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Spillover Effects of Minimum Wages: Theory and Experimental Evidence

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Abstract

We study the spillover effects of minimum wages in a laboratory experiment. In a bilateral firm-worker bargaining setting, we find that the introduction of a minimum wage exerts upward pressure on wages even if the minimum wage is too low to be a binding restriction. Furthermore, raising the minimum wage to a binding level increases the bargained wage above the new minimum wage level. While the Nash solution cannot explain the existence of spillover effects, the Kalai-Smorodinsky solution yields results that are qualitatively more in line with our experimental findings.

JEL-Code: C710, C910, J380.

Keywords: minimum wage, bargaining, Kalai-Smorodinsky solution, labor market experiments.

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1. Introduction

A central concern in labor economics is to understand the social consequences of minimum wages. The general question whether a minimum wage should be introduced or increased is much debated. A recurring issue in this discussion is the magnitude of so-called spillover effects. Although only a relatively small percentage of the workforce will gain directly from the introduction of, or a rise in, the minimum wage, there is substantial empirical evidence that minimum wages have spillover effects, i.e. that they exert upward pressure on wages higher up in the wage distribution (Card and Krueger 1995, Katz and Krueger 1992).

A number of empirical studies have addressed the issue of spillover effects of minimum wages.[1] Grossman (1983) shows that an increase in the minimum wage increases the wages of occupations above the new minimum wage, at least in the short run. Katz and Krueger (1992) study the effect of the increase in the US federal minimum wage on fast-food restaurants in Texas. They find that about one-third of surveyed restaurants reacted to the minimum wage increase by maintaining their wage hierarchy, which means that the wages of workers who used to earn more than the old minimum wage are raised to a level exceeding the new minimum wage. Among firms in which the starting wage was already above the new minimum wage, 60 percent reacted to the higher minimum wage by raising their wages even further. DiNardo et al. (1996), Lee (1999), and Manning (2003) examine changes in the US distribution of wages and find evidence of spillover effects above the minimum wage. Neumark et al. (2004) estimate the impact of changes in the US minimum wage on the wages of workers already earning more than the new minimum. To control for contemporaneous general wage growth, they compare workers in states in which the minimum wage was raised to workers at the same position in the wage distribution in states in which the minimum wage stayed constant. Their results are indicative of substantial short-run spillovers to higher wage groups. For workers with wages close to the new minimum wage, the wage elasticity with respect to the minimum wage is 0.8. This elasticity is smaller for higher wage groups, but still amounts to 0.15 for workers who earn between 1.5 and two times the minimum wage.

Two important stylized facts on spillover effects of minimum wages emerge from the empirical literature:

[1] Comprehensive reviews of the empirical literature on spillover effects of minimum wages are provided by Card and Krueger (1995, Ch. 5) and Neumark and Wascher (2008, Ch. 4).

1. a substantial number of firms raise the wages of workers that used to earn less than the new minimum wage above the minimum level required, and

2. it seems to be common practice that workers already earning wages above the new minimum wage receive wage raises as well.

The empirically observed spillover effects can occur for a number of reasons and can be explained by different theoretical models of the labor market. A first potential explanation builds on changes in the relative price of low-skilled labor. If workers have different productivities, the introduction of a minimum wage might directly affect the wage of low-skilled workers. This causes a shift in labor demand since firms will substitute workers with productivity above the new minimum wage for workers with lower productivities, resulting in higher wages for workers who were already better-paid (Pettengill 1981). A second explanation can be derived in equilibrium search models with monopsonistic firm behavior. Manning (2003) shows that, in a modified Burdett-Mortensen (1998) framework, firms that previously paid relatively high wages to attract workers from low-wage firms can – following the introduction of a relatively low minimum wage – only hire employees if they increase their wages too. Third, spillover effects can arise in efficiency wage models. Grossman (1983) develops a model with skilled and unskilled labor in which the effort exerted by skilled workers depends on their wage relative to that received by unskilled workers. An increase in the legal minimum wage raises the wages of unskilled workers. The smaller wage differential between skilled and unskilled work reduces skilled workers' effort, so that firms have to increase the wage received by higher-paid workers as well.

All of these theoretical explanations might play a role in explaining spillover effects in real labor markets. However, there is substantial evidence that spillover effects are even more universal and also occur in situations which cannot be characterized by maintaining an internal wage hierarchy, ensuring competitive wages compared to other firms, or preserving incentives for effort. In an experimental study by Falk et al. (2006), the aforementioned factors are excluded by design. In their laboratory experiment, a rent is shared between participants acting as "workers" and "firms". Firms set a wage which leads to the creation and distribution of a rent if it exceeds the reservation wage set in advance by workers. The introduction of a minimum wage affects the labor market equilibrium by raising workers' reservation wages often even above the new minimum. This pushes equilibrium wages above the new minimum as well. Similar findings are reported by Brandts and Charness (2004) who show experimentally that the introduction of a minimum wage, even if it is non-binding, affects workers' effort

provision negatively. Both experimental studies point to the existence of menu dependence (Sen 1997): changes in the range of wages that are potentially attainable for both sides can affect the wage determination process even if they were not chosen in equilibrium.

In this paper, we build on the recent experimental evidence of spillover effects. We conduct a laboratory experiment with homogeneous workers and bilateral wage bargaining in which a minimum wage is introduced and subsequently increased. Similar to Falk et al. (2006), we therefore exclude the standard explanations for spillover effects by our experimental design. In contrast to Falk et al. (2006), however, the wage in our labor market setting is determined by bilateral bargaining between workers and firms.[2] Our experimental results confirm the stylized facts known from the empirical literature. First, the introduction of a minimum wage at a low level leads to higher wages even if wages were initially already above the minimum wage. Second, raising the minimum wage above the level observed in the absence of minimum wages lifts most wages not only to this new minimum, but even higher. Obviously, these spillover effects cannot be explained by standard wage hierarchies or effort provision models since we have explicitly excluded these effects by the design of our experiment. To explain our findings, we make use of bargaining theory and compare the effects of minimum wages in two well-known bargaining solutions. We show that the commonly used Nash solution is unable to explain these findings, but the application of the Kalai-Smorodinsky solution can provide a theoretical foundation for the existence of spillover effects.[3] Quantitatively, however, neither the Nash nor the Kalai-Smorodinsky solutions are able to give a sufficiently precise description of the actual bargaining outcome.

We will proceed as follows. In section 2, we present the experimental design. Section 3 discusses how the introduction of and subsequent increases in the minimum wage affect the wage distribution in our bargaining experiment. Section 4 compares the experimental results with theoretical bargaining solutions when bargaining follows either the Nash or the Kalai-Smorodinsky solution. Section 5 concludes.

[2] Therewith, we cover the stylized fact that labor markets in many OECD countries are characterized by minimum wages as well as individual or collective wage bargaining.
[3] Dittrich and Knabe (2010) provide an application of this theoretical reasoning in a union bargaining framework.

2. Experimental design

In this section, we give a brief overview on the related literature on minimum wage experiments. We then describe the experimental design and provide information on the treatments and the procedures of our experiment.

Related literature

In addition to the empirical observations described above, the impact of minimum wages was examined in laboratory experiments. Falk et al. (2006) explore potential driving forces behind the observed spillover effects. In their experimental labor market setting, a firm offers a wage to three potential employees. The firm only makes one (non-discriminating) offer. Each worker can either accept or reject the firm's offer. If the worker accepts, he receives the wage, while he receives nothing when rejecting the firm's offer. Firm's profit is total revenue minus the wages. After each round, all players are informed about both the firm's and workers' payoffs. Moreover, Falk et al. (2006) used the strategy method to elicit workers' individual acceptance threshold, i. e. the lowest wage offer they would accept. Before workers were informed about the actual wage offer, they had to indicate their reservation wages which remained private information. Workers were then separated into three groups with a high, an intermediate and a low reservation wage, respectively. After this, one worker from each group was randomly matched with one firm.

To analyze the impact of minimum wages, Falk et al. (2006) played two different settings. In the first setting, there was no minimum wage, while a binding minimum wage was introduced in the second setting. Both settings were played for 15 periods. The majority of wages in the first setting was below the level at which the minimum wage was introduced in the second setting. Similar to the observations in the empirical literature, the introduction of the minimum wage shifted the entire wage structure upwards and lifted most wages above the minimum wage level. Falk et al. (2006) argue that the set of feasible alternatives affect workers perception of a fair wage offer and hence their reservation wages. If minimum wages increase the lowest possible wage offer a firm can make, the same offer by the firm might appear less generous to the worker. For example, a wage offer of EUR 8 per hour might be judged as fair in the absence of a minimum wage because the firm could have offered much less. If the same offer was made while the minimum wage was at EUR 8 as well, however, workers might consider this wage offer as rather unfair. Taking this into account, higher min-

imum wages raise reservation wages, which leads firms to offer wages above the minimum wage.

A similar argument can be found in the experimental study of Brandts and Charness (2004). They apply a gift exchange game with both variable effort in the labor market and variable quality in the goods market. In the labor market, the firm offers a wage whose level can be seen as a gift. Afterwards, the workers choose their effort levels, thereby implicitly deciding on the extent of the returned gift. The income of the firm consists of its endowment minus the wage plus 5 times the effort level. The income of the worker consists of the endowment minus the effort level plus 5 times the wage. In stage one, firms' offers were written on a blackboard and hence were public information. The minimum wage was introduced at a level of half of the endowment. Workers had to choose one of the offers made. In stage two, each worker wrote his effort level on a prepared form which was only communicated to the respective firm. There was no possibility for a worker to reject an offer. After introducing the minimum wage, Brandts and Charness (2004) find that effort decreased. Given the same wage level workers showed lower effort. Since the introduction of the minimum wage forced firms to be more "generous", their feasible alternatives have been reduced and affected the workers' perception of fairness, and thus their effort levels, negatively. This effect could also be shown to arise for very low, non-binding minimum wages.

Experimental wage negotiations

In our experiment, a "worker" and a "firm" bargain over the division of a rent. Participants are told that the firm is offered a contract by some customer worth 300 experimental currency units ("tokens"). To fulfill the contract, it needs to hire a worker. There is only one, currently unemployed worker available, with which the firm has to agree on a wage before hiring. The rent of 300 tokens can be split between the firm and the worker via bargaining over the worker's wage w. If there is a bargaining agreement, the worker is hired by the firm and the contract is carried out. The worker receives the bargained wage w and the firm's profit is $300 - w$. If bargaining breaks down, the firm is assumed to have some alternative production possibility. This outside option, for which employing the worker is not needed, generates a payoff of 110 tokens for the firm. The worker stays unemployed and receives nothing, i.e. his outside option is assumed to be zero.

In contrast to Falk et al. (2006) and Brandts and Charness (2004), the wage is determined via alternating-offers bargaining (as in Rubinstein 1982). In the first round, the firm offers a

wage which can be accepted or rejected by the worker. If the worker accepts the offer, he will be hired, the output is produced and the game ends. If the worker rejects, he can make a counteroffer in round 2 which can then be accepted or rejected by the firm. Bargaining is over if an offer is accepted in any round or if bargaining breaks down exogenously after an offer has been rejected. The probability of such a breakdown is 20 percent for each bargaining round in which an offer is rejected. To give the participants the chance to make their first offer and counteroffer without having to fear the breakdown of negotiations, rejections could only lead to breakdowns after round 3.

Subjects and procedures

The experiments were conducted during one day at TU Dresden with a total of 122 participants. All participants were undergraduate students with various majors. Before the start of the experiment, half of the subjects were randomly assigned to the role of a worker and the others to the role of a firm. These roles remained fixed for the whole experiment. Each participant bargained in 20 separate negotiations ("periods"). The right to make the first offer alternated after a negotiation concluded, i. e. in period 1 the firm made the first offer, in period 2 the worker made the first offer, and so on. Subjects were randomly matched into bargaining pairs (one worker, one firm) in each period and could only sign a wage agreement within their respective pair. Participants were randomly re-matched after each period.

To make sure that the subjects understood the bargaining procedures and the payoff consequences of their actions, each subject was given a detailed set of instructions before the experiment started. The players were asked to read through the written instructions. Afterwards, each participant had the possibility to ask questions. These were answered privately by the experimenter. No additional questions were answered and any form of uncontrolled communication was made impossible during the actual experiment. Whenever the players had to act, they had to fill out prepared forms. The basic setup was as follows: In round 1, the first player offered a wage by entering the offer into the prepared form. Then the form was passed to the other player and round 2 started. Now the other player could either put a check mark in a specific box if he accepts the wage offered or he could enter a new wage in the form. Again the form was passed to the first player. This procedure went on until an agreement was reached or bargaining broke down.

Treatments

We conducted five treatments directly one after another, where each treatment was played for four periods, respectively. In each period, the worker and the firm bargained over the wage via alternating offers as described above. The various treatments only differed in the level of the legal minimum wage. Treatment 1 (periods 1-4) had no minimum wage, i.e. the range of permissible wages was $0 \leq w \leq 300$. In treatment 2 (periods 5-8), a minimum wage of 70 tokens was introduced. Even though wages below the minimum could be offered, the eventual agreement had to obey the wage constraint $70 \leq w \leq 300$. Agreements below the minimum wage were regarded as breakdowns. However, the minimum wage of 70 was a non-binding restriction for almost all wage agreements in setting 1. In treatment 3 (periods 9-12), the minimum wage was raised to 95. Again, this minimum was non-binding for most wage agreements in the previous periods. In treatment 4 (periods 13-16), the minimum wage was raised to 160 implying a binding restriction for most wage agreements in previous periods. Finally, the minimum wage was abolished in treatment 5 (periods 17-20).[4]

Payments

The exchange rate between tokens and real money was 50 tokens = EUR 1 (US $ 1.35). Hence, the rent which was bargained over in each period by the worker and the firm had a value of EUR 6. At the end of the experiment, one out of the four bargaining agreements in each treatment was randomly chosen. These agreements were relevant for the payoffs in the respective treatment. The experiment lasted approximately 90 minutes and subjects earned on average EUR 17.50, including a show-up fee of EUR 6.[5] All participants were paid in cash directly after the experiment.

Hypotheses

Based on the stylized facts of the empirical literature described in section 1, we formulate two hypotheses to be tested in our experiment:

Hypothesis 1: *The introduction of a non-binding minimum wage will raise the bargained wage.*

[4] Due to time restrictions when conducting the experiment, 30 students participated in treatments 3 to 5 only for two instead of four periods. We checked that our results are robust to excluding this group from the analysis and also to restricting our analysis to the periods in which all subjects participated.
[5] The comparable market wage for undergraduate students in Dresden is approximately EUR 8 per hour.

Treatment 2 will be most relevant for testing Hypothesis 1. The minimum wage of 70 is below the level of wages that one would expect to see in this experiment even in the absence of minimum wages. If we nevertheless detect an impact of such a low, non-binding minimum wage on the wage distribution, this can be interpreted as evidence for spillover effects. As we will see when we discuss the results, also the minimum wage of 95 (Treatment 3) is too low to be a binding restriction for most negotiations. Hence, examining the switch between Treatments 2 and 3 allows to draw conclusions about the existence of spillover effects when raising (as compared to introducing) a minimum wage.

Hypothesis 2: *The introduction of a binding minimum wage will raise the wage to a level above the minimum wage.*

Treatment 4 serves to test our second hypothesis. The minimum wage of 160 is above the wage levels we expect to arise without minimum wages. Hence, it constitutes a binding restriction on most negotiations. If actual bargaining outcomes are found above the level of 160 in this treatment, this would constitute evidence in support of spillover effects of binding minimum wages.

3. Results

We now turn to the results of our experiment. In the first subsection, we discuss how the introduction of minimum wages at a relatively low level and subsequent increases in the minimum wage affect the wage distribution arising in our bargaining experiment. This should give us a clear indication whether minimum wages have spillover effects or not. In the second subsection, we provide further evidence on how the two parties approach the negotiations under the presence of minimum wages. In particular, we will analyze how each side's first offer and the respective counteroffer are affected by the minimum wage. This helps to shed light on the mechanisms driving the impact of minimum wages on the wage bargain.

3.1 Minimum wages and the wage distribution

Table 1 and Figure 1 present descriptive statistics and histograms of the wage distribution in the five different treatments. There is no minimum wage in the first treatment. 90% of all bargained wages are in the interval between 100 and 150, which correspond to payoffs for the employer between 200 and 150, respectively. The lowest observed wage is 35, the highest is

165. The median wage is at 130, the mean wage at 124.40. This corresponds to a median payoff of 170 and a mean payoff of 175.54 for the employers. That illustrates that the employers' outside option of 110 does not act as a binding constraint on the bargaining outcome, but instead improves the employers' bargaining position and raises their average payoff clearly above the equal-split solution of 150.

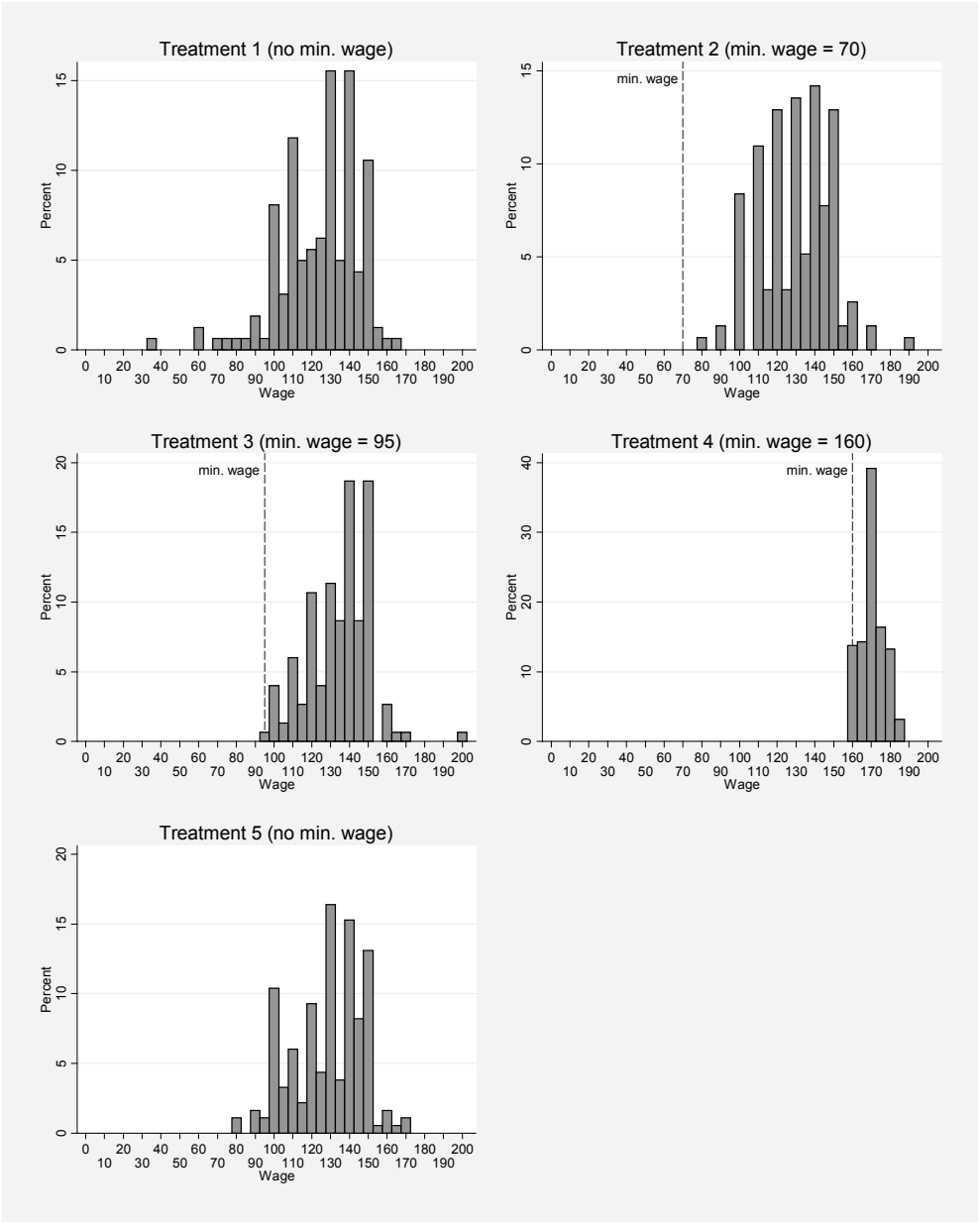
Table 1: Bargaining outcomes

treatment	minimum wage	mean	s.e. of the mean	percentiles 10	25	50 (median)	75	90
1	-	124.40	2.00	100	110	130	140	150
2	70	129.93	2.14	100	119	130	145	150
3	95	134.47	1.85	110	121	139	145	150
4	160	170.43	0.58	161	165	170	175	180
5	-	128.68	2.23	100	115	130	145	150

Note: standard errors clustered at the individual ("employer") level (62 clusters).

In Treatment 2, a minimum wage of 70 is introduced. Based on the wage distribution of Treatment 1, this minimum wage is binding for less than 2 percent of wages. Even though the minimum wage of 70 prohibits only very low wage levels that were only very rarely observed in Treatment 1, it affects the entire wage distribution. The mean of the wage distribution shifts up from 124.40 to 129.93. The wage distribution shifts at the lower and the upper end. The 25^{th} percentile increases from 110 to 119, the 75^{th} percentile from 140 to 145. Due to the concentration of bargaining outcomes at prominent numbers, wages at the 10^{th}, 50^{th} and 90^{th} percentiles do not change. Figure 1 shows that even though a few negotiations agreed to wages below 70 in Treatment 1, even the lowest wage agreement in Treatment 2 is strictly larger than the minimum wage.

Figure 1: Wage distribution with and without minimum wages



We conduct various statistical tests to check whether the shift in the wage distribution following the introduction of the minimum wage is statistically significant. As Table 2 shows, a t-test of the equality of means shows that mean wages differ significantly between Treatments 1 and 2 ($p < .01$).[6] We also run a linear regression, where we regress bargaining outcomes on dummy variables for the five different treatments and add individual fixed effects. The regres-

[6] To take into account that observations within and across treatments are obtained from a limited number of participants, we calculated clustered standard errors at the individual level. In about 3% of the negotiations, one of the bargaining parties forgot to write their preassigned ID on the negotiation form. We assigned all unknown IDs to one cluster, so that we obtained 62 clusters for individuals acting as employers and 62 clusters for employees. We checked that clustering of standard errors at the level of employers yields qualitatively equivalent results to clustering at the level of employees.

sion results also support the claim that mean bargaining outcomes were shifted upwards between Treatments 1 and 2.[7] Since the Shapiro-Wilk-test and the one-sample Kolmogorov-Smirnov-test reject the hypothesis that bargained wages are normally distributed, we also apply the non-parametric Wilcoxon matched-pairs signed-ranks test. We calculate mean bargaining outcomes for each participant under each treatment and compare them across Treatments 1 and 2. This test also rejects the hypothesis that the wage distributions under both treatments are the same.

Since a few wages in Treatment 1 are below the minimum wage in Treatment 2, the mean wage and the wage distribution under both treatments could differ even if there were no spillover effects. It would suffice that these very low wages would be raised to the new minimum wage level. When we compare the means and wage distributions of Treatments 1 and 2 and exclude all observations in Treatment 1 that were below the new minimum wage of 70 (not reported in Table 2), the distributions become more similar, but the t-test and the Wilcoxon signed-ranks test still reject the equality hypothesis ($p < .1$).

In Treatment 3, the minimum wage is raised to 95. This minimum wage level is still very low relative to the wage distributions observed under Treatments 1 and 2. In Treatment 1, only 6 percent of wage negotiations were below this new minimum wage level. Compared to Treatment 2, where the minimum wage was already at 70, only 2 percent of the bargaining outcomes would be affected by this increase in the minimum wage. Despite its small "bite", the new minimum wage shifts up the entire wage distribution even further. Only one bargaining pair (< 1 percent) ends up at exactly the new minimum wage. The new mean wage is 134.47. The 10^{th} and 25^{th} percentiles and the median of the wage distribution increase compared to Treatment 2. All three statistical tests in Table 2 reject the hypothesis that the wage distribution was not affected by the increase in the minimum wage from 70 to 95.

Table 2: Hypotheses tests concerning bargaining outcomes

Hypothesis	t-test (no further controls)	t-test (controlling for individual fixed effects)	Wilcoxon matched-pairs signed-ranks test
Treatment 1 = Treatment 2	0.007	0.046	0.009
Treatment 2 = Treatment 3	0.024	0.008	0.083
Treatment 3 = Treatment 4	0.000	0.000	0.000
Treatment 5 = Treatment 1	0.069	0.166	0.025
mean of Treatment 4 = 160	0.000	0.000	0.000

Note: p-values reported, clustering at the individual ("employer") level (62 clusters).

[7] The complete regression results are presented in the Appendix.

We raise the minimum wage to 160 in Treatment 4. This level constitutes a binding constraint for most bargaining outcomes observed in Treatments 1-3. 99%, 95%, and 95% of observed bargaining outcomes were below the new minimum wage level of 160 in Treatments 1, 2, and 3, respectively. Figure 1 shows that, at this relatively high minimum wage, bargaining outcomes are located in the rather narrow interval between 160 and 185. Despite the fact that the vast majority of bargained wages were strictly below the minimum wage before it was raised, less than 10% of the bargaining outcomes in Treatment 4 are exactly at 160, and only about 15 percent are below 165. The mean, median and the mode of the wage distribution are all at about 170. The statistical tests presented in Table 2 also support the hypotheses that the wage distribution in Treatment 4 differs significantly from that in Treatment 3 and, more importantly, that its mean and median differ significantly from the minimum wage of 160. This suggests that the minimum wage produces strong spillover effects in our experimental bargaining setting. Looking at the wage distribution in Treatment 1, one could expect that a minimum wage of 160 would lead to a large spike at exactly 160. Instead, most wages are driven strictly above this minimum wage level.

The results of Treatments 1-4 provide strong evidence that minimum wages cause substantial spillover effects if wages are bargained over. Even very low minimum wages cause an upward shift of the entire wage distribution. We do not observe that minimum wages, not even at rather high levels, result in a spike in the distribution at the minimum wage level. This suggests that the minimum wage does not simply truncate the wage distribution at the bottom end, but instead acts as a lower limit to the interval of wages over which the employer and the employee bargain. The actual bargaining outcome is found somewhere inside this interval, such that the minimum wage occurs only rarely as a bargaining outcome. We will return to this point later.

In Treatment 5, we abolish the minimum wage again. A quick glance at Figure 1 shows that the wage distribution shifts downwards and returns to a position similar to that in Treatment 1. Even though Treatment 1 and 5 are equivalent with respect to all parameters relevant to the negotiation (rent, outside options, minimum wage), the mean wage and the wage distribution differ significantly between both treatments. This finding is supportive of the results of Falk et al. (2006), who also find that the wage increase occurring when a minimum wage is introduced is larger than the reduction in wages when this minimum wage is abolished. Our findings differ from those of Falk et al. (2006) in that we have the same subjects (although in different bargaining pairs) playing the entire sequence of the introduction and later elimina-

tion of the minimum wage. Falk et al. (2006) played two different treatments with different groups of subjects – one that started without a minimum wage but had it introduced halfway through the experiment, and another one that started with a minimum wage and abolished it later. Since subjects in our experiment could still remember how they behaved in Treatment 1 when Treatment 5 starts, it does not come as a surprise that both treatments yield rather similar results. Nevertheless, the differences are large enough to be statistically significant.

3.2 Is there a first-mover advantage?

Our experimental bargaining game is set up in a way that is similar to a Rubinstein (1982) alternating-offers game; it gives an advantage to the party making the first offer. This first-mover advantage does not play a role in the first two rounds of offers and counteroffers, because there is no risk that bargaining breaks down if the side receiving an offer does not accept it. Thus, there is no pressure on the bargaining parties to come to an agreement immediately. Nevertheless, nothing prevents the bargainers from agreeing on an offer made in the first two rounds. In fact, we observe that about 8 percent of all agreements are struck in rounds 1 or 2.

If a negotiation reaches round 3, it is again the side's turn that had to make the very first offer. From this round on, however, the respective responder knows that rejecting an offer can lead to the breakdown of the negotiation with a probability of 20 percent, in which case each side receives only its outside option. Both bargainers have a mutual incentive to agree as quickly as possible to avoid the risk of losing their common rent. Rational bargaining should conclude immediately once the negotiation reaches round 3. In our experiment, 20 percent of all agreements were made in round 3. Only a fifth of all agreements were struck after round 5.

As is well-known from the model of Rubinstein (1982), the threat of a random breakdown of the negotiation should the responder reject gives the proposer a first-mover advantage. The proposer can reduce his offer to the responder's expected value from rejecting and making a counteroffer that the other side is willing to accept. In our experiment, this first-mover advantage should result in lower bargained wages when an employer makes the first offer than in the cases where it is the employee's turn to make the first move.

Table 3: First-mover advantage?

treatment	minimum wage	first mover = employer		first mover = employee		significance of difference between	
		mean	median	mean	median	means (t-test; p-values)	distributions (Wilcoxon matched-pairs signed-ranks test; p-values)
1	-	123.9	130	125.1	130	0.71	0.97
2	70	130.2	130	129.7	130	0.79	0.10
3	95	132.9	135	137.4	140	0.08	0.45
4	160	169.7	170	171.1	170	0.11	0.31
5	-	127.6	130	129.8	130	0.28	0.49

Note: p-values are calculated with clustering at the individual ("employer") level (62 clusters).

Table 3 shows how bargained wages differ when employers or employees make the first offer. Except for Treatment 2, mean wages are always higher when employees make the first offer. The median wage differs only in Treatment 3, where it is also higher when the employee is the first mover. In most cases, the differences between mean wages and between wage distributions are not statistically significant. In the case where the t-test suggests that the means are statistically different, the Wilcoxon test does not produce sufficient evidence to reject the hypothesis that the distributions of wages are the same, and vice versa. Overall, these results suggest that the bargainers are not able to exploit a potential first-mover advantage in our experiment.

3.3 Minimum wages and initial offers

To understand why even minimum wages that are far below actually observed wages affect the bargaining outcome, it is helpful to take a look at how both bargaining parties approach each other in the different treatments of our experiment. In the first two bargaining rounds of each period, neither party has to fear that a rejection of its offer or counteroffer leads to a breakdown of the negotiation. Hence, there is no pressure to make offers or counteroffers that are immediately acceptable to the other side. In our experiment, we observe that both parties use this opportunity to state claims that are substantially more favorable to them than the later bargaining outcome. Even the 90^{th} percentile of all wages offered by employers in the first round is lower than the median of eventual wage agreements. Similarly, the 10^{th} percentile of wages demanded by employees in their first offers is above the later median wage. Even though the wages stated in the first two rounds of each period are, in principle, of no imme-

diate consequence for the bargainers' choices in later rounds, we observe that the wages stated in the first two rounds fix the bounds of the wage interval in which both parties make mutual concessions in later rounds. In more than 90 percent of all cases, employers raise their subsequent offer compared to their previous bid and only in 3.6 percent of all cases do they reduce it. Likewise, employees reduced their previously demanded wage two rounds later in 85 percent of all cases and increased it in only three percent of all offers. Only in five percent of all negotiations did one of the parties make a bid in later rounds that was outside the interval demarcated in the first two rounds. This suggests that the choice of first offers and counteroffers is informative about how both parties approach the negotiation and what they hope to get out of it.

Table 4: Distribution of wages offered by employers in first round

treatment	minimum wage	mean	s.e. of the mean	percentiles 10	25	50 (median)	75	90
1	-	79.37	3.68	36	60	80	100	115.5
2	70	83.29	2.76	70	70	80	100	110
3	95	103.15	1.96	95	95	100	110	120
4	160	158.76	2.05	160	160	160	165	170
5	-	82.22	5.07	10	60	90	110	125

Note: standard errors clustered at the individual ("employer") level (62 clusters).

Hypothesis	t-test (no further controls)	t-test (controlling for individual fixed effects)	Wilcoxon matched-pairs signed-ranks test
Treatment 1 = Treatment 2	0.247	0.392	0.227
Treatment 2 = Treatment 3	0.000	0.000	0.000
Treatment 3 = Treatment 4	0.000	0.000	0.000
Treatment 5 = Treatment 1	0.523	0.936	0.924

Note: p-values reported, clustering at the individual ("employer") level (62 clusters).

The distribution of wages offered in the first round when the employers start the negotiation is summarized in Table 4. Compared to the results in Table 1, one sees that the first wage offers are substantially lower than eventual wage agreements. Even the 90th percentile of wage offers is less than the eventual mean and median wage agreements. If we compare the different treatments, we see that the introduction and raises of the minimum wage shift the mean first offer upwards. Looking at the entire distribution, the shift in the mean wage offer seems to be driven by shifts at the lower end of the wage distribution. The lowest 25 percent

of first wage offers in Treatment 1 were below 60, and thus also below the minimum wage in Treatment 2. When the minimum wage is introduced, the lower end of the distribution is pushed upwards towards the new minimum. One should keep in mind that the minimum wage applies only to eventual outcomes. There are no provisions that prevent employers' to offer a wage below the minimum in intermediate bargaining rounds. In our experiment, 6.8 percent of first wage offers are below the minimum wage in Treatment 2. The shift in the distribution of first offers is, however, statistically insignificant.

Increasing the minimum wage to 95 shifts the distribution of first offers even further upwards (Treatment 3). This increase in the minimum wage does not only affect the bottom of the distribution, but also shifts the upper part upwards. The change in the distribution is statistically significant according to all three tests used. Increasing the minimum wage to 160 shifts the wage distribution further upwards. In Treatment 4, 65 percent of all initial wage offers are at exactly 160. Abolishing the minimum wage in Treatment 5 causes wage offers to fall substantially. The difference between the distributions of first offers in Treatments 1 and 5 is not statistically significant.

Table 5: Distribution of wages demanded by employees in first round

treatment	minimum wage	mean	s.e. of the mean	percentiles 10	25	50 (median)	75	90
1	-	171.48	3.26	140	150	175	190	200
2	70	171.10	3.17	140	150	170	190	200
3	95	167.66	2.99	140	150	170	180	200
4	160	190.35	2.03	175	180	189	200	200
5	-	168.63	3.19	143	150	170	180	200

Note: standard errors clustered at the individual ("employee") level (62 clusters).

Hypothesis	t-test (no further controls)	t-test (controlling for individual fixed effects)	Wilcoxon matched-pairs signed-ranks test
Treatment 1 = Treatment 2	0.878	0.573	0.029
Treatment 2 = Treatment 3	0.140	0.453	0.150
Treatment 3 = Treatment 4	0.000	0.000	0.000
Treatment 5 = Treatment 1	0.444	0.552	0.296

Note: p-values reported, clustering at the individual ("employee") level (62 clusters).

The wages demanded by employees when they can make the first offer do not appear to be affected by very low minimum wages. In most cases, mean wage demands and the distribution of demanded wages do not exhibit statistically significant differences between Treat-

ments 1, 2, 3, and 5. Only in Treatment 4, when the minimum wage is very high, do we observe that employees start off the negotiations with relatively high wage demands. This effect is mainly due to increasing wage demands at the bottom of the distribution. The top of the distribution of demanded wages does not change very much.

A similar picture emerges when we look at the counteroffers made in round 2 (Table 6). Even though the initial wage demands of employees are not affected by the minimum wage, employers respond by making higher counteroffers in the presence of a minimum wage. Again, this is mainly due to the necessity seen by employers to offer at least the minimum wage when making a counteroffer (less than 2 percent of the counteroffers are made below the minimum wage in Treatments 2-4). Round 2-counteroffers by employees do not seem to be affected by changes in the minimum wage, except for Treatment 4. If anything, the higher minimum wage and wage offers by employers in Treatment 3 even lead to a reduction of the wage demanded in the employees' counteroffer.

Table 6: Distribution of counteroffers in second round

treatment	minimum wage	mean	s.e. of the mean	percentiles 10	25	50 (median)	75	90
employers' counteroffers								
1	-	90.19	4.23	50	70	90	110	130
2	70	97.15	3.10	70	80	100	115	130
3	95	112.47	2.45	95	100	110	125	140
4	160	164.56	0.74	160	160	165	170	170
5	-	99.80	4.49	50	80	100	122	140
employees' counteroffers								
1	-	161.08	2.68	130	147	160	180	190
2	70	162.71	3.00	130	150	160	180	190
3	95	158.55	2.33	130	145	160	170	180
4	160	187.92	2.38	170	180	185	190	210
5	-	158.35	2.75	130	150	155	175	185

Note: standard errors clustered at the individual level (62 clusters).

The reaction of employers' and employees' initial offers and counteroffers to the changes in the minimum wage suggests a specific channel through which minimum wages affect the wage bargain. Even a low minimum wage forces employers to start the negotiation off less aggressively because it effectively prohibits them from making very low initial offers. It does not seem to affect the initial demands raised by the employees. Hence, it increases only the

lower end of the wage interval demarcated by the first offer-counteroffer-combination. Both bargaining parties then start a process of making mutual concessions. Since the minimum wage forces employers to start at a position less favorable to them, the bargaining process converges towards higher wages. Even if the minimum wage in Treatments 2 and 3 lies far below most wage agreements observed in Treatment 1, the minimum wage forces employers to start approaching employees' wage demands from a higher wage level, thus ending up at higher bargained wages. In Treatment 4, the relatively high minimum wage of 160 means that employers have to start making concessions at this wage level. In the end, most wages are agreed upon at levels strictly above 160. This process of making mutual concessions starting at one's most desired wage level could explain why minimum wages lead to spillover effects if wages are bargained over. In the next section, we will discuss how this reasoning can be captured by theoretical wage bargaining models.

4. Comparison to theoretical bargaining solutions

4.1 Theoretical considerations

We consider two players, $j = \{1,2\}$, who bargain over the partition of a rent. To analyze wage negotiations between firms and workers under the presence of minimum wages, we assume the two players to be a worker $(j = 1)$ and a firm $(j = 2)$. If there is a bargaining agreement, the firm-worker pair produces some output good which generates revenue R. This revenue is split between the firm and the worker, where the worker's share is the wage s_1 and the firm's share is the profit $s_2 = R - s_1$. If no bargaining agreement is reached, the worker and the firm obtain their disagreement payoffs d_1 and d_2, respectively.

The Nash bargaining solution

We first analyze the bargaining outcome of the Nash solution. Nash (1950) specifies four axioms: Pareto efficiency, invariance to equivalent utility representations, symmetry, and independence of irrelevant alternatives. Nash shows that there is precisely one bargaining solution satisfying these axioms. It is described by

$$\max_{s_1, s_2 \in S} \Omega = (s_1 - d_1)(s_2 - d_2) \quad \text{s.t.} \quad s_1 + s_2 \leq R, \tag{1}$$

where Ω is the value of the Nash product. From the maximization problem (1), we obtain

$$s_j^{Nash} = d_j + \frac{1}{2}\left(R - d_1 - d_2\right). \tag{2}$$

The Kalai-Smorodinsky bargaining solution

The plausibility of Nash's IIA axiom has received some criticism (Luce and Raiffa 1957). This controversial axiom states that eliminating some apparently irrelevant alternatives should not change the point picked out by the solution function. Kalai and Smorodinsky (1975) replace this axiom with the property of individual monotonicity. This axiom implies that the players must not suffer from an enlargement of the bargaining set that leaves the maximum utilities attainable by both players unchanged. The KS solution consists of equalizing the players' relative sacrifice of their maximum payoff in excess of their disagreement payoff. It can be described by the so-called KS curve

$$\frac{s_1 - d_1}{s_1^* - d_1} = \frac{s_2 - d_2}{s_2^* - d_2}, \tag{3}$$

where s_j^* denotes the bliss point. The bliss point is the vector of the largest payoffs each player could obtain, given that the other player receives at least his disagreement payoff. It is easy to see that the respective bliss points are given by $s_1^* = R - d_2$ and $s_2^* = R - d_1$. Solving (3) for the optimal payoffs, subject to the constraint $s_1 + s_2 \leq R$, yields

$$s_j^{KS} = d_j + \frac{1}{2}\left(R - d_1 - d_2\right). \tag{4}$$

In this simple model, the KS solution (4) is equivalent to the Nash solution (2). This equivalence arises from the assumption of risk-neutral players but does not hold for a more general utility function.

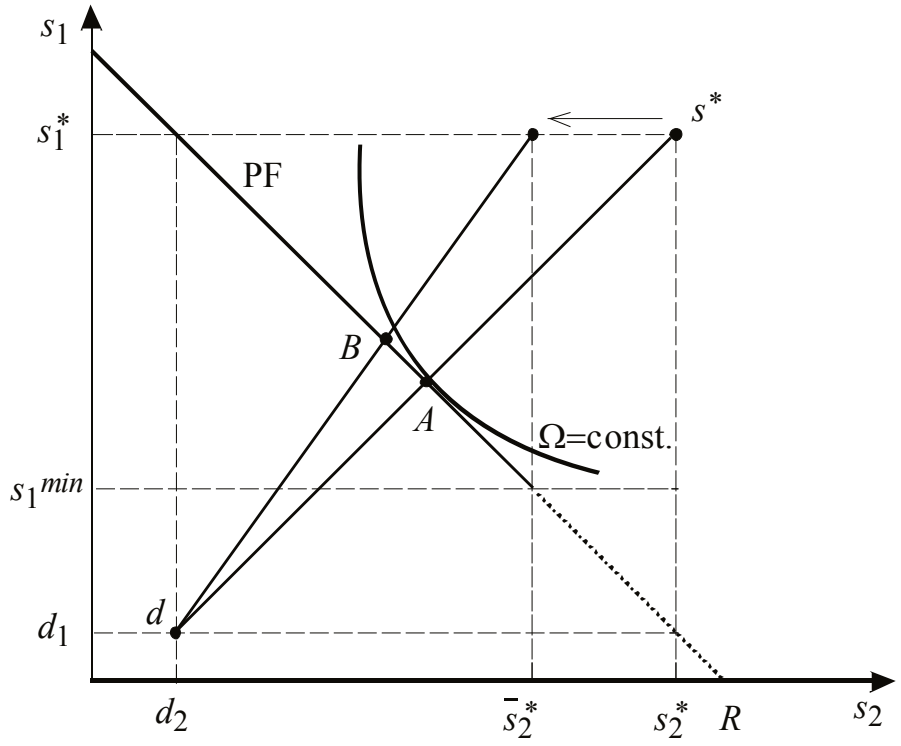
The effects of a minimum wage

We now turn to the analysis how a non-binding minimum wage affects the bargaining outcomes in both the Nash and the KS solution. A minimum wage is not binding if it does not exceed the previously bargained wage. In the Nash solution, even a non-binding minimum wage reduces the bargaining set by making a range of low wages legally unattainable. However, the initial bargaining outcome remains part of the bargaining set. Hence, the reduction of the bargaining set has no impact on the bargaining outcome.

The KS solution implies that both players agree on a wage that equalizes their relative payoff gains. These gains are given by the ratio of the actual gain to the maximum feasible gain, where the maximum is defined by the payoff each player can secure by pushing the other player to the minimum it would just be willing (or allowed) to accept. If a non-binding minimum wage is introduced which exceeds the worker's disagreement payoff, the firm's bliss point will be reduced. The best the firm can achieve now would be to push the wage down to its legal minimum. This reduction of the firm's bliss point raises the bargained wage. Therefore, it is straightforward that the KS solution is menu dependent. A change in the choices available to the two players that does not affect their ability to choose their original agreement causes a shift in the bargaining outcome.

Figure 2 illustrates this effect. The payoff frontier (PF) defines the boundary of the bargaining set. Without a minimum wage, the Nash bargaining solution is at the point where the highest iso-Nash-curve is tangent to the PF (point *A*). The KS solution is given by the intersection of the PF and the line which connects the bliss point s^* and the disagreement point *d*. Given our simple model assumptions, the solution in the absence of minimum wages is in point *A* as well. The introduction of a minimum wage $s_1^{min} > d_1$ cuts off a segment of the PF (dotted). In the Nash solution, this reduction of the bargaining set has no effect on the bargaining outcome due to the IIA axiom. In the KS solution, however, the minimum wage shifts the firm's bliss point to the left. Since the disagreement point stays unchanged, this causes a rotation of the KS curve. The bargaining outcome shifts from *A* to *B*, which leads to an increase in the worker's wage.

Figure 2: The Nash and the KS bargaining solution



4.2 Experimental evidence

In our experimental setup, it is easy to calculate the bargaining outcome predicted by the Nash and Kalai-Smorodinsky bargaining solutions (Table 7). Both bargaining solutions yield the same outcome when there is no minimum wage. Minimum wages at or below 95 do not affect the Nash solution, but do increase the outcome of the Kalai-Smorodinsky bargaining solution. The relatively high minimum wage of 160 constitutes a binding constraint on the Nash solution, so it predicts a wage agreement of 160. The Kalai-Smorodinsky solution predicts that the bargained wage should be strictly greater than the minimum wage even if it is at this high level.

Table 7: Theoretical and experimental bargaining outcomes

treatment	minimum wage	Nash solution	Kalai-Smorodinsky solution	experimental outcome (95%-confidence interval)
1	-	95	95	124.40 (120.40; 128.40)
2	70	95	116.45	129.93 (125.65; 134.21)
3	95	95	126.67	134.47 (130.77; 138.16)
4	160	160	164.09	170.43 (169.27; 171.60)
5	-	95	95	128.68 (124.22; 133.14)

Note: standard errors clustered at the individual level (62 clusters).

Table 7 gives us two important insights. The first insight is that the Kalai-Smododinsky solution provides a better qualitative description of the actually observed behavior in our experiment than the Nash solution. Rising minimum wages always increase the bargaining outcome of the Kalai-Smorodinsky solution, which also predicts that the high minimum wage should not be binding ex post. This corresponds exactly to what we observe in the experiment. The Nash solution is unable to explain the positive wage effect from low minimum wages.

Neither solution can provide a perfect prediction of the bargaining outcome. Even though the predictions derived from the Kalai-Smorodinsky solution are closer to observed behavior than those from the Nash solution, both predictions are outside the confidence interval of mean wages in all treatments of our experiment. Both theoretical bargaining solutions predict wages that are too low compared to our experimental bargaining outcomes. Thus, our experiment cannot resolve the question which theoretical bargaining solution provides an adequate description of real-life bargaining behavior.

5. Conclusion

In this paper, we have examined the effects of a minimum wage when wages are bargained over between a worker and a firm. We reported the results of a laboratory experiment in which a minimum wage is first introduced and later increased. Our experimental results broadly confirm the stylized facts of spillover effects from the empirical literature: 1) the wage of workers that used to earn less than the new minimum wage rises above the minimum level, and 2) a minimum wage increases the wage of workers already earning a wage above

the new minimum wage. These results suggest that spillover effects of minimum wages also occur in labor markets that cannot be described by standard wage hierarchy or effort provision.

Moreover, we have compared our experimental findings with the prediction from theoretical bargaining models. While the Nash solution cannot explain the existence of spillover effects, the Kalai-Smorodinsky solution yields results that are qualitatively similar to our experimental findings. A minimum wage, even if it is less than a worker's current wage, reduces the maximum payoff a firm could hope to obtain if it succeeded to reduce the worker's payoff as much as possible. In the Kalai-Smorodinsky bargaining solution, this weakens the firm's bargaining position and leads to higher wages. Even though the Kalai-Smorodinsky solution is able to explain the existence of spillover effects of minimum wages, wages actually observed in our bargaining experiment differ substantially from the predictions of the Kalai-Smordinsky solution. Hence, neither the Nash nor the Kalai-Smorodinsky solutions are able to provide a perfect description of observed bargaining behavior.

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Appendix

Table A 1: Regression results

	Bargaining outcome (Table 2)	first-mover: employer first-round wage offer (Table 4)	first-mover: employee first-round wage demand (Table 5)
Treatment 1 (no minimum wage)	reference	reference	reference
Treatment 2 (MW = 70)	4.29**	2.99	-1.47
	(2.11)	(3.47)	(2.60)
Treatment 3 (MW = 95)	8.26***	22.18***	-3.49
	(2.15)	(3.81)	(3.41)
Treatment 4 (MW = 160)	45.10***	76.93***	18.48***
	(2.23)	(4.53)	(4.13)
Treatment 5 (no minimum wage)	2.84	0.34	-2.46
	(2.03)	(4.23)	(4.10)
Indiv. fixed effects	yes	yes	yes
Number of observations	838	542	535
Number of clusters	62	62	62
R^2	0.76	0.78	0.57

Note: Standard errors reported in parentheses (clustered at the individual level); *** p<0.01, ** p<0.05, * p<0.1