difficulties that are absent (or less pronounced) in the *Average* technology. In the *Maximum* (*Minimum)* production technology the firm's payoff is an increasing function of the maximum (minimum) effort chosen by the workers. Thus, it is worthwhile for a worker who wishes to reciprocate a "fair" wage to do so "if and only if" (not exactly for a large increment) it will increase the maximum (minimum) effort for the group. If a worker expects that another worker will provide the highest (lowest) effort level, he may regard own gesture as irrelevant and thus wasteful. Moreover, under these two production technologies, if workers perceive that their effort will not always determine the firm's profit, they may react negatively to having smaller responsibility. The *responsibility-alleviation* effect (Charness, 2000) states that an agent who bears the responsibility for an outcome will behave in a more cooperative ('pro-social') manner, as an increase in responsibility augments internal impulses towards honesty, loyalty, or generosity. According to this principle, we should expect impulses toward generosity with *Maximum* and *Minimum* production technology to be decreased with respect to the *Average* production technology. Regarding the firm's decision, we conjecture that wages offered under the *Maximum* production technology will be larger than under the other two technologies and also that wages under the *Average* will be larger than under the *Minimum* production technology. The firm could have an incentive to pay above the minimum wage expecting workers to provide effort level above the minimum. For a similar distribution of effort levels, the a priori probabilities of obtaining an implemented effort level that compensates setting wages above the minimum would be higher under the *Maximum* production technology than under the other two technologies and, in turn, higher under the *Average* than *Minimum* production technology. Thus, while the *Maximum* production technology would increase the expectations of the firm in the output obtained from her workers, the *Minimum* production technology would reduce it.

Moreover, under the *Maximum* production technology firms may be less reluctant to offer high wages since a single reciprocal worker is needed to affect production favorably. Besides, the presence of a single reciprocal worker prevents selfish ones to harm the firm. However, this is reversed under the *Minimum* production technology. A single selfish worker may handedly harm production and his presence prevents reciprocal ones to affect production favorably.

With reference to the size of the team, we expect that an increase in the number of workers will exacerbate the impact of the production technology on the behavior of workers and the firm. A larger team could increase the free riding motivation of workers under the three production technologies but more significantly with *Maximum* and *Minimum* production technologies. Under these two production technologies and with a larger number of workers, workers may assign a lower probability to the fact that their particular effort level determines the firm's profit. Consequently, they could react negatively to this lower responsibility. Regarding the firm's decisions, a larger team increases (decreases) the a priori probabilities of obtaining an implemented effort, i.e., an output that compensates setting wages above the minimum under the *Maximum* (*Minimum*) production technology. Thus, a larger number of workers could intensify the wage differences among the production technologies.

We find that the *excess* cooperation, in the sense of trust and reciprocity, still holds when the workers are part of a team regardless of production technology. In particular, results show a positive relationship between wages and effort. This occurs even with the *Maximum* and *Minimum* production technologies although they may entail some additional coordination problems.

Our data also show that, with a high enough number of workers, the *Maximum* and *Minimum* drive workers to provide lower effort levels than the *Average* production technology. This result suggests that different production technologies affect the final outcome not only through the implemented effort but also by affecting workers' individual performance. In other words, we could say that production technologies that involve some additional coordination problems, as with *Maximum* and *Minimum*, could diminish the reciprocity of workers.

Results suggest that the firm reacts not to the efforts provided by their workers, but to the final outcome derived from production. We observe that the *Maximum* production technology leads the firm to assign higher wage levels than under the other two technologies. However, our conjecture that wages under the *Average* will be larger than under the *Minimum* production technology only holds when there are two workers per firm.

Finally, results show that, for a given production technology, the number of workers does not affect workers' behavior, but it does affect the firm's behavior. An increase in the labor force leads firms to set both higher wage levels under the *Maximum* and lower wage levels under the *Average* and *Minimum* production technologies.

The remainder of the paper is organized as follows. Section 2 provides a brief literature discussion, and Section 3 explains the experimental design. We describe and discuss the main results in Section 4 and conclude in Section 5.

## 2. Literature Review

Regarding the analysis of the principal-agent problem with several workers, most previous papers have focused on horizontal fairness, analyzing the effect of social comparison among workers. Charness and Kuhn (2007) propose an experiment in which there are two workers (one with high productivity and other with low productivity) employed by the same firm. They find that while workers' effort choices are highly sensitive to their own wages, effort is not affected by the coworker's wage. In the experiment proposed by Güth, Königstein, Kovács, and Zala-Mezõ (2001), in which a firm also faces two workers with different productivities, the authors find that when wages are observable, the firm offers less asymmetric wages than when they are not observable. Bartling and von Siemens (2011) consider two treatments: in one of them, the team members always receive the same wage, and in the other, wages may differ. They do not find evidence that wage inequality has a significant impact on effort choices.

Gätcher and Thöni (2010), in a gift-exchange game with two workers per firm, observe that only disadvantageous wage discrimination has an effect on effort levels. While advantageous wage discrimination does not increase efforts on average, disadvantageous discrimination leads to lower efforts. They also conduct an experiment where wages are chosen at random. In this way, they explore whether wage comparison effects are due to intentional wage discrimination or due to payoff differences. They show that reactions to wage discrimination can be attributed to the underlying intentions of discrimination rather than to payoff consequences.

Abeler, Altmann, Kube, and Wibral (2010) examine a two-workers-gift-exchange game where workers first choose their efforts, and the firm then decides wages. In one treatment, the firm can choose the level of the wage, but she is obliged to pay the same wage to both workers. In a second treatment, the firm can offer a different wage to the two workers. They find that the use of equal wages elicits substantially lower efforts. They argue that the treatment difference is driven by the fact that the norm of equity is violated far more frequently in the equal wage treatment.

As we are not concerned about horizontal comparisons in this paper, the article that comes closest to ours is Maximiano, Sloof, and Sonnemans (2007). They analyze the effect of the size of the labor team on the performance of the workers. They compare a bilateral gift exchange game with a treatment in which each employer has four workers. They do not find a large effect of the size of the workforce, as effort levels in the one-employer-four-workers treatment are only marginally lower than in the one-employer-one-worker treatment. They differ from our work in the use of the strategy method and the play of just a single round. Besides, since they are concerned with vertical fairness between an employer and her workers, each worker receives the same wage by design.

We contribute to the existing literature on employment relationships by analyzing the impact on firms and workers' behavior of three different production technologies, the *Average,* the *Minimum,* and the *Maximum* production technology. Most of previous gift exchange experiments with several workers focus on the *Average* production technology. As far as we know, the only paper, apart from ours, where the firm's technology in a gift-exchange game has a weakest-link structure is Brandts and Cooper (2007). Using a game with one firm and four workers, they study how the firm's communication with workers and ability to increase workers' financial incentives to coordinate affect the firm's payoff. They find that communication is a more effective tool than incentive changes for increasing the firm's payoff.

Our paper is also similar to Goerg, Kube, and Zultan (2010). They explore the interplay between the production function and the performance of workers within a team of three employees. More specifically, they test whether workers' behavior is sensitive to the type of the production function that they face in their joint project. They have two different production functions, one of complementarity where the technology has increasing returns to scale and another of substitutability where the technology has decreasing returns to scale. They find that unequal salaries can potentially increase performance by facilitating coordination, and the effect strongly interacts with the exact shape of the production function. In contrast to our paper, they do not analyze the relationship between a principal and her workers and only focus on workers' behavior.

## 3. Experimental Design

The experimental design consists of six treatments: Ave2, Min2, and Max2 and Ave4, Min4, and Max4, where 2 and 4 denote the number of workers matched to each firm. Each one is a modified version of the two stage gift-exchange game introduced by Fehr et al. (1993).

In the first stage, the firm chooses the wage ($w$) she is going to offer to each of her workers. In this stage, the firm also asks for a non-binding effort, $\hat{e}$. The firm can choose a different wage to each worker.

In the second stage, after observing the wage offered and desired effort, workers decide simultaneously and independently how much effort they want to provide, $e$. Exerting effort is costly for workers.

Values for wages and effort levels are displayed in Table 1.

Table 1. Wage and Effort Levels

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Wage | 0 | 2 | 4 | 8 | 12 | 16 | 20 | 24 | 30 | 36 |
| Effort | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 |

Each firm is anonymously paired with different workers in each period, and this is common information. That is, this treatment uses a strangers matching protocol. At the end of each period, the firm is informed about her payoff and the effort levels provided by her workers. Workers only have information about their own situation with respect to the firm. That is, each worker only knows his own wage. Workers do not have any information about coworkers. They know neither the coworkers' wages, nor coworkers' efforts.[6]

[6] During the experiment subjects did not receive any historical information.

The combination of wage and effort determines outcomes and monetary payoffs for both employer and employees in each period. The payoff function for each of the workers is the same for all treatments:

$\Pi_W = w - e.$

For the firm, the payoff function depends on the output generated by the different production technologies. Thus, for each treatment, the firm's payoff is as follows:

- *Ave2* and *Ave4* treatments: the average effort level provided among all the workers of the firm gives the output of the firm. Hence, the firm's payoff function is:

  $\Pi_F = 15 + 2.5 \times n\ (\sum_{i=1}^{n} e_i/n) - (\sum_{i=1}^{n} w_i) = 15 + 2.5\times(\sum_{i=1}^{n} e_i) - (\sum_{i=1}^{n} w_i)$

  where $n$ stands for the number of workers (in this case, $n = 2$ for *Ave2* and $n = 4$ for *Ave4*).

- *Min2* and *Min4* treatments: the only difference with respect to the previous treatments is the production technology that generates the output. In these treatments, output is given by the worker who provides the minimum effort level for his firm. Hence, the payoff function is:

  $\Pi_F = 15 + 2.5\times n\ (min\ \{e_1,.., e_n\}) - (\sum_{i=1}^{n} w_i).$

- *Max2* and *Max4* treatments: in these treatments, the worker who provides the maximum effort level for his firm determines the output of the firm. The payoff function is:

  $\Pi_F = 15 + 2.5\times n\ (max\ \{e_1,.., e_n\}) - (\sum_{i=1}^{n} w_i).$

The experiment was conducted at the University of Castellón with 581 participants, who were recruited using the online recruitment system ORSEE (Greiner, 2004) in the Faculty of Economics. The experiment was programmed and conducted with the software z-Tree (Fischbacher 2007). Participants played for 15 periods in all treatments. Upon arrival at the lab, each participant was randomly assigned a role as either a firm or a worker; this role was fixed throughout the whole session. No one participated in more than one treatment or session. We conducted four sessions for each treatment. On average, each person received around 9€ (approximately $11.50 US at the time) for a 50 minute session.

## 4. Results

We start by analyzing whether the positive relationship between wage and effort usually found in the gift exchange literature still appears with the different production functions in our experiments. Next, we study what the effect of the different production technologies on workers' behavior is. Third, we determine whether wages offered by firms are sensitive to the technology. Finally, we examine how the size of the team affects both workers and firms' decisions under the different production technologies.

### *4.1 Relationship between wage and effort level.*

One of the most robust results in gift-exchange experiments is the positive relationship between wages and effort levels. However, most of this evidence has been found in one-worker-one-firm labor environments, so the first question we have to answer is whether this positive relationship still holds when the workers are part of a team.

Table 2 summarizes the average wage, desired effort, effort, implemented effort, and firm's and worker's profit by treatment. In contrast to the standard theoretical prediction, both average wages and average effort levels are larger than the Nash Equilibrium prediction for all treatments. That is, compared to the theoretical predictions, the firm sets wages higher than the minimum ($w_m = 0$), and workers reciprocate by providing effort levels higher than the minimum ($e_m = 2$).

**Table 2: Summary Statistics**

| | Max2 | Ave2 | Min2 | Max4 | Ave4 | Min4 |
|---|---|---|---|---|---|---|
| Average wage | 6.77 | 5.87 | 3.02 | 7.62 | 2.96 | 2.72 |
| Average desired effort | 9.58 | 10.25 | 10.89 | 8.81 | 12.27 | 9.60 |
| Average effort | 2.61 | 2.89 | 2.46 | 2.95 | 2.76 | 2.45 |
| Average implemented effort | 3.16 | 2.89 | 2.05 | 4.99 | 2.76 | 2.01 |
| Average firm's profit | 17.27 | 17.72 | 19.22 | 34.39 | 30.27 | 24.25 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Firm's profit (% of NE profits)* | 0.69 | 0.71 | 0.77 | 0.98 | 0.87 | 0.69 |
| Average worker's profit | 4.16 | 2.97 | 0.56 | 4.67 | 0.20 | 1.19 |

*In order to compare n = 2 and n = 4, we divide a firm's profit by the profit a firm obtains if subjects played the Nash equilibrium (minimum wage and minimum effort). This profit is 35 in n = 4 and 25 in n = 2. So, we compute this variable as firm's profit/35 if n = 4 and firm's profit/25 if n = 2.

Figures 1 and 2 present evidence supporting this reciprocal behavior. For each production function, they show the average effort level provided by workers for different wage ranges.

**Figure 1. Average Effort Level by Wage, n=2**

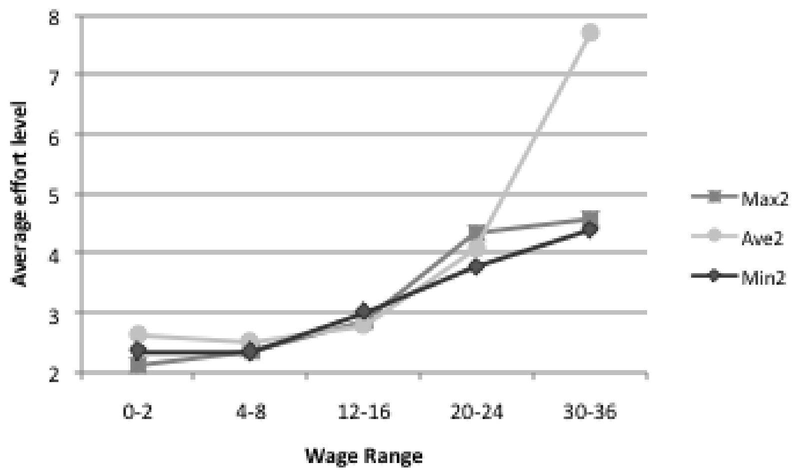
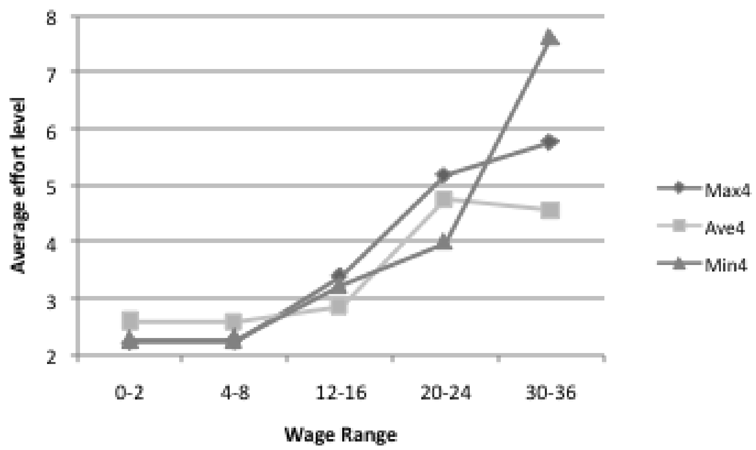



**Figure 2. Average Effort Level by Wage, n=4**




Similar to previous findings in the gift exchange literature, we observe a positive relationship between wages and effort levels for all production technologies. This result shows that the reciprocity found in one-worker-one-firm labor environments still holds when employees work within a team. This pattern of behavior is true not only for the standard production function, in which the output is given by the average effort level provided by workers (as shown in Maximiano et al, 2007), but also for production technologies that might involve coordination problems, such as *Maximum* and *Minimum* technologies.

The econometric analysis presented in Table 3 provides support for the previous intuition. For this analysis we consider a GLS random-effects model in which the dependent variable is the effort level. As explanatory variables, we introduce the wage in the current period ($Wage_t$), the wage received by the worker in the previous period ($Wage_{t-1}$), and the effort provided by the worker in the previous period ($Effort_{t-1}$). We run six regressions, one specification for each production function and for the different number of workers.

**Table 3: GLS Random Effects Regression on Effort**

| | Max2 | Ave2 | Min2 | Max4 | Ave4 | Min4 |
|---|---|---|---|---|---|---|
| $Wage_t$ | 0.071***<br>(0.008) | 0.079***<br>(0.011) | 0.046***<br>(0.016) | 0.096***<br>(0.006) | 0.053***<br>(0.012) | 0.096***<br>(0.008) |
| $Effort_{t-1}$ | 0.445***<br>(0.033) | 0.545***<br>(0.029) | 0.424***<br>(0.039) | 0.234***<br>(0.024) | 0.467***<br>(0.023) | 0.116***<br>(0.021) |
| $Wage_{t-1}$ | -0.034***<br>(0.008) | -0.072***<br>(0.011) | -0.027*<br>(0.015) | -0.026***<br>(0.006) | -0.039***<br>(0.010) | -0.017**<br>(0.008) |
| Constant | 1.161***<br>(0.116) | 1.259***<br>(0.136) | 1.307***<br>(0.135) | 1.648***<br>(0.100) | 1.407***<br>(0.100) | 1.896***<br>(0.078) |
| R-squared | 0.282 | 0.349 | 0.227 | 0.207 | 0.230 | 0.124 |
| N | 672 | 756 | 448 | 1400 | 1399 | 1378 |

All specifications in Table 3 show that wages offered by the firm and workers' effort in the previous period have a positive and significant effect on the effort level chosen by workers in the current period.

**Result 1:** *We find a positive relationship between wage and effort for all production functions independent of the number of workers.*

*4.2 Production technology effects on effort levels*

In this section we analyze whether the production technology that determines the output of the work team affects workers' behavior. With the *Minimum* technology, if workers want to reciprocate a fair wage, all of them need to coordinate on high effort, which would imply a high output and high firm's profit. However, with this technology they face considerable strategic uncertainty, because one 'selfish' worker is sufficient to make the rest of workers' efforts worthless. This difficulty of coordination and the strategic uncertainty may lead workers to reduce their efforts compared with the *Average* technology. Indeed, many experimental studies analyzing the weakest link mechanism in public goods contexts have found that the difficulty of coordination usually leads to converging towards the least efficient equilibrium, especially in large groups. The efficient coordination has been reached only in very small groups (e.g., Knez and Camerer, 1994; Cachon and Camerer, 1996; Weber et al., 2001; Brandts and Cooper, 2006; Brandts and Cooper, 2007; Brandts et al., 2007; Hamman et al., 2007; Chaudhuri et al., 2009; Kogan et al., 2011).

On the other hand, with the *Maximum* technology, where one worker's effort is sufficient to create high output, if workers want to reciprocate a fair wage, only one worker should provide high effort, and the rest of the workers should exert zero effort. The problem is that workers cannot coordinate their efforts, so they behave according to their beliefs. Thus, the infeasibility for coordination and the fact that all positive effort levels less than the largest one are unnecessary, in the sense that they do not increase the firm's profit and only decrease workers' earnings, may lead workers to reduce their efforts compared with the *Average* technology.

Moreover, under the *Maximum* and *Minimum* production technologies, the fact that workers perceive that their effort will not always determine, not even affect, the firm's profit, may affect them negatively and lead them to provide even lower effort levels. Thus, according to this "responsibility alleviation effect" (Charness, 2000), we should also expect impulses toward generosity with *Maximum* and *Minimum* production technologies to be decreased compared to the *Average*.

In the case of two workers per firm, Table 2 shows that efforts chosen by the workers were 2.61, 2.89, and 2.46 in Max2, Ave2, and Min2, respectively. A two-tailed Mann-Whitney test confirms that all differences are statistically significant (Z=2.093, p=0.036, for the comparison between Ave2 and Max2; Z=-2.155, p=0.031, for the comparison between Max2 and Min2; and Z=-3.915, p=0.000 for the comparison between Ave2 and Min2).[7]

To find out whether the effort levels are larger in Max2 than in the other two treatments when we control for the wage, we run an econometric analysis in which we consider a GLS random-effects model with effort level as the dependent variable. As explanatory variables we introduce the wage in the current period ($Wage_t$), the wage received by the worker in the previous period ($Wage_{t-1}$), the effort provided by the worker in the previous period ($Effort_{t-1}$), a dummy variable which takes value 1 if we are in the *Maximum* and 0 otherwise (T-Max), a dummy variable which takes value 1 if we are in the *Minimum* and 0 otherwise (T-Min), and a dummy variable which takes value 1 if we are in the *Average* and 0 otherwise (T-Ave).

Specification (1), (2), and (3) in Table 4 shows that, similar to Table 3, wages offered by the firm have a positive and significant effect on the effort level chosen by workers. In the same line, workers' effort in the previous period has a positive effect on their effort in the current period. We also observe that the wage received by the worker in the previous period plays a role on the effort chosen by the worker in the current period. Although this result could seem counterintuitive, we view this as a reference point effect. Given a wage level received in period $t$, a higher wage received in period $t-1$ could make the worker perceive the offer of the current period to be low, reducing his effort level. Similarly, given the same wage received in period $t$, a low wage in period $t-1$ could make the new wage to be perceived as high, increasing the worker's effort level. Finally, Table 4 shows that, controlling for the wage level, workers did not choose on average different effort levels in any treatment. This fact leads to our second result.

**Result 2:** *Under Max2 and Min2, controlling for wage, workers provide similar effort levels as in Ave2.*

[7] However, a more conservative non-parametric test using session-level data shows that differences between production technologies are not statistically significant. A Wilcoxon rank sum test gives p = 0.1266, p= 1.000 and p= 0.5637 for the comparison between Max2 and Ave2, Max2 and Min2 and the comparison between Ave2 and Min2, respectively.

**Table 4: GLS Random Effects Regression on Effort, n=2**

| | (1) | (2) | (3) |
|---|---|---|---|
| $Wage_t$ | 0.072***<br>(0.006) | 0.072***<br>(0.006) | 0.072***<br>(0.006) |
| $Effort_{t-1}$ | 0.495***<br>(0.019) | 0.495***<br>(0.019) | 0.495***<br>(0.019) |
| $Wage_{t-1}$ | -0.049***<br>(0.006) | -0.049***<br>(0.006) | -0.049***<br>(0.006) |
| T-Max | -- | -0.179<br>(0.109) | -0.007<br>(0.128) |
| T-Ave | 0.179<br>(0.109) | -- | 0.172<br>(0.124) |
| T-Min | 0.007<br>(0.128) | -0.172<br>(0.124) | -- |
| Constant | 1.128***<br>(0.102) | 1.307***<br>(0.098) | 1.134***<br>(0.108) |
| R-squared | 0.309 | 0.309 | 0.309 |
| N | 1876 | 1876 | 1876 |

Notes: ***, **, * denote significance at $p$ = 0.01, 0.05, and 0.10, respectively. Robust standard errors are in parentheses.

When the firm is matched with four workers, average efforts chosen by the workers are 2.95, 2.76 and 2.45 in Max4, Ave4 and Min4, respectively. A two-tailed Mann-Whitney test confirms that all differences are statistically significant (Z=-3.633, p=0.000, for the comparison between Max4 and Ave4; Z=-6.155, p=0.000, for the comparison between Max4 and Min4 and Z=-2.293, p=0.022 for the comparison between Ave4 and Min4), so the first impression is that in Max4 average efforts are larger than in the other two treatments.[8]

When we run an econometric analysis, Table 5 shows that, controlling for the wage level, workers provide higher effort in Ave4 than in the other two treatments (where workers did not choose different effort levels).[9] So, our third result is summarized as:

**Result 3:** *Under Max4 and Min4, controlling for wage, workers provide lower effort levels than in Ave4.*

[8] However, as in the case of two workers, a more conservative non-parametric test using session-level data shows that differences in effort levels between production technologies are not statistically significant. A Wilcoxon rank sum test gives p = 0.275, p= 0.275 and p= 0.5127 for the comparison between Max4 and Ave4, Max4 and Min4 and the comparison between Ave4 and Min4, respectively.

[9] The econometric analysis was the same as in Table 4 but for the case of four workers per firm instead of two. So, the significance and sign of the other explanatory variables are the same as Table 4.

This result highlights that for the effect of the production technology on workers´ behavior to be significant, the number of workers must be large enough.

**Table 5: GLS Random effects regression on effort, n=4**

| | (1) | (2) | (3) |
|---|---|---|---|
| $Wage_t$ | 0.087*** (0.005) | 0.087*** (0.005) | 0.087*** (0.005) |
| $Effort_{t-1}$ | 0.299*** (0.013) | 0.299*** (0.013) | 0.299*** (0.013) |
| $Wage_{t-1}$ | -0.035*** (0.005) | -0.035*** (0.005) | -0.035*** (0.005) |
| T-Max | -- | -0.182** (0.093) | 0.092 (0.092) |
| T-Ave | 0.182** (0.093) | -- | 0.274*** (0.089) |
| T-Min | -0.092 (0.092) | -0.274*** (0.089) | -- |
| Constant | 1.595*** (0.082) | 1.777*** (0.073) | 1.504*** (0.073) |
| R-squared | 0.176 | 0.176 | 0.176 |
| N | 4177 | 4177 | 4177 |

Notes: ***, **,* denote significance at $p$ = 0.01, 0.05, and 0.10, respectively. Robust standard errors are in parentheses.

On the other hand, it should be noticed in Figure 2 of the previous subsection that we can observe larger effort levels in Ave4 than in Max4 for low wages, but for the case of high wages, these effort levels are larger in Max4 than in Ave4. This finding highlights the need to refine our third result in which we state that controlling for wage level, workers provide lower effort levels under Max4 and Min4 than under Ave4.

Given Figure 2, we could say that the support of the econometric analysis to Result 3 comes mainly from low wage levels. When we look at workers' behavior under high wage levels, we observe that in Max4 effort levels are larger than in Ave4. This result supports the idea that the "responsibility alleviation" effect might appear only with low wages. The intuition for this is as follows. In the Max technology, a firm may offer high wage to just one worker in order to get a large output (implemented effort) without incurring "unnecessary" high cost. Thus, when a worker receives low wage he think that another worker received a higher wage than his.

So, the worker with the largest wage has the responsibility of to provide the highest effort level in the group. This possibility did not appear in Ave4 since all effort levels are decisive in computing the firm's profit. However, when a worker receives a high wage in Max4, the "responsibility alleviation" might not play a role. If a worker is receiving a high wage, contrary to the case of the low wage, he may think that he is the worker with the highest wage in the team, so he is responsible for the final outcome of the firm. If this is so, then the "responsibility alleviation" effect should disappear for higher wages, and workers should provide similar effort levels in Ave4 and Max4. This is exactly what we observe in Table 6, which displays the same econometric analysis as specification (2) in Table 5 but using only a subsample in which we restrict data to wages above 8.

**Table 6: GLS Random Effects Regression on Effort, n=4 w>8**

| | (1) |
|---|---|
| $Wage_t$ | 0.099***<br>(0.013) |
| $Effort_{t-1}$ | 0.194***<br>(0.039) |
| $Wage_{t-1}$ | -0.017<br>(0.011) |
| T-Max | 0.511<br>(0.441) |
| T-Ave | -- |
| T-Min | 0.338<br>(0.482) |
| Constant | 1.154***<br>(0.453) |
| R-squared | 0.165 |
| N | 708 |

Notes: ***, **, * denote significance at $p$ = 0.01, 0.05, and 0.10, respectively. Robust standard errors are in parentheses.

In Table 6 we also observe that workers provide similar effort levels in Ave4 and Min4, meaning that Result 3 for Ave4 and Min4 comes mainly from low wages too. The intuition for this is as follows. In contrast to the Max technology, with the Min technology, it makes less sense to expect that a firm will offer high wage to just one worker. Consequently, when a worker receives a low wage in Min4, he may think that the other workers have also received low wages, so this worker believes, with high probability, that one of these workers provides a low effort, making it useless to choose high effort. However, when a worker receives a high wage in Min4, contrary to the case of the low wage, he may think that all other workers have also received a high wage, and then, the probability that one of the workers provides a low effort level is small. Thus, choosing a low effort would make the worker responsible for a bad outcome to the firm. If this is so, then the "responsibility alleviation" effect should also disappear, as in the Max4 case, for higher wages.

### *4.3 Production technology's effect on wages*

Turning to wages, results in Table 2 show that in the case of two workers, wages were 6.77, 5.87 and 3.02 in Max2, Ave2 and Min2, respectively. However, differences were significant only for the comparison between Min2 and Ave2 and between Min2 and Max2.[10] In order to analyze deeply the main factors determining wages offered by firms, we consider a GLS random-effects model in which the dependent variable is the average wage offered by the firm. As explanatory variables we introduce the average effort provided by the firm's workers in the previous period ($Effort_{t-1}$), the profit obtained by the firm in the previous period (Firm's $Profit_{t-1}$), a dummy variable which takes value 1 if we are in the Max2 treatment and 0 otherwise (T-Max2), a dummy variable which takes value 1 if we are in the Min2 treatment and 0 otherwise (T-Min2), and a dummy variable which takes value 1 if we are in the Ave2 treatment and 0 otherwise (T-Ave2).

Table 7 shows that the effort level provided by workers in the previous period has a positive and significant effect on wages. The positive effect of previous effort on wages is quite intuitive: if firms are receiving a large effort in one period, they will increase the wage in the next period due to some kind of reciprocity, even when the workers receiving the wage are not the same who provided the effort.

Results in Table 7 also show that the profit obtained by the firm in the previous period have a negative effect on wages. This negative effect is explained as follows: if a firm gets a very small profit in one period, she may try to switch her strategy in order to increase her profits, hence increasing the wage offered to the workers.

Finally, we observe that being in the Max2 treatment (compared to being in the other two treatments) has a positive and significant effect on wages. In the same way, being in the Ave2 treatment (compared to being in the Min2 treatment) leads to higher wages.

[10] Two-tailed Mann-Whitney test are Z=-0.471, p=0.637, for the comparison between Max2 and Ave2; Z=-4.755, p=0.000, for the comparison between Max2 and Min2 and Z=-4.883, p=0.000 for the comparison between Ave2 and Min2.

**Result 4**: *Under Max2, firms assign higher wage levels than in Ave2. Under Min2, firms assign lower wage levels than in the Ave2.*

The intuition behind this result is the following. In all three treatments firms assign wages higher than the Nash prediction.[11] Firms could deviate from NE expecting some kind of reciprocity (i.e., workers providing effort level above the minimum) and then increasing their profits. In this sense, for a similar distribution of effort levels, the a priori probability of obtaining an implemented effort that compensates the wage deviation from NE is higher in the Max2 than in Ave2 and higher in Ave2 than in Min2.

**Table 7: GLS Random Effects Regression on Wage, n = 2**

| | (1) | (2) | (3) |
|---|---|---|---|
| $Effort_{t-1}$ | 1.555*** (0.116) | 1.555*** (0.116) | 1.555*** (0.116) |
| Firm's $Profit_{t-1}$ | -0.244*** (0.014) | -0.244*** (0.014) | -0.244*** (0.014) |
| T-Max2 | 2.796*** (0.538) | 1.062** (0.467) | -- |
| T-Ave2 | 1.734*** (0.528) | -- | -1.062** (0.467) |
| T-Min2 | -- | -1.734*** (0.528) | -2.796*** (0.538) |
| Constant | 3.343*** (0.530) | 5.077*** (0.479) | 6.138*** (0.469) |
| R-squared | 0.323 | 0.323 | 0.323 |
| N | 938 | 938 | 938 |

Notes: ***, **,* denote significance at $p = 0.01$, 0.05, and 0.10, respectively. Robust standard errors are in parentheses.

In the case of four workers, results are similar to the case of two. See Table 8. The main difference is that wages in Ave4 are not significantly different from wages in Min4. Although the previous intuition holds, this lack of significance could be due to the fact that the average wage under the Average production technology is very low for the case of four workers, so there is no room for having significantly lower wages in Min4. The intuition lying behind this low wage level under Ave4 is explained in the next section.

**Table 8: GLS Random effects regression on wage, n=4**

| | (1) | (2) | (3) |
|---|---|---|---|

[11] However, firms also assigned wages that coincided with the Nash equilibrium prediction. In fact, the percentage of times subjects playing NE is 39% in Max2, 32% in Ave2 and 50% in Min2. This also happened for the case of four workers per firm. This percentage is 25% in Max4, 51% in Ave4 and 57% in Min4.

| | | | |
|---|---|---|---|
| $Effort_{t-1}$ | 1.236*** (0.976) | 1.236*** (0.976) | 1.236*** (0.976) |
| Firms' $Profits_{t-1}$ | -0.057*** (0.005) | -0.057*** (0.005) | -0.057*** (0.005) |
| T-Max | 5.004*** (0.673) | 4.672*** (0.659) | -- |
| T-Ave | 0.331 (0.672) | -- | -4.672*** (0.659) |
| T-Min | -- | -0.331 (0.672) | -5.004*** (0.673) |
| Constant | 0.509 (0.541) | 0.841 (0.535) | 5.513*** (0.548) |
| R-squared | 0.374 | 0.374 | 0.374 |
| N | 1023 | 1023 | 1023 |

Notes: ***, **,* denote significance at $p$ = 0.01, 0.05, and 0.10, respectively. Robust standard errors are in parentheses.

### *4.4 Effects of the size of the workforce.*

So far we have analyzed, differentiating by two and four workers per firm, whether having different production technologies has an effect on the firms and workers' decisions. The remaining question is, for a given production technology, whether and how the number of workers per firm influences subjects' behavior.

First at all, we examine whether the size of the labor team has an effect on the firm's profit. In order to provide meaningful comparisons between the profit obtained by the firm with the two different sizes of teams, for a given production technology, we divide the firm's profit by the profit a firm obtains if subjects played the Nash equilibrium (minimum wage and minimum effort). The firm's profit playing Nash equilibrium is 35 in n = 4 and 25 in n = 2. So, we compute this variable as firm's profit/35 if n = 4 and firm's profit/25 if n = 2. See Table 2.

In the case of two workers per firm, Table 2 shows that the percentage of the firm's profit over the potential profit a firm could make by playing the Nash equilibrium is 0.69, 0.71 and 0.77 for Max2, Ave2 and Min2, respectively; and this percentage of profits is 0.98, 0.87 and 0.69 for Max4, Ave4 and Min4, respectively. Two tailed Mann-Whitney tests show that these differences in the percentage of profits are statistically significant with the production technologies under Max and Ave (Z= -3.027, p = 0.003, for the comparison between Max2 and Max4; Z= -6.378, p= 0.000 for the comparison between Ave2 and Ave4 and Z= -0.772, p= 0.439 for the comparison between Min2 and

Min4). This last finding suggests that while some production technologies (Max and Ave) benefit from working with larger teams, others (Min) are not affected.

Next, we analyze whether the size of the workforce has an effect on the effort levels chosen by the workers. In order to do so, we consider a GLS random-effects model in which the dependent variable is the effort level provided by the worker. As explanatory variables we introduce the wage received by the worker in the current period ($Wage_t$), the effort provided by the worker in the previous period ($Effort_{t-1}$), the wage received by the worker in the previous period ($Wage_{t-1}$), a dummy variable which takes value 1 if n=4 and 0 otherwise (n4). Specification (1) uses data from the treatments in which the production technology is the *Maximum*, specification (2) uses data from the treatments in which the production technology is the *Average,* and specification (3) uses data from the treatments in which the production technology is the *Minimum*. The econometric analysis in Table 9 shows that, controlling for the wage, the size of the labor team (n4) does not play a significant role in explaining effort level. This gives rise to our next result.

**Result 5:** *For a given production technology, controlling for wage, the size of the labor force does not have any effect on the effort level chosen by workers.*

**Table 9: GLS Random Effects Regression on Effort**

| | Max (1) | Ave (2) | Min (3) |
|---|---|---|---|
| $Wage_t$ | 0.089***<br>(0.005) | 0.067***<br>(0.008) | 0.089***<br>(0.007) |
| $Effort_{t-1}$ | 0.283***<br>(0.019) | 0.493***<br>(0.018) | 0.179***<br>(0.019) |
| $Wage_{t-1}$ | -0.029***<br>(0.005) | -0.053***<br>(0.007) | -0.024***<br>(0.007) |
| n4 | 0.143<br>(0.103) | -0.020<br>(0.117) | -0.021<br>(0.105) |
| Constant | 1.430***<br>(0.101) | 1.363***<br>(0.117) | 1.800***<br>(0.102) |
| R-squared | 0.218 | 0.268 | 0.125 |
| N | 2072 | 2155 | 1826 |

Notes: ***, **,* denote significance at $p$ = 0.01, 0.05, and 0.10, respectively. Robust standard errors are in parentheses.

Next, we analyze whether the size of the team has an effect on the wages chosen by the firm. Changing the number of workers could lead to the following situation. Let us define the net profit per worker as the profit the firm obtains minus the profit the firm could have obtained by playing the Nash Equilibrium strategy. When the firm deviates from NE, the net profit per worker is negative. This could be considered the cost of having "other regarding preferences." When the size of the labor force increases, and given that the average effort provided by workers does not change but the variance does, we could get the following effect on the wages.[12] Under the *Average* production function, since the implemented effort does not change, the cost of having other regarding preferences increases, leading the firm to reduce her wage levels.

This intuition also holds for case of the *Minimum* production function. Since the net profit per worker is negative, a larger population would increase the cost of having other regarding preferences, leading firms to reduce their wage levels as well. Under the *Maximum* production function, the higher variance associated to a larger labor force leads to a higher implemented effort that reduces the cost of having other regarding preferences. Hence, we should observe that the wages with the *Maximum* production function do not decrease when we increase the number of workers from two to four.

In order to study the effect of the size of the labor force on the firm's decisions, we consider a GLS random-effects model in which the dependent variable is the average wage chosen by the firm. As explanatory variables we introduce the average effort provided by the workers in the previous period ($\text{Effort}_{t-1}$), the percentage of profit obtained by the firm (compared to the profit the firm could have made by playing the Nash equilibrium) in the previous period (% of NE $\text{Profit}_{t-1}$), a dummy variable which takes value 1 if there are four workers with the firm and 0 otherwise (n4). We propose three different specifications. Specification (1) uses data from the treatments in which the production technology is the *Maximum*, specification (2) uses data from the treatments in which the production technology is the *Average*, and specification (3) uses data from the treatments in which the production technology is the *Minimum*.

Results in Table 10 show that, as expected, increasing the number of workers has a negative effect on wages under the *Average* and *Minimum* production technologies and a positive effect under the *Maximum* production technology.

[12] As we have just shown above, the average effort chosen by workers does not change when, for a particular production technology and controlling for the wage level, we switch from two to four workers.

**Result 6:** *We find that an increase in the labor force results in higher wage levels in the* Max *and lower wage levels in the* Ave *and* Min *treatments.*

Results in Table 10 also show that the effort provided by workers in the previous period has a positive effect only under the *Maximum* and *Average* production technologies. This fact is explained as follows. If firms are receiving a large effort in one period, they will increase the wage in the next period due to some kind of reciprocity, even when workers who receive the wage are not the same ones who provided the effort.

The percentage of profits obtained by the firm (over the Nash equilibrium) in the previous period has a negative effect on wages. The explanation for this negative effect is similar to the one in the previous section; that is, a firm may try to switch her strategy by increasing wages offered to workers in order to get larger profits. The lower the previous profit obtained, the larger the interest in changing tendency, and hence, the higher the increase in wages.

**Table 10: GLS Random Effects Regression on Wage**

| | Max (1) | Ave (2) | Min (3) |
|---|---|---|---|
| $Effort_{t-1}$ | 3.507***<br>(0.172) | 1.264***<br>(0.116) | 0.116<br>(0.113) |
| % of NE $Profit_{t-1}$ | -4.717***<br>(0.278) | -5.708***<br>(0.316) | -5.091***<br>(0.329) |
| n4 | 1.274**<br>(0.572) | -1.745***<br>(0.421) | -0.692**<br>(0.356) |
| Constant | 0.121<br>(0.556) | 5.659***<br>(0.449) | 6.035***<br>(0.515) |
| R-squared | 0.491 | 0.361 | 0.345 |
| N | 686 | 720 | 555 |

Notes: ***, **,* denote significance at p = 0.01, 0.05, and 0.10, respectively. Robust standard errors are in parentheses.

## 5. Conclusions

Our paper is the first direct experimental study of team size and technology on employer-worker (principal-agent) relationships. We specifically analyze if and to what extent previous findings of trust and reciprocity depend on critical characteristics such as production technology and the number of workers per firm.

Our main findings are: first, cooperation in the form of trust and reciprocity still holds between a principal and a team of workers. A positive relationship between wages offered and effort exists regardless of the production technology used. Second, we also observe that when production technologies intensify *free-riding* and/or *coordination* problems, as in the *Maximum* and *Minimum* cases, workers provide lower effort levels. This result suggests that production technologies that increase such problems could reduce reciprocity of workers towards their firm. Finally, the firm reacts to the final outcome and not to the efforts provided by their workers. We find that firms offer the highest wage levels with the *Maximum,* and the lowest wage levels with the *Minimum,* production technology. Moreover, an increase in team size results in higher wages only with the *Maximum* production technology.

We use *strangers- matching protocol* although a vast majority of real life labor relationships are long-term and more complex than those analyzed here. For example: i) principals may, or may not, be able to monitor workers; ii) workers may, or may not, be able to monitor other workers on their team; and iii) reputation may play a role. These additional features may affect the behavior of firms and/or workers. A repeated game setting would allow us to study this richer environment and is left for our future research. Still, our strangers-matching protocol has allowed us to isolate the impact and importance of team size and production technology on trust and reciprocity (and non-Nash equilibrium cooperation) in principal-agent relationships.

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