# Spillover Effects of Minimum Wages - A Theoretical and Experimental Analysis

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**Abstract**

In this study, we theoretically and experimentally investigate whether the introduction of a minimum wage not only increases the wages of workers who previously earned less than this minimum wage, but also of those who earned considerably more already. In theoretical and empirical literature, these wage increases for the latter group are called minimum wage spillovers. Our theoretical model focuses on relative income preferences and predicts that minimum wage spillovers exist. The model is also the blueprint for the experimental design. By limiting attention to relative income preferences, the experiment is capable of exclusively testing the impact of these specific preferences on minimum wage spillovers, while empirical field studies do not offer this opportunity. The main experimental finding is that minimum wage spillovers exist. Results of a control treatment suggest that relative income preferences, indeed, cause the wage spillovers.

***JEL classification:*** C90, J30, J38

***Keywords:*** minimum wage, experimental economics, wage spillover, relative income

# 1 Introduction

Recent legislative decisions in Australia, Ireland, and the USA show that minimum wages are still a prevailing topic across the world (see, e.g., The Australian (2009), Irish Times (2009b), or Washington Post (2009)). In this study, we theoretically and experimentally examine so-called *minimum wage spillover effects*, instead of focusing on employment effects of minimum wages like the majority of other economic studies did.

What is a *minimum wage spillover effect*? For convenience, let us distinguish between two groups of workers: the group of workers whose wages are above the minimum wage before its introduction (henceforth, *high-income workers*), and the group of workers who earn less than the minimum wage before it is introduced (henceforth, *low-income workers*). Literature speaks of a *minimum wage spillover effect* or simply of a *minimum wage spillover* when not only the wages of the low-income workers increase after the introduction of the minimum wage, but also the wages of the high-income workers increase. We follow this convention.

If minimum wage spillovers existed, the consequences for lawmakers and their scientific counsels would be straightforward: in this case they should not only consider the direct effects of minimum wages on wages of low-income workers, but also the indirect effects on wages of high-income workers.[1] Since no other experimental paper known to us concentrates on such minimum wage spillover effects and the controlled laboratory environment can diminish confounding effects, we are confident to enrich the knowledge on minimum wages with our study. At the end of this section, we will be able to explain that we also contribute to the literature on relative income with our theoretical model.

Economics textbooks have frequently criticized minimum wages for decades, since simple partial market analyses suggested that minimum wages are destroying jobs (or are irrelevant at best). Although some theoretical studies doubted the universality of this reasoning (see, e.g., Stigler (1946), Drazen (1986), Lang (1987))[2], empirical findings for the USA, Australia,

[1] The paper of Bauer et al. (2008), e.g., is such an empirical study suitable for policy advice that does not deal with minimum wage spillovers. The authors investigate the employment and fiscal effects of several hypothetical minimum wages for Germany and explicitly exclude potential minimum wage spillovers from their analysis.

[2] The monograph of Manning (2003) solely deals with monopsonistic labor markets, the most prominent counterexample against conventional wisdom. Rebitzer and Taylor (1995)

the UK, and Continental Europe have questioned it more enduringly (see Katz and Krueger (1992), Card and Krueger (1994, 1995), Dolado et al. (1996), Stewart (2004)). However, there have been methodological controversies about the two studies that can be seen as the extreme points in answering the question whether minimum wages destroy jobs or not. While, on the one hand, Card and Krueger (1994) refuted the standard textbook prediction that minimum wages increase unemployment, the study of Leigh (2003, 2004a), on the other hand, largely supported conventional wisdom.[3]

In addition, Katz and Krueger (1992) and Card and Krueger (1995) also provided empirical evidence that the introduction of minimum wages in the US fast-food industry not only raised the wages of low-income workers, but also those of high-income workers. They observe that such minimum wage spillover effects are strongest for workers whose wages were only slightly above the minimum wage before its introduction. The empirical parts of the articles analyzing US data sets by DiNardo et al. (1996), Lee (1999) and Teulings (2000, 2003) imply similar minimum wage spillovers[4], while Dickens and Manning (2004) find only small minimum wage spillover effects for the UK.

Minimum wage spillovers are also suggested by non-scientific publications. For instance, the recent raise in the US minimum wage in July 2009 is said to have an impact on wages of high-income workers (New York Times (2009)).

Several causes for minimum wage spillovers have been discussed in theoretical literature. We want to categorize this literature into four classes: a) models with (partial market) substitution effects, b) relative income models, c) general equilibrium models, and d) search and bargaining models.

The basic idea of models with substitution effects for a firm with heterogeneously qualified workers is straightforward. For simplification, let us assume that only two skill groups exist that also differ income: high-skilled, high-income workers and low-skilled, low-income workers. If workers of different skills are substitutable, then a minimum wage increases the relative costs of low-skill, low-income labor. Thus firms may want to substitute low-skilled with high-skilled workers what raises the demand for, and eventually

combine monopsonies with efficiency wage considerations.

[3]Neumark and Wascher (2000) criticized Card and Krueger (1994) for using telephone surveys and got other results for payroll records. Card and Krueger (2000), in turn, confirmed their initial results when broadening their data set. The findings of Leigh (2003, 2004a) were doubted by Watson (2004) and later defended by Leigh (2004b).

[4]A short overview over these studies can be found in Manning (2003).

the wages of, high-skilled workers, i.e., substitution effects cause minimum wage spillovers.

Relative income models rely on the idea that employees' work effort depends on their relative position in the wage hierarchy. Grossman (1983) was the first author focusing on minimum wage spillovers. He was able to explain them in a theoretical model incorporating substitution effects and relative income considerations.[5]

Teulings (2000, 2003) broadens substitution effects to a whole economy in his general equilibrium framework to analyze minimum wage spillovers.

The bottom line of the search models of Flinn (2006, 2008) is, roughly spoken, that by introducing minimum wages, the disagreement outcomes of the Nash bargaining solution increase for all different-skilled workers. This not only increases the wages for low-income, but also for high-income workers, i.e., minimum wage spillovers follow.[6]

We will present a relative income model with heterogeneously qualified workers who also differ in income to analyze minimum wage spillover effects. This means that we will solely focus on one of the several causes for minimum wage spillovers discussed in economic theory. This narrow focus not only allows us to limit our theoretical model to the cause for minimum wage spillovers we perceive best established evaluating the literature, but also to design an according experiment capable of testing this specific cause. Furthermore, by relying on a relative income model we inevitably also add to the large body of work on relative income. Since Grossman (1983) also uses a relative income model, we will discuss where his approach fundamentally differs from ours when describing our model.

To the best of our knowledge, the works of Brandts and Charness (2004) and Falk, Fehr and Zehnder (2006) are the only experimental studies on minimum wages. Contrary to our study, both studies do not investigate minimum wage spillovers between heterogeneously qualified workers differing in income. Note that Falk, Fehr and Zehnder (2006) confirm the hypothetical value of our research topic by shortly discussing it in their concluding remarks.

Our main research questions are: 1) Does a relative income model predict minimum wage spillovers?, 2) Do minimum wage spillovers occur in an experiment?, and 3) If minimum wage spillovers are found experimentally: are

[5]Summers (1988) relies on relative and efficiency wages to analyze unemployment and briefly touches minimum wages.

[6]Some other search models can be found in literature (see, e.g., van den Berg (2003)).

they caused by the relative income considerations discussed in our model?

Our main results are that a) in a theoretic model minimum wage spillovers follow from a rather general set of relative income assumptions, b) minimum wage spillovers also occur in an experiment designed accordingly to our theoretical model, and c) there is evidence that these minimum wage spillovers are mainly caused by the relative income effects discussed in our model.

We proceed as follows: We start by summarizing the experimental studies and the relative income literature most important for our analysis. In Section 3, we discuss our four-person minimum wage game and its solution based on a simple relative income model. We give our experimental design of the minimum wage game in Section 4 and the hypotheses in Section 5. Section 6 presents the experimental results, before Section 7 concludes.

# 2 Related literature

## 2.1 Minimum wage experiments

We are aware of two other experimental studies analyzing minimum wages: the studies by Brandts and Charness (2004) and by Falk, Fehr and Zehnder (2006) (henceforth, FFZ2006).

Insights on minimum wages have not been the sole purpose of Brandts and Charness (2004) who analyzed influences of market conditions in gift exchange games. In an one-sided auction, employers offered wage contracts consisting of a fixed wage to homogeneously skilled employees. Employers could hire one worker at most, what excluded investigating minimum wage spillovers. In a second stage, employees chose effort levels and thereby determined final outcomes. In the treatments with minimum wages, employers were forced to post offers larger than (or equal to) this minimum wage. Amongst other things, Brandts and Charness (2004) found that effort reactions to the same accepted wage were smaller when minimum wages prohibit lower offers. This suggested that workers might have perceived a wage offer only slightly above the minimum wage as rather unfair and thus reacted by spending less effort.[7]

[7] This is in line with findings in experimental studies on other topics: the set of alternatives for player A seems to be crucial for the perceived kindness and thus the reaction of player B (see, e.g., McCabe et al. (2003) or Falk and Fischbacher (2006) or the more extensive discussion in Section 6.2).

The fairness perceptions caused by minimum wages are the main focus of the study by FFZ2006 whose experiment is more similar to ours. Six firms and 18 homogeneously qualified workers participated in each period of their experiments. Firms' revenues from employing a specific worker did not depend on this worker's effort choice, but were predetermined.[8] All participants knew that each firm could hire up to 3 employees (with decreasing marginal revenues) and that firms were free to offer jobs to 0, 1, 2, or 3 workers, but were limited to unitary wage offers, $w \geq 0$. Due to the unitary wage offers, minimum wage spillovers were impossible by definition. The wages the employers offered were take-it-or-leave-it offers, such that for each single pair of employer and employee the game has the characteristics of an ultimatum game.

The authors used the *strategy method*, i.e., asked each worker to name their reservation wage (or threshold wage) below which they were not willing to work. Their reservation wages were insofar a commitment, since they determined their later choices: wage offers below this threshold were automatically rejected. Thereby the *strategy method* gave FFZ2006 the whole strategy profile of the participant, since it determined his or her decision for each possible wage – for hypothetical ones as well as for the one eventually offered. We will employ a similar method for our experiment.

After eliciting the threshold wages via the *strategy method*, FFZ2006 distinguished workers into three groups: a group with low, a group with medium and a group with high reservation wages. In each period, the random matching guaranteed that firms were matched with one worker from each group whom they could employ or not. This was common knowledge. FFZ2006 used this procedure to fasten adjustment processes.

In the first 15 periods of *sequence I* the game was played as described above (unrestricted phase (*u phase*)), before a minimum wage, $m$ – restricting offers to $w \geq m$ – was introduced and another 15 periods followed (minimum wage phase (*mw phase*)). The authors checked for sequence effects. In particular, *sequence II* reversed the order of phases with and without minimum wage, i.e., it started with a minimum wage and then removed it. This means that each sequence consisted of the same two phases, but in different order.

For *sequence I* the authors found that paid wages in all periods were larger than the game-theoretical prediction of $w = 0$. Wages in the *u phase* were smaller than the minimum wage and smaller than those in the *mw phase*.

[8]As in our model, perfect monitoring could be a possible rationale, see Section 3.1.

Moreover, in most observations the introduction of the minimum wage led to an increase in paid wages above this new boundary $m$. The paid wages were about 8 percent higher than the minimum wage. This was in concordance to reservation wages that in many cases also exceeded 0 before and $m$ after the introduction of the minimum wage.[9]

While paid wages in the phases with minimum wage were quite similar in *sequences I* and *II*, the sequencing largely changes the picture for the *u phases*. In *sequence II*, reservation wages and paid wages after the removal of the minimum wage were significantly higher than in *sequence I* that started with the *u phase*. They were now closer to the level of the removed minimum wage.

Overall, these results suggest that minimum wages affect reservation wages and paid wages by a kind of *fairness perception effect* that increases wages a little above the minimum wage.

## 2.2 Relative income studies

Essentially, studies on *relative income* are studies on *relative utility*. The common basis of relative income studies is the assumption that an individual's utility not only depends on his or her's absolute income, but also on this income in comparison to other individuals' incomes. In literature the terms *relative income (utility function)* and *income comparison (utility function)* are thus often used synonymously.

This relativity is also assumed to exist for many other goods, but income is regularly the leading example. In the broadest sense, i.e., with relative utility for any kind of good, studies are numerous in many sciences. The following is by far not a exhaustive overview, but rather a brief, in parts chronological summary of what we perceive to be the main trends. We primarily focus on economic studies on income (see Diener et al. (1999), Frank and Sunstein (2001), Falk and Knell (2004), Clark, Frijters and Shields (2008) or Senik (2009) for more copious summaries of studies in economics, psychology and sociology).

Early empiricists interested in relative utility at least implicitly equated people's answers to survey questions about life satisfaction (or happiness) with people's utility. Recently, this assumption is criticized, but there are

[9] Note that FFZ2006 use the term *spillover effect* to describe their finding that wages are increased above the minimum wage, while we use it alternatively.

some hints indicating that the connection between happiness scores and true utility is not totally random.[10] The most prominent early works are probably those of Duesenberry (1949) and Easterlin (1974). The former intended a reformulation of the theory of saving, the latter observed two seemingly contradictory facts nowadays known as *Easterlin Paradox*: 1) within-country empirical findings suggested that absolute incomes were a good predictor of person's happiness (and thus utility), and 2) comparisons between countries or within a specific country at different times refuted this clear pattern: in particular, happiness remained relatively stable in several countries during the middle of the 20th century, although absolute income largely increased. Easterlin (1974, pg. 118) concluded that relative income considerations might solve this puzzle and claimed that *"people tend to compare their actual situation with a reference standard or norm, derived from their prior and ongoing social experience"*. The comparison norm that stems from own prior experience is named *adaptation* in literature (see Clark, Diener, Georgellis and Lucas (2008) for an introduction). We will not further discuss this concept here, but will briefly pick it up below when interpreting of our experimental results.

The main working hypothesis derived from Easterlin's original findings was that a person's utility decreases for increasing incomes of other individuals. This relationship between own and others' incomes is called *relative income effect*. With this effect, it is easy to construct a situation in which absolute income gains might not (proportionally) increase an individual's utility, as long as relative position remains unchanged or even deteriorates. Many theoretical works have assumed that the relative income effect exists.[11]

Since the mid of the 90s a lot of economic studies using happiness surveys as a proxy for utility again were published that empirically tested the relative income effect. One can summarize that the vast majority of these studies confirmed the relative income effect (see, e.g., Clark and Oswald (1996),

[10] An extensive discussion would go beyond the scope of this study. The equation of happiness and utility is commonly dated back to Jeremy Bentham's definition of utility. Critical discussions can be found in Di Tella and MacCulloch (2006), Kahneman and Krueger (2006), Kahneman and Thaler (2006), Kimball and Willis (2006) or Weinzierl (2006).

[11] Frank (1984a,b, 1985) is often cited for revitalizing the idea in economic theory, although Hammermesh (1975), Pollak (1976), and Boskin and Sheshinski (1978) earlier relied on similar ideas. Later examples are works on unemployment (Summers (1988) and Akerlof and Yellen (1990)) or on evolutionary games and agency theory (Rayo and Becker (2007)).

Neumark and Postlewaite (1998), McBride (2001), Blanchflower and Oswald (2004), Ferrer-i-Carbonell (2005), Luttmer (2005), Weinzierl (2006) or Clark, Frijters and Shields (2008)).[12]

In recent years things have become a little more complicated: While results stayed the same for "Old Europe" and for economies as a whole, a number of studies suggested that for transition economies, the USA and within a specific firm an opposite effect might occur, i.e., own happiness/utility might increase when wages of co-workers increase (see, e.g., Galizzi and Lang (1998), Alesina et al. (2004), Senik (2004, 2008), or Clark et al. (2009)). This effect is named *future earnings effect* in literature. The intuition is that, especially in the cases described above, increasing wages among peers might be interpreted as a signal or promise that own earnings are likely to increase in the future, rather than as a threat to one's own relative income position.[13] When discussing our model we will explain why this effect should be only of limited importance in our context.

The number of experimental studies (and related theoretical attempts) on relative income depends on how broad one's view on this topic is. Of course, all experimental work on other-regarding preferences, in particular on inequality aversion, is inevitably connected to relative income.[14] The same is true for the theory of relative deprivation originating in sociology (see Clark and Oswald (1998) for a short discussion). When narrowing the view, the quasi-experimental studies on relative income of Solnick and Hemenway (1998), Johansson-Stenman et al. (2002) and Alpizar et al. (2005) are comparable. These studies used surveys in which participants had to decide between two hypothetical societies: one in which their (or their grandchildren's) absolute income was larger, but their relative position was worse, and one with

[12]Some empirical works by psychologists doubted the relative income effect or at least its magnitude (see, e.g., Veenhoven (1991) and Diener et al. (1993, 1999)). Medical studies suggested that workers earning (much) less than others are unhealthier due to mental distress induced by the lower relative wage rank (Marmot and Bobak (2000), Deaton (2003)).

[13]Hirschman and Rothschild (1973) earlier discussed comparable ideas on a much more general level dealing with economically developing societies. They argued that future earnings effects might only outweigh relative income effects in the beginning of economic development when others' gains still are perceived as own welfare promises, but eventually disappear if those promises fail to fulfill.

[14]Fehr and Schmidt (2006) summarize theory and experiments in economics. Walster et al. (1978) present psychological experiments based on the seminal *equity theory* paper by Adams (1965).

opposite characteristics. They all found evidence in support of the relative income effect.[15] While Charness and Grosskopf (2001) found rather little concern for relative income when maximizing social welfare was another option for experiment participants, Zizzo et al. (2001) and Brown et al. (2008) reported that their experimental subjects were, indeed, interested in (ordinal ranks of) relative income.

The results of a neuroeconomical study by Fliessbach et al. (2007) also support the relative income effect. The authors found that during the (laboratory) experiment they performed, the activity in participants' brain regions associated with positive feelings such as rewards increased with higher relative reward payments.

Falk and Knell (2004) and Senik (2009) investigate theoretically and empirically which groups are chosen for income comparisons, a question analyzed in many fields of research since the seminal paper on social comparisons by Festinger (1954). Roughly spoken, the results imply that people tend to compare themselves more to similar others than to more divergent ones.[16]

Let us briefly summarize the most important points of this overview of relative income studies: 1) there is reason to believe that peoples' utility from income to some extent depends on relative income, 2) peoples' utility decreases if others' incomes increase and this increase is not interpreted as own future prospects and 3) such considerations might be of greater importance for people more comparable to each other. We will refer to these findings in the following sections.

# 3 The relative income model

In this section, we first introduce our minimum wage game. It is the blueprint for our experimental design and is constructed such that models relying on substitution effects, general equilibrium models and search and bargaining models are not applicable to derive its solution. We outline our alternative solution design in Section 3.2. There, we also introduce the relative income

[15] Solnick and Hemenway (1998) and Alpizar et al. (2005) additionally distinguished between different goods and found relative position to be more important for some goods (e.g. cars) than for others (e.g. vacation time) with income somewhere in between.

[16] Psychology studies of *social comparisons* often analyze comparisons of abilities, rather than incomes. A nice overview can be found in Wood (1996).

utility functions used in literature. In Section 3.3, we discuss our set of rather general assumptions, before we derive the equilibria before and after the introduction of a minimum wage, and compare them in a comparative statics analysis in Sections 3.4 and 3.5.

## 3.1 The minimum wage game

In our minimum wage game, workers[17] differ in their production skills, i.e., their skill levels determine productivity. In such a setup, it is intuitive to expect that more productive workers earn more than less productive ones. An existing wage hierarchy is, obviously, the prerequisite for analyzing wage spillovers. As will be shown below the results of our theoretical model do not critically depend on the existence of the specific wage hierarchy in which high-productive workers earn more than low-productive workers, but also hold for other wage orders, as long as there exists any wage hierarchy at all.

The **minimum wage game** that is the blueprint for our experimental design is basically designed as follows. One principal (P) interacts with three workers (agents) who differ in productivity. We define productivity as the value of the good produced by the worker. Just like FFZ2006, we assume productivity to be exogenously given to keep things simple. An interpretation could be that effort choices, indeed, determine output, but firms are able to force each worker to spend his specific maximum effort (through perfect monitoring) when hiring them. One of the agents is high-skilled what induces high productivity (agent H), one has medium productivity (agent M) and one low productivity (agent L). The worth of the good produced by agent $i$ is denoted by $R_i$. It is assumed to be immediately sold. We demand the revenues $R_i$ to fulfill $R_L < R_M < R_H$.

The game is played for $l1 + l2$ periods. In the first $l1$ periods **without a minimum wage** the principal proposes a wage tuple $(w_L, w_M, w_H)$ with $0 < w_i \leq R_i$ (for all $i$). There are no other restrictions or capacity barriers, i.e. principals can hire all three workers. The contract rules are those of three unrestricted, parallel ultimatum games with all agents knowing all wage offers.[18] We think that at least when interpreting the employment

[17]From now, we will use the terms *employer*, *firm*, and *principal*, on the one hand, and *employee*, *worker*, and *agent*, on the other hand, synonymously for reasons of variation. We will also use the feminine (masculine) form for the principal (agents).

[18]With the aim of receiving more information, we used a kind of *contingent strategy*

decision at the end of each period of our game as the decision a worker reaches after a sum of a few real life working periods this assumption is not far-fetched: eventually, every worker in a real world firm is most likely able to accurately approximate others' earnings and to compare these with his own wage. Specifically, for our game this means that each agent knows all three wage offers and is confronted separately with a take-it-or-leave-it offer: If agent $i$ chooses to accept the offer $w_i$, he earns $w_i$, irrespective of whether the other agents accept their offers. The principal then earns $R_i - w_i$ from employing $i$. In case agent $i$ declines the offer, he and the principal earn nothing in this relationship. A principal's overall payoff is the sum of the payoffs from all his workers. We try to keep things simple by disallowing firms to compete for workers. There are also no other, similar productive workers competing for the same job. Also the firm composition does not change which will allow us to analyze wage spillovers within firms.[19]

The introduction of the minimum wage, denoted $m$, is assumed to happen surprisingly before the last $l2$ periods, i.e., these periods are played **with a minimum wage**. This minimum wage is assumed to lie above the lowest of the wages in the last of the first $l1$ periods and below the second lowest.[20] The minimum wage applies to all workers. All of these rules are common knowledge, except for the introduction and the deduction rule of the minimum wage.

## 3.2 Solution design and income comparison utility functions

For the ultimatum games outlined in the preceding section, game-theoretical predictions for players whose utility solely depends on (and increases in) their own payoff are straightforward: Irrespective whether players' utilities and payoffs are mapped by an identity function what is often used to generate benchmark predictions in literature or by more elaborate relationships, principals should offer the smallest possible amount to all workers before the minimum wage applies (i.e., either 1 if $w \in \mathbb{N}$ as is the case in our experimental setting or the smallest feasible other offer), and $m$ afterwards. The workers

*method* in the experiment, see Section 4. This is irrelevant for our model and its solution.

[19]This is a major difference to FFZ2006 where firm composition randomly changes each period.

[20]For the case of equal lowest and second lowest wages the minimum wage is assumed to be equally high than both wages.

should always accept. However, numerous experimental studies since Güth et al. (1982) refuted this (see, e.g., Kagel and Roth (1995) for a survey).

The simple set-up of the minimum wage game outlined before prohibits several of the other approaches discussed in literature from being useful: substitution effects and general equilibrium models are not helpful, since firms can not substitute low-skilled workers by employing additional high-skilled workers, and search and bargaining models can be ruled out, since there is no wage bargaining in our minimum wage game. Instead, relying solely on a relative income model to derive theoretical deductions seems a plausible approach, since workers in the minimum wage game can compare their incomes with that of their co-workers and the theoretical and empirical studies discussed above suggested the importance of relative income. In summary, the construction of the minimum wage game allows us to focus on relative income preferences to theoretically answer whether minimum wage spillovers occur or not, and this limitation will, later on, enable us to exclude confounding effects when experimentally testing our theoretical predictions.

Since Grossman (1983) also used relative income considerations to analyze minimum wage spillovers, we want to emphasize that our minimum wage game fundamentally differs from his setting in several aspects. First of all, in his case workers choose their effort level and thereby influence the employer's revenues, while in our setting they only decide whether to work (with a fixed effort and revenue level) or not. Furthermore, we concentrate on one firm and exclude substitution effects that largely drive his theoretical results. Finally, in our minimum wage game, the employer can not employ as many low-skilled workers for the minimum wage as he wants to, i.e., our labor supply of the low-skilled workers is not infinitely elastic, while it is in the study of Grossman (1983).

Before introducing the basic assumptions of our model, let us shortly discuss the concrete income comparison utility functions used in literature and their parameter estimates given by empirical studies, since these insights will be helpful later on.

There are basically two classes of functions used to model relative income in economic literature. Suppose worker $i$'s utility $u_i$ depends on his own wage, $w_i$, and the average wage of workers in his reference group, $\overline{w}_{-i}$.[21]

In *ratio comparison utility* (RCU) functions, utility depends on own income and the ratio of own versus others' earnings. A concrete example is:

[21] We will discuss the exact definitions of reference groups in a few paragraphs.

$$\text{(RCU)} \quad u_i = w_i^{1-\alpha} \cdot \left(\frac{w_i}{\overline{w}_{-i}}\right)^{\alpha} = \frac{w_i}{(\overline{w}_{-i})^{\alpha}} \tag{1}$$

In *additive comparison utility* (ACU) functions, utility depends on absolute differences between own and others' incomes. An example is:

$$\text{(ACU)} \quad u_i = (1-\alpha)w_i + \alpha(w_i - \overline{w}_{-i}) = w_i - \alpha\overline{w}_{-i} \; . \tag{2}$$

Both types of functions capture the same idea: $\alpha$ is a measure of an individual's concern for relative income with $\alpha = 0$ representing the standard neo-classical model, in which only absolute wage matters and utility and wages are mapped by an identity function. For $0 < \alpha < 1$ own utility is increasing, if own wage increases, but decreases for average wages rising.[22]

Comparable RCU and ACU functions are used by, e.g., Johansson-Stenman et al. (2002), Alpizar et al. (2005) or Weinzierl (2006) to estimate $\alpha$. Parameter estimates range from $\alpha \approx .3$ to $\alpha \approx .7$, which suggests that relative standing is rather important. Clark and Oswald (1998) discuss theoretical differences of both functions. Johansson-Stenman et al. (2002) and Alpizar et al. (2005) find only minor empirical differences when comparing parameter estimates and prediction accuracy of RCU and ACU functions.

## 3.3 Basic assumptions

We try to derive main insights without committing to specific utility functions. Thus, the set of basic assumptions (A.1)–(A.3) discussed in this section is held as general as possible. However, we use the ACU and RCU functions as an illustrative guide occasionally. In following sections, we will add further tie-breaking standard assumptions (A.4)–(A.7) that guarantee the existence of an interior solution equilibrium.

The principal and each worker $i$ are assumed to be utility maximizers.

What else do we assume for workers' utility functions? First of all, note that for his empirical parameter estimations of RCU and ACU functions Weinzierl (2006) defined the reference group for worker $i$ by workers of the same gender, same birth year interval and similar education and in their experimental instructions Johansson-Stenman et al. (2002) and Alpizar et al.

[22] Note that ACU functions also resemble the functions used in experimental literature on inequity aversion or fairness (see, e.g., Fehr and Schmidt (1999) or Charness and Rabin (2002)).

(2005) simply speak of *"your grandchild's income"* and the *"average income in society"*. The empirical works on relative income mentioned in section 2.2 use similar approaches (see Ferrer-i-Carbonell (2005) for an overview). Although these definitions of reference group (wages) are not extremely narrow, we think that the heterogenous qualification of workers and the fact that there are only three workers in our minimum wage game has to been taken into consideration. We thus assume worker $i$'s utility, $u_i$, to depend on his wage, and on each of his two co-workers' wages instead on an wage average only. Formally, we introduce $u_i(w_i, w_j, w_k)$ with $i, j, k \in \{L, M, H\}$ and $i \neq j \neq k$.[23]

The principal's utility, which we call profit for reasons of distinguishability from now on, shall depend on the wages paid to the three workers $(\Pi(w_i, w_j, w_k))$.

We also introduce reservation utilities $r_i$ and, for technical reasons only, a binary variable $z_i$ that takes the value of 1, if worker $i$ accepts a contract offer and 0 otherwise. The workers utility and principal's profit functions are assumed to be twice continuously differentiable. We additionally demand:

$$\textbf{(A.1)} \quad \exists\, r_i \text{ with } 0 \leq r_i \leq R_i; \quad z_i = 1, \text{ iff } u_i(w_i, w_j, w_k) \geq r_i$$

$$\textbf{(A.2)} \quad \frac{\partial \Pi}{\partial w_i} < 0; \quad \frac{\partial^2 \Pi}{\partial w_i^2} \leq 0$$

$$\textbf{(A.3)} \quad \forall i \neq j: \quad \frac{\partial u_i}{\partial w_i} > 0; \quad \frac{\partial^2 u_i}{\partial w_i^2} \leq 0; \quad \frac{\partial u_i}{\partial w_j} < 0; \quad \left|\frac{\partial u_i}{\partial w_i}\right| > \left|\frac{\partial u_i}{\partial w_j}\right|$$

The *reservation utility assumptions* **(A.1)** demand that each worker has some reservation utility that must be reached for him to accept a contract offer. From now on, we will assume this reservation utility to be exogenous and fixed, i.e, it will never alter. We think this is reasonable within the limits of a firm. When thinking of concrete ACU or RCU functions, e.g., reservation utility can be thought of as representing the threshold level the firm's payment scheme must imply for worker $i$ to accept a job offer. It is apparent that $r_i > 0$ is a technical necessity for RCU functions, since they are by definition always larger than zero for positive wages.

[23] Below, we will also introduce modified versions of the standard RCU and ACU functions that incorporate this broader definition of reference group wages.

The *profit assumptions* **(A.2)** are standard and imply that the principal wants to set wages as low as possible and that the profit function is concave (or linear).

The last assumptions, **(A.3)**, deal with *marginal utilities*. The first two of them are the standard assumptions of non-increasing positive marginal utilities of own income. In accordance with the the empirical and experimental findings discussed in Section 2, the third assumption states that own utility will, c.p., decrease, if others' incomes increase. This is exactly the definition of the *relative income effect*.

Although, we can not definitely exclude the *future earnings effect* in our model (and experiment), we perceive its occurrence to be unrealistic or at least its magnitude to be negligible. Since participants are heterogeneously qualified and we give them no reason to expect this to change (see also the experimental design below), there is little reason for them to perceive other participants' wages as an proper indicator of own future earnings. Additionally, Clark et al. (2009) found evidence that the importance of the future earnings effect diminishes for workers soon to be retired. Although the players in our model (and experiment), of course, do not necessarily retire afterwards, they know that the game will end after the $l1 + l2$ periods what should further decrease a future earnings effect, if occurring at all. Overall, we think we can assume that co-workers' earnings are *"uninformative about the individual's own future income prospects"* which according to Clark et al. (2009) is the exact prerequisite for $\partial u_i/\partial w_j$ being negative.

Finally, (A.3) also demands that worker $i$ prefers an own wage increase over an equal sized wage decrease for worker $j$. This assumption not only seems intuitive, but is also fruitful for equilibrium characterizations as will be shown below.[24]

## 3.4 Equilibria without minimum wage

The principal's maximization problem without minimum wage is:

$$\max_{w_L,\, w_M,\, w_H} \Pi(w_L, w_M, w_H) \tag{P1}$$

[24]The reader may argue that while ACU functions obviously always fulfill this assumption, RCU functions do not necessarily have to. However, as will be shown in footnote 27 below, this special case hurting the last assumption of (A.3) does not limit the results to be derived at all.

$$\text{s.t.} \quad \forall i: \;\; u_i(w_L, w_M, w_H) \geq r_i \, .$$

We assume an interior solution, named assumption **(A.4)**, i.e., we assume a) the positivity constraints ($w_i \geq 0$) for the wages to be not binding and thus irrelevant in the following, i.e., we refrain from discussing the unlikely extreme case of border solutions, and we b), consequentially, also demand agents' aspirations to be below their respective revenues. Then, it immediately follows that all three constraints of (P1) must be binding in equilibrium. If, e.g., only the constraint for worker $M$ was not binding, the principal wants to lower $w_M$ which would make both other constraints non-binding which disqualifies this case as an equilibrium. Analog logic prohibits all other cases than the case with three binding constraints from describing the equilibrium.

We assume that an equilibrium exists. Obviously, all following considerations would be meaningless if no equilibrium existed. Additionally to existence, uniqueness of the equilibrium can be guaranteed by a variety of settings: the most immediate approach, for example, would be to demand the sufficient conditions that either the principal's profit function is strictly concave and the constraint set is convex or the opposite case with concavity and strict convexity. However, we will stick to our approach to be as general as possible and simply assume the equilibrium without the minimum wage, $w^* := (w_L^*, w_M^*, w_H^*)$, to be the unique maximum of (P1). The assumption of an existing, unique equilibrium is denoted assumption **(A.5)**.

The equilibrium $w^*$ is then defined implicitly by the first order conditions of the corresponding standard *Lagrange function* $L(w_L, w_M, w_H, \lambda_L, \lambda_M, \lambda_H)$ where $\lambda_i$ represents the multiplier for the utility constraint of worker $i$. It is subgame-perfect in all $l1$ periods due to its uniqueness.

With our set of general assumptions, we can not characterize the resulting wage order. Since it will become apparent in the remainder that it does not matter what specific wage order occurs, but only that there are preferences establishing similar wage orders before and after the introduction of a minimum wage, we limit ourselves here to assume the intuitive wage ordering, namely the one mirroring the revenue differences:

$$\textbf{(A.6.1)} \quad w_L^* < w_M^* < w_H^* \, . \tag{3}$$

Appendix B discusses under which assumptions (3) holds.

## 3.5 Equilibria with minimum wage

Following our earlier description of the minimum wage game, now a minimum wage is introduced that lies somewhere between the lowest and the second lowest wage: $w_L^* < m < w_M^* < w_H^*$.

We, again, assume the existence of an unique equilibrium $(w_L^{**}, w_M^{**}, w_H^{**})$ fulfilling:

$$\textbf{(A.6.2)} \quad w_L^{**} < w_M^{**} < w_H^{**} \ . \tag{4}$$

This seems only consequent considering the wage profile we assumed in (A.6.1) before. As long as the minimum wage lies below $w_M^*$ assuming the wage hierarchy to change seems far-fetched. However, we want to stress again that although we will proceed with (3) and (4) holding, all subsequent results are also valid for any other wage profile, as long as the wage ordering stays the same.

The principal's maximization problem now becomes:

$$\max_{w_L,\ w_M,\ w_H} \Pi(w_L, w_M, w_H) \tag{P2a}$$

$$\begin{aligned} \text{s.t.} \quad \forall i: \ & u_i(w_L, w_M, w_H) \geq r_i \\ \forall i: \ & w_i \geq m \ . \end{aligned}$$

Finally, let us *ex ante* assume for the time-being that the low productive worker's utility, $u_L$, after introducing a minimum wage $m$ fulfilling $m > w_L^*$, increases, which allows us to drop his participation constraint (assumption **(A.7)**). This simplification is not only necessary for deriving any comparative static results at all, but is justified in so far as it will be shown below that worker $L$'s utility certainly increases for all meaningful parameters of the two classes of income comparison utility functions discussed in literature. We are now able to state:

***Proposition 1****:*
*With assumptions (A.1) – (A.7) unique equilibria $w^*$ and $w^{**}$ exist. Positive minimum wage spillovers occur, i.e., workers $M$ and $H$ earn higher wages in $w^{**}$ than in $w^*$.*

***Proof:*** The first part of *Proposition 1* is fulfilled by assumption. With, (A.1), (A.2), (A.6.2), and (A.7), we can simplify (P2a) in four ways. Firstly, by noticing that the principal will set $w_L^{**} = m$, since there can not be a local

optimum with $w_L^{**} > m$ due to the uniqueness of $w^*$ and the non-convexity of $\Pi$. Secondly, by deducing from (A.6.2) that the minimum wage constraints for workers $M$ and $H$ are non-binding, thirdly, by detecting that in optimum the utility constraints of (P2a) for $M$ and $H$ must be binding (due to analog reasons as in the previous section), and, fourthly, by dropping the constraint for worker $L$.
Overall, the principal then solves this maximization problem:

$$\max_{w_M,\ w_H} \Pi(w_M, w_H; m) \tag{P2b}$$
$$\text{s.t.} \quad u_M(w_M, w_H; m) = r_M$$
$$u_H(w_M, w_H; m) = r_H \ .$$

Thus, by introducing a minimum wage, $m$, fulfilling $w_L^* < m < w_M^* < w_H^*$ we inevitably ended up in the cases for which it is possible to do comparative statics (the cases with $u_L > r_L$, $u_M = r_M$, and $u_H = r_H$).

In the corresponding *Lagrangian function* of (P2b), $L(w_M,\ w_H,\ \lambda_M,\ \lambda_H; m)$, the multiplier $\lambda_i$ again captures worker $i$'s utility constraint. The four first-order conditions of the *Lagrangian function* implicitly define a set of four equations $F(w_M,\ w_H,\ \lambda_1,\ \lambda_2;\ m)$. Amongst other things, this gives us $w_M^{**}$ and $w_H^{**}$ as functions of $m$, $f(m)$. By using total differentials, Cramer's Rule and some simplifications[25], the two interesting comparative static results follow as:

$$\frac{d\,w_M^{**}}{dm} = \frac{\dfrac{\partial u_H}{\partial w_H}\dfrac{\partial u_M}{\partial m} - \dfrac{\partial u_H}{\partial m}\dfrac{\partial u_M}{\partial w_H}}{\dfrac{\partial u_H}{\partial w_M}\dfrac{\partial u_M}{\partial w_H} - \dfrac{\partial u_H}{\partial w_H}\dfrac{\partial u_M}{\partial w_M}} \tag{5}$$

$$\frac{d\,w_H^{**}}{dm} = \frac{\dfrac{\partial u_M}{\partial w_M}\dfrac{\partial u_H}{\partial m} - \dfrac{\partial u_M}{\partial m}\dfrac{\partial u_H}{\partial w_M}}{\dfrac{\partial u_H}{\partial w_M}\dfrac{\partial u_M}{\partial w_H} - \dfrac{\partial u_H}{\partial w_H}\dfrac{\partial u_M}{\partial w_M}} \tag{6}$$

The numerators of (5) and (6) are both smaller than zero, since a positive term is subtracted from a negative one. Furthermore, both denominators are

[25]See Appendix C for details.

exactly the same which implies that either both comparative static derivatives are positive or both are negative. Less technically, this means that either wages of both high-income workers increase and we have the classical, *"positive"* minimum wage spillover effect or both wages decrease and we have the opposite result of decreasing wages, which one could call a *"negative"* minimum wage spillover.[26] The last assumption of (A.3) is a sufficient, but not necessary condition for the spillover to be strictly positive. It implies that both parts in the second term on the right side of the denominators are larger than their respective counterparts in the first term on the left side. Since the second term is subtracted from the first and all other signs vanish, this makes the denominator negative and thus the derivatives $dw_M^{**}/dm$ and $dw_H^{**}/dm$ positive.[27] This means that the wages of the medium and the high productive worker increase, although they do not have to, since the minimum wage is smaller than $w_M^*$ and $w_H^*$, respectively, have been. *q.e.d.*

We *ex ante* demanded $u_L$ to increase. What is still left is to give some justification for this assumption. With the total differential of $u_L(m, w_M^{**}(m), w_H^{**}(m))$ or simply the chain rule, asking for $u_L$ to increase formally means:

$$\frac{du_L}{dm} = \frac{\partial u_L}{\partial m} + \frac{\partial u_L}{\partial w_M^{**}} \cdot \frac{dw_M^{**}}{dm} + \frac{\partial u_L}{\partial w_H^{**}} \cdot \frac{dw_H^{**}}{dm} > 0 \, . \tag{7}$$

Let us now use illustrative functions to determine in which cases (7) holds. As mentioned earlier it seems appropriate to slightly modify the standard RCU and ACU functions for our minimum wage game, since we have are only three, heterogeneously qualified workers. We propose the RCU function

$$u_i = w_i^{1-\alpha_i-\beta_i} \cdot \left(\frac{w_i}{w_j}\right)^{\alpha_i} \cdot \left(\frac{w_i}{w_k}\right)^{\beta_i} \tag{8}$$

and the ACU function

[26] As mentioned in the introduction, the economic literature uses the term 'minimum wage spillover' only for positive effects.

[27] In footnote 24 we mentioned unlikely cases in which RCU functions do not fulfill the last assumption of (A.3) – with functions defined like the following equation (8) and $w_L^{**} < w_M^{**} < w_H^{**}$, e.g., this is the case if either $w_L \le \alpha_M w_M$, $w_L \le \beta_H w_H$ or $w_M \le \alpha_M w_H$. Then, the denominators of (5) and (6) are nevertheless always smaller than zero for $w_H w_M (\alpha_H \beta_M - 1) < 0$ which is obviously true as longs as either $\alpha_H$ or $\beta_M$ is smaller unity.

$$u_i = (1 - \alpha_i - \beta_i)w_i + \alpha_i(w_i - w_j) + \beta_i(w_i - w_k) \tag{9}$$

with $i \in \{L, M, H\}$, $i \neq j \neq k$, $\alpha, \beta \geq 0$ and $\alpha + \beta \leq 1$, where $\alpha$ is the parameter measuring the relativity preference for the more similar worker (for worker $M$ this worker shall be the low productive worker $L$). Then, it can be easily shown[28] that (7) is larger than zero for all parameter sets with $(1 - \alpha_i - \beta_i) > 0$ holding for at least one subject $i$. This means that the low productive worker's utility will, indeed, increase after introducing a minimum wage if there is at least one player who is at least marginally interested in absolute position. The empirical findings of Johansson-Stenman et al. (2002), Alpizar et al. (2005) and Weinzierl (2006) suggested that the parameter measuring a worker's preference for absolute income – denoted $(1 - \alpha)$ there – should lie somewhere between .3 and .7. This is so far away from 0 that it seems reasonable to expect that our parameter measuring similar preferences, $(1 - \alpha_i - \beta_i)$, should be larger than 0 as well. We then immediately derive that $u_L$ should increase after introducing the minimum wage.[29]

The magnitude of wage spillovers can also be analyzed theoretically. Most of the empirical and theoretical results discussed above argued that minimum wage spillovers are larger for worker $M$ than for worker $H$. Comparing (5) and (6), we derive that the medium productive worker's wage change is larger than the high productive one's, iff

$$\frac{\left|\frac{\partial u_M}{\partial m}\right|}{\frac{\partial u_M}{\partial w_M} + \frac{\partial u_M}{\partial w_H}} > \frac{\left|\frac{\partial u_H}{\partial m}\right|}{\frac{\partial u_H}{\partial w_H} + \frac{\partial u_H}{\partial w_M}} . \tag{10}$$

Here, conclusions can only be speculative considering our set of general assumptions. By (A.3), the denominators in (10) are both positive. The numerators represent the absolute utility loss for worker $M$ and $H$, respectively, from a wage increase for the low productive worker. The studies discussed in Section 2 suggest the medium productive worker to be more affected, since comparisons to others are likely to be more important the more similar the

[28] See Appendix D for details.

[29] A possible further step could be, for example, to add factors into the brackets of the RCU function (8) that do not demand for equal wages, but, e.g., demand wages to mirror revenue differences. However, this does not change results. See Appendix D for details.

other worker is to oneself. This means that $|\partial u_M/\partial m| > |\partial u_H/\partial m|$ should hold – at least for a wage profile mirroring the revenue differences which we will assume for the next paragraphs. But even when abstracting from the fact that the simplifying equalization of $\partial u_M/\partial w_M$ and $\partial u_H/\partial w_H$ might not hold for large enough wage differences, one would additionally need to require the net utility loss $|\partial u_M/\partial w_H|$ to be larger than (or equal to) $|\partial u_H/\partial w_M|$ to come to a definitive conclusion. This requirement means that the absolute utility loss worker $M$ experiences, if worker $H$ leaps one unit further away, outweighs (or equals) worker $H$'s loss, if $M$ comes closer. Then, the denominator on the left side of (10) would be smaller than the one on the right side. General studies on upward and downward comparisons do not give an unambiguous answer to the question whether $|\partial u_M/\partial w_H|$ is larger than $|\partial u_H/\partial w_M|$ or not, especially when considering that we deal with heterogeneously qualified workers (see, e.g., Major et al. (1991) or Falk and Knell (2004) for (short) summaries), but the empirical study by Ferrer-i-Carbonell (2005) finds some evidence for a trend fur upward comparisons in Germany.

We thus limit ourselves here to state that if the net utility gain from equal marginal wage changes for both workers has the same effect on both of them, i.e., if the denominators in 10 are equal, then wage spillovers should indeed be larger for worker $M$ than for worker $H$.

Let us now quickly discuss if our model can incorporate the findings of FFZ2006 who argue that minimum wages might change fairness perceptions and thus increase wages of workers immediately affected by the minimum wage. An extension of our model that incorporates this idea is straightforward: If the minimum wage establishes a kind of psychological barrier that the new wage $w_L$ must significantly lie above, this could be catched by substituting $m$ with $m + \delta_m$ ($\delta_m > 0$), i.e., by demanding the new wage to be a little larger than the minimum. Main results are obviously qualitatively unaltered from this modification as long as $m + \delta_m < w_M^*$ holds. As we will discuss in greater detail during our experimental results, there is little reason to expect similar *fairness perceptions effect* influencing the wages of workers $M$ and $H$, since they are likely to earn a lot more than the minimum wage before its introduction. This also means that $m + \delta_m < w_M^*$ is not a very restrictive assumption.

In our setting the minimum wage is newly introduced, i.e., it is introduced in a labor market in which previously no minimum wage existed. Nevertheless, it is apparent that the effects we discuss would also apply for the alternative case in which lawmakers raise an existing minimum wage to a new level as long as the minimum wage change fulfills our assumptions. We thus think our results are also important for such changes in existing minimum wage legislation.

# 4 Experimental design

Our experiment basically followed the model, i.e., groups of four participants interacted during the experiment: one principal (P-participant), and the three workers (participants L, M, and H). The roles were assigned randomly before the start of the experiment and stayed the same throughout. Up to five groups of four formed a session with 20 participants.[30] Anonymity was guaranteed by seating players arbitrarily into two laboratories.

We set the revenues to $R_L = 100$, $R_M = 200$, and $R_H = 300$. Each group interacted for 10 periods. In each period, the principal had to offer a contract consisting of a fixed wage only to each agent, i.e., to propose a tuple $(w_L, w_M, w_H)$. We restricted the offers to positive integers smaller than or equal to the corresponding revenue.

In the minimum wage treatment (**treatment MW**), the first 5 periods (**MW1-5**) were played as three parallel ultimatum games without minimum wages. First, principals made their offers, then each agent $i$ was informed about the offers to the two other agents and asked to name the threshold wage $t_i$ ($\leq R_i$) above or equal to which he was willing to accept the principal's offer.

This means we apply a modified *strategy method* in our experiment. The strategy method is frequently used in experimental economics. It demands from participants to decide for all hypothetically possible situations of the played game, before the one situation that really applies is revealed to them.[31]

[30] Due to a larger number of no-shows than expected from prior experiments, we had to run a couple of sessions with less than 5 groups. Since groups of four did not interact at all this should not be important at all.

[31] This gives researches the whole strategy profiles of players, while the *decision method* (in which players only decide for the one factual situation) does not offer this insights. The advantage of the decision method is that it seems to represent the more natural way of decision making. However, most studies found no (see, e.g., Brandts and Charness (2000), Seale and Rapoport (2000), Oxoby and McLeish (2004), Solnick (2007)) or only negligible behavioral differences (Casari and Vason (2009)) between strategy and decisions methods, while Brosig et al. (2003) report some differences.

Asking workers to name their threshold wage knowing the wage offers to the other worker means that we deviate from the standard *strategy method* and introduce a kind of *contingent strategy method*. It gives us the worker's decision for each of his (up to 300) possible wage offers, but limits this insight to the factual wage offers to the other workers. We think this is the logical step in a case like ours in which the standard strategy method is theoretically possible, but not practicable: for worker $L$, for example, the strategy method would require to ask his threshold wage for each wage combination $(w_M, w_H)$ – in our setting 60,000 $(200 \cdot 300)$ of this combinations exist.

We admit that this approach might have accentuated participants' genuine disposition for income comparisons (as well as the standard strategy method would have), but perceived this a minor sacrifice compared to the broader insights to participants' decision behavior. Moreover, even using the *decision method*, i.e., giving participants the whole wage profile $(w_L, w_M, w_H)$ before their decisions, should have a similar effect, since wage comparisons were still possible. This strengthens the comparative advantage of this contingent strategy method.

We are not aware of another study that applies a similar *contingent strategy method*. Our approach is thus a novelty.

If an agent's threshold was lower or equal than the offer, he earned $w_i$ and the principal $R_i - w_i$, else both earned 0. A principal's overall payoff was the sum of the earnings in all three ultimatum games. After periods 1 to 5 (p1-5) there was a short break in which participants got the instructions for the *"second part"* of the experiment.

In the last 5 periods (**MW6-10**) contract offers were further restricted by minimum wages. Instead of pre-committing to a specific minimum wage, the minimum wage was deduced by the contract offers of period 5. Since we are interested in relative changes in wage hierarchies, we feared that *ex ante* defining a specific minimum wage for all groups would question their comparability, since then the minimum wage could lie above, below or between the existing wage profiles. We chose period 5, because wages were likely to increase during p1-5 (see Section 5). Let us denote the lowest wage in a specific period with $w_{low}$ and the second lowest wage with $w_{s\text{-}low}$. We set the minimum wage, $m$, to the integer nearest to the point defined by $w_{low} + .25(w_{s\text{-}low} - w_{low})$, i.e., the minimum wage was set between the lowest and the second-lowest wage paid in p5.[32] We additionally restricted it to be

[32] Or at least equal to both in case of equal wages.

not larger than 99 to guarantee meaningful offers to worker L. Participants did not learn this deduction rule, and were only told the concrete minimum wage applying to their group. Although we are not aware of other experimental studies that use a similar method of a group-specific treatment condition, we perceive it as crucial to guarantee comparability of observations in an experiment like ours. Workers' wage thresholds additionally had to fulfill $t_i \geq m$ now to prohibit non-binding decisions which is another difference to FFZ2006.

We ran a control treatment (**treatment CTR**) to check whether wage increases in p6-10 would also occur when no minimum wage was introduced. If this was the case, one would have to consider that possible wage spillovers detected in treatment MW were maybe not originating in relative income motives. In treatment CTR periods 1 to 5 (**CTR1-5**) were played exactly as MW1-5, but after the break 5 identical periods followed (**CTR6-10**).

At the beginning of each session, participants were randomly assigned to the roles of employers and employees. We gave participants no reason to believe that their productivity might change after MW1-5. On the one hand, stating something like *"your productivities will not change"* would have diminished possible, but anyhow improbable, *future earnings effects*, but, on the other hand, we feared that with this information participants might have started to ask themselves what else would change. Participants did know however, that there was going to be *"another part of the experiment"*.

The instructions were cautiously framed referring to *"employer"*, *"employee"*, and so on. The objections against framed instructions are that they might overemphasize imported views, but using these terms not only seems more natural, but in a similar labor market experiment by Fehr and Schmidt (2007) only negligible differences to a framing with *"buyer"*, *"seller"*, etc. was found. However, to the best of our knowledge, no study exists that explicitly analyzes the framing effect of the term *"minimum wage"*. We thus chose the conservative way to describe the minimum wage as *"lower bound"* additional to the standard labor market terminology used in our instructions. Representative instructions are given in Appendix A.

In our experimental session, 35 groups altogether played MW, 30 played CTR. Before the experiment started, participants had to answer some control questions (at their computer terminal) that checked their proper understanding of the instructions. All sessions were conducted at the experimental computer laboratory in Karlsruhe, in May and June 2009. Participants were students from the Karlsruhe Institute of Technology (KIT), mainly in business engineering. Average earnings were € 13.25 for about 65 minutes (about € 12.50 per hour).

# 5 Hypotheses

Our main research question is whether minimum wage-spillovers occur or not. For treatment MW, it makes sense to contrast between three kinds of hypotheses to tackle this question: a) the **benchmark hypothesis** with standard rational, payoff-maximizing subjects, b) the **fairness hypothesis** that loosely interprets findings from ultimate game experiments and other behavioral literature, and c) the **relative income hypothesis** based on our relative income model.

The benchmark predictions based on the subgame-perfect equilibria with payoff-maximizing players and *common knowledge* are straightforward.

***Benchmark hypothesis (hypothesis I)****: Employers offer the smallest possible wage to all three workers in p1-5 and the minimum wage in p6-10; employees always accept these contracts. Full employment results. No minimum wage spillovers occur.*

Results of ultimatum games doubt these predictions, although most often ultimate game experiments focused on only one game and not three parallel ones. In ultimatum game experiments, proposers frequently offered more equal proportions of the pie and responders regularly denied unequal offers (see Kagel and Roth (1995) or Camerer (2003) for comprehensive summaries). The equal split often was the modal observation. Motives like altruism, or fairness preferences (see, e.g., Rabin (1993)) were used to explain these results.

FFZ2006 use the heuristic of about 30 to 40 percent of the total pie size to predict firms' offers in their experiment which is comparable to ours. Offers below this should usually be rejected. Similar approximate estimations are given in meta-studies like Fehr and Gächter (2000) or Camerer (2003). The rejected offers suggest to expect less than full employment. When focusing on the findings of aspired pie shares, these results do not indicate that minimum wage spillovers should be expected.

***Fairness hypothesis (hypothesis IIa)****: In p1-5, employers offer on average about 30 - 40 percent of the revenue $R_i$ to worker $i$. In p6-10, employers* *either offer about the same as before or the minimum wage (depending on which value is larger). Less than full employment results and no minimum wage spillovers occur.*

The findings of Brandts and Charness (2004) and FFZ2006 suggest to modify hypothesis IIa a little. They both emphasize that a minimum wage might be perceived as a new wage threshold the principals have to overbid to induce acceptance of contract offers. FFZ2006 find in their setting that wages lie about 8 percent above the minimum wage.

***Fairness hypothesis (hypothesis IIb)****: In p6-10, employers either offer about the same as before or more than the minimum wage (depending on which of these two values is larger).*

Due to the rather large productivity differences, intuitive reasoning lets us expect a wage profile mirroring the productivity differences, i.e., $w_L \leq w_M \leq w_H$ should hold, probably with strict inequality. Positive minimum wage spillovers should occur, if our assumptions hold and relative income matters.

For every experiment testing a model with common knowledge, one has to consider that it should take a while for employers to accurately predict their workers' reservation wages.[33] Thus, denials of offers should occur and wage offers should follow an increasing trial-and-error path.

When discussing the experimental results below, we will argue that focusing attention to those wages that actually led to employment is most important, since they describe the factual contracts and exclude the extreme (trial balloon) cases. We thus formulate the following hypothesis for these paid wages already, although the differences are almost only semantical here. We will extensively discuss whether the experimental results differ between all wages and paid wages only.

With regard to paid wages, we feel tempted to predict them to be a little higher than 30 - 40 percent of revenues, not only because these are the wages that are accepted. Workers are likely to (greedily) notice that employers' payoffs are rather high due to the fact that their profit is the sum of three ultimatum games, i.e., inequity aversion motives (see, e.g., Bolton and Ockenfels (2000)) might shape reservation wages. We thus use the upper

[33] This is not only true for our work and fairness models, but also for the standard game-theoretic model underlying the benchmark hypothesis, if taking the theory to its logical conclusion.

bound of the wage interval proposed by FFZ2006 as benchmark prediction. As discussed before, our basic model does not directly predict wages for worker $L$ to exceed the minimum wage.

***Relative income hypothesis (hypothesis III)****: In p1-5, paid wages amount to about 40 percent of the revenues $R_i$. In p6-10, worker L is paid the the minimum wage. The wages of workers M and H increase compared to their wages in p1-5, i.e., there are positive minimum wage spillovers. Less than full employment results.*

Treatment CTR was performed with the main purposes to provide a check whether wages increase in p6-10 anyhow and whether the wage increases in MW6-10, if occurring, are larger than those in CTR6-10. Since CTR6-10 was played with the same rules as CTR1-5, only the parts of the hypotheses dealing with p1-5 apply to treatment CTR.

# 6 Experimental results

If not explicitly mentioned otherwise, we will always use parametric tests for cases with $n > 30$ and non-parametric statistics for smaller samples, probably violating normality, or ordinal data. Whenever a significance criterion is necessary, it is $\alpha = .05$. We will use two-sided tests as default and only deviate from this rule when the hypothesis explicitly demands otherwise. For nonparametric tests, we adjust for ties when necessary. When comparing the population means of two large samples, we revert to the Welch-Satterthwaite independent two sample t test without prior variance checks instead of using the standard t test. This has been proposed by numerous studies (e.g., Moser et al. (1989), Neuhäuser (2002), Ruxton (2006), or Zimmerman (2004)).

In treatment MW the tie-breaking wage of 99 applies in one group, i.e., we have 34 of 35 groups that are identical in so far, as the minimum wage is set equal to $w_{low} + .25(w_{s-low} - w_{low})$. Consequentially, the group violating this rule is excluded from the following analysis.[34] Furthermore, the averages of all wage offers for all workers increase during MW1-5 and, quite surprisingly, during MW6-10. This is illustrated in the following Figure 1 whose vertical axis is limited to a reasonable interval.[35] The figure visually confirms that

[34]Apart from the quite high wage offers, results for this group were not really different from the other groups. Data on request.

[35]We will do this in all following figures for reasons of presentability.

using the wages of p5 to determine the minimum wage was the right decision.

As expected, the condition $w_L \leq w_M \leq w_H$ holds in all 34 groups of treatment MW for period 5, and the two averages MW1-5 and MW6-10. In MW1-5 and MW6-10 it does so with strict inequality in 33 out of 34 cases; in period 5 of MW this is true in 31 cases. In treatment CTR things are even more unambiguous: In period 5 of MW and in MW6-10 the condition $w_L \leq w_M \leq w_H$ holds with strict inequality in all 30 cases. The same is true for 29 groups in MW1-5, and only one group violates even the weaker equality restriction. In this particular group, the principal offers worker M much more than worker H in the first two periods, but then switches to the expected wage profile with strict inequality after noticing that worker H never accepts. Overall, wage profiles are as expected which shows that the earlier assumptions were not far-fetched.

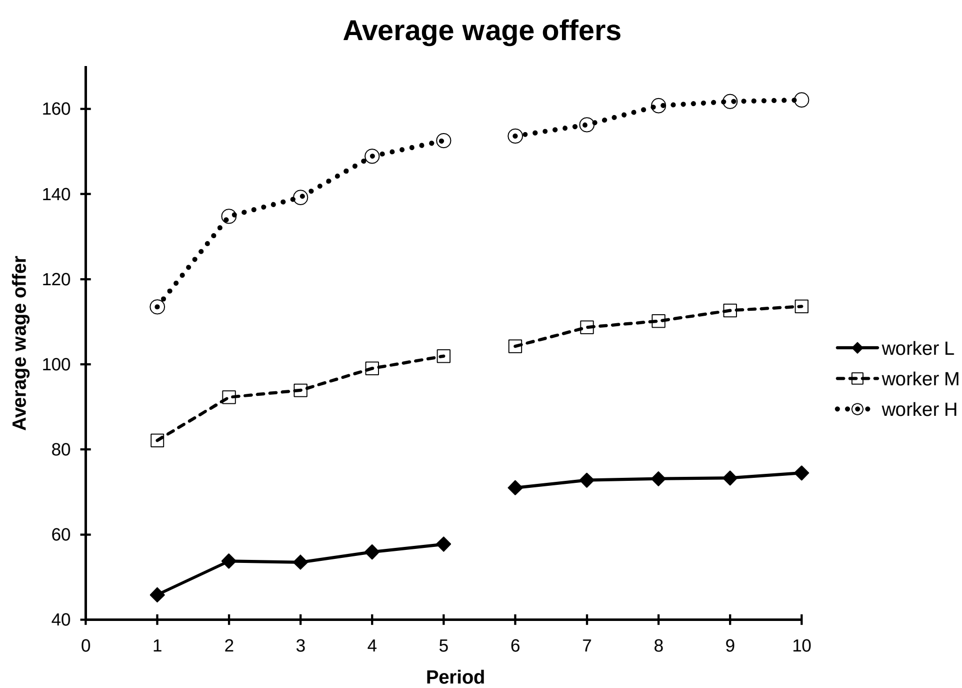


Figure 1: Treatment MW, average wage offers

## 6.1 The minimum wage treatment: General results

For each group of four (the principal $P$ and the three workers $L$, $M$, and $H$) we calculate two averages: the average of, e.g., wage offers before the introduction of the minimum wage (MW1-5), and the one after its introduction (MW6-10). The averages over all groups in MW1-5 are treated as mutually independent observations, the same holds for MW6-10. The observations after the introduction of the minimum wage (MW6-10) are dependent on the ones before (MW1-5). In Table 1 averages of totally hired workers ($hrd$), the resulting payoffs ($Pay_i$) and the welfare defined as payoff sum ($WF$) are given. These information are already also summarized for treatment CTR for later discussions (Section 6.4).

| | treat. MW (34 obs.) | | treat. CTR (30 obs.) | |
|---|---|---|---|---|
| | MW1-5 | MW6-10 | CTR1-5 | CTR6-10 |
| $hrd$ | 2.11 | 2.58 | 2.07 | 2.50 |
| $Pay_P$ | 201.16 | 209.87 | 198.32 | 234.32 |
| $Pay_L$ | 39.36 | 66.42 | 39.63 | 47.61 |
| $Pay_M$ | 79.45 | 98.12 | 72.92 | 85.93 |
| $Pay_H$ | 93.56 | 128.53 | 103.80 | 139.47 |
| $WF$ | 413.53 | 502.94 | 414.67 | 507.33 |

Table 1: Hiring frequencies and payoffs

It would be rather bold to expect full employment, since workers probably got reservation wages that employers have to learn. In our experiment, employers hire 2.34 workers during MW1-10 on average. This is significantly different from full employment (one sample t test, $p < .001$). However, there are two hints that employers get some experience in aspired wages: The average of hired workers not only increases from 2.11 to 2.58 from MW1-5 to MW6-10 (dependent sample t test, $p < .001$) which might be attributed to wage increases because of the minimum wage $m$, but also during the 5 periods before and after introducing $m$. While in period 1, e.g., 1.56 workers are employed, this average increases monotonically to 2.76 in period 5, before it drops to 2.09 in the first period with $m$ and then again increases monotonically to 2.79 in the last period. These findings contradict the full employment prediction of *hypothesis I*, while confirming the alternative *hypotheses II and*

*III*. Payoff results are less important than factually paid wages, since they include payoffs of both groups: employed and unemployed. However, it is interesting that payoffs not only significantly increase for all workers, but also modestly for the employer, obviously due to the increase in average hiring. Welfare is also much higher in MW6-10.[36] Overall, we conclude that hiring behavior rejects the *benchmark hypothesis I*, but confirms *hypotheses IIa, IIb and III.*

***Result 1****: In treatment MW, full employment does not occur on average, but hiring averages rise after the introduction of the minimum wage and during MW1-5 and MW6-10. Payoffs of all workers largely increase after the introduction of the minimum wage.*

## 6.2 The minimum wage treatment: Wages

In the experiment, contract offers do not always lead to employment and we expect them to follow a trial-and-error-path, since principals have to learn their workers preferences. We will thus start by limiting our analysis to those offers that are accepted. These observations seem most appropriate to characterize results, since they represent factual contracted wages and exclude (extreme) trial balloon wage offers rejected by workers. Let us, from now on, synonymously use the terms *successful wage offers* or simply *paid wages* when referring to the wage offers that are accepted by workers and thus actually apply. We will discuss the negligible differences between paid wages and all wage offers at the end of this section.

To guarantee comparability between groups, we did not introduce one concrete minimum wage for all groups, but rather used a group-specific value depending on the wage offers in MW5. Therefore, the absolute paid wages alone are still only of limited explanatory power and we additionally compute the relative change (in percent), named *chg*, between the paid wage offers in MW1-5 and those of MW6-10 for each group. Table 2 gives averages of paid wages (and successful wage thresholds already) for all three workers in MW1-5 and MW6-10 as well as the average minimum wage. In the fifth column the average of relative changes is given. The last column gives the number of observations for MW1-5, MW6-10 and *chg*.[37]

[36] Resulting $p$-values of dependent sample t tests for these five variables are: $p = .399$ for $Pay_P$, $p = .001$ for $Pay_M$ and $Pay_H$, and $p < .001$ for $Pay_L$ and $WF$.

[37] In one group worker $H$ was never hired in MW1-5 and in another group never in

| | MW1-5 | $m$ | MW6-10 | $chg$ | # of obs. |
|---|---|---|---|---|---|
| $w_L$ | 57.20 | 69.03 | 73.35 | 29.37 % | 34, 34, 34 |
| $w_M$ | 99.65 | – | 111.40 | 14.44 % | 34, 34, 34 |
| $w_H$ | 149.71 | – | 161.75 | 10.93 % | 33, 33, 32 |
| $t_L$ | 43.08 | 69.03 | 70.34 | 104.65 % | 34, 34, 34 |
| $t_M$ | 83.84 | – | 100.12 | 28.96 % | 34, 34, 34 |
| $t_H$ | 136.50 | – | 150.34 | 15.11 % | 33, 33, 32 |

Table 2: Treatment MW, paid wages and successful wage thresholds

Averages of paid wages in MW1-5 are 57.20 for worker L, 99.65 for worker M and 149.71 for worker H, which obviously rejects the *benchmark hypothesis*, but also all other hypotheses, since it is significantly larger than 40 percent of the respective pies.[38] Instead, paid wages amount to about 50 percent of the respective pies for workers $M$ and $H$ and to a little larger fraction for workers $L$.

***Result 2****: In the first five periods of MW, workers earn more than 40 percent of the respective revenues $R_i$.*

Paid wage averages increase from MW1-5 to MW6-10 to 73.35 for L, 111.40 for M and 161.75 for H. The average relative wage change is highest for workers $L$ who are the only ones immediately affected by the minimum wage. Their wages increase for 29.37 percent on average.

Our main research hypothesis predicted that minimum wage spillovers occur, i.e., that wages of the medium and the high productive worker also increase in MW6-10, although these workers already earned more than the minimum wage in p5 (and MW1-5). Since $w_L \leq m \leq w_M \leq w_H$ always holds (see the sections before), the wages of workers $M$ and $H$, indeed, do not have to increase, but the relative wage changes for these groups suggest that they nevertheless do, i.e., they suggest that minimum wage spillovers exist. The relative increase for workers $M$ is 14.44 percent and thus still half as high as the increase for workers $L$. The increase for high productive workers is a little lower with 10.93 percent. We can test whether the increases are statistically

MW6-10. So we have 33 observations there and can compute relative changes in 32 cases.

[38]One sample t tests against 40 (worker L), 80 (worker M) and 120 (worker H), respectively. Resulting $p$-values are: $p < .001$ in all three cases.

significant by performing dependent sample t tests that use the averages of MW1-5 and MW6-10 for each group. Since we hypothesized wage increases for all workers, we perform the tests one-sided. All tests deliver significant results ($p < .001$ for workers $L$ and $M$ and $p = .010$ for worker $H$).

Before summarizing results, let us further analyze the relation of minimum wages and worker's wages. The average minimum wage is $m = 69.03$ and the average of paid wages to workers $L$ in MW6-10 is only a little, yet significantly higher than this minimum wage ($w_L = 73.35$).[39] This means that there is some reason to believe that a *fairness perception effect*, as FFZ2006 found it, exists. We calculated the relative change between the wages $L$ in MW6-10 and the minimum wage for each group. On average, paid wages are about 6.5 percent higher than the minimum wage which is only a little less than the about 8 percent FFZ2006 found. To put it another way: the difference between the successful wage offers to workers $L$ in MW1-5 and the minimum wage amounts to about 23 % and accounts for only three fourths of the 29.5%- wage increase we observe.

The question that now arises is: Is it likely that similar effects are accountable for the wage increases we observed for workers $M$ and $H$, i.e., is there reason to believe that the minimum wage spillovers should be attributed to fairness perception effects instead of *relative income effects*?

The wages paid in MW1-5 to workers $M$ and $H$ are on average already about 45.5 percent and 119 percent, respectively, higher than the minimum wage, i.e., the minimum wage cuts off a part of the interval of feasible wages much below the wages factually paid to $M$ and $H$. Considering these large differences, the intuitive intermediate conclusion should be that there is little reason, if any at all, to believe that fairness perception effects similar to that for worker $L$ should be of importance.

Although there is no one-to-one experimental evidence for this intuitive reasoning, the study of Falk and Fischbacher (2006) gives some justification. In their experiment, recipients had to evaluate the kindness of hypothetical splits of 10 Swiss Francs offered by a proposer. The kindness had to be rated on a scale ranging between 0 (very unkind) and 100 (very kind). In scenario (i), participants were told that every integer split was possible, i.e., 10 for the proposer and 0 for them ($(10, 0)$), or one unit for them ($(9, 1)$), or $(8, 2)$ and so on until $(0, 10)$. On the other hand, in scenario (vii), only the offers $(2, 8)$,

[39]Dependent sample t test using the observations for MW6-10 and $m$ for each group, two sided: $p < .001$.

$(1,9)$, and $(0,10)$ were feasible, i.e., the lowest offers of the original scenario were disallowed. We think that comparing these two scenarios resembles our experimental setting quite well: scenario (i) is similar to the first five periods without the minimum wage (MW1-5) and scenario (vii) for the later five periods (MW6-10) in which the minimum wage restricts the feasible offers.

Unsurprisingly, the *kindness evaluations* of the offer $(2,8)$ in scenarios (i) and (vii) largely differed according to Falk and Fischbacher (2006). Responders evaluated kindness of $(2,8)$ with +62.0 in (i) and only with +40.8 in (vii) where $(2,8)$ was the lowest feasible offer. Evaluations were still differing a little for $(1,9)$ with +68.0 in (i) and +62.0 in (vii). Note that the value for $(2,8)$ in (i) is exactly equal to the value for $(1,9)$ in (vii) which means that a larger amount had to be offered to achieve the same level of perceived kindness. Roughly transferred to our setting this can be used to explain the fairness perception effect for workers $L$: the new lower bound of $(2,8)$, resembling our minimum wage, is obviously perceived as being unkind and might thus be avoided by mindful principals.

However, our observations for $M$ and $H$ are much different: Their wages are much larger than the minimum wage in MW1-5 and MW6-10 and are thus much more comparable to the extreme offer of $(0,10)$ in scenarios (i) and (vii). In fact, the kindness evaluations of $(0,10)$ the authors reported were almost identical. Average kindness amounted to +72.3 in (i) and was even a little higher with +73.4 in (vii). These results strengthen our intuitive argument that fairness perception effects for workers $M$ and $H$ should be quite modest, if existing at all.

After all, the considerations just presented do, at least, not disqualify the relative income effect as the main source of the positive minimum wage spillovers we observe. However, it will not be until the discussion of the control treatment, before we can give a more definitive answer. For now, we limit ourselves to summarize that the predictions of *hypothesis III* are essentially confirmed.

***Result 3****: Paid wages in MW1-5 are highest for workers $H$, followed by paid wages for workers $M$ and $L$. The average minimum wage is higher than the wages of workers $L$, but lower than those of workers $M$ and $H$. In MW6-10, paid wages are higher than in MW1-5 for all workers, i.e., there are positive minimum wage spillovers for workers $M$ and $H$.*

We now want to visualize and deepen the preceding analysis by discussing relative wage changes in all 10 periods. For this purpose, we introduce $rel_{i,p}$

as a measure of relative wage change for worker $i$ in period $p$. We define it as the fraction between the wage in period $p$ ($w_p$) and the average successful wage offer in MW1-5 ($w_{1-5}$) times 100 minus 100, i.e., this variable gives the relative change in percent between the wage paid in a period compared to the average wage before the introduction of the minimum wage.[40] Figure 2 depicts all ten periods on the horizontal axis and gives the averages of $rel_{i,p}$ on the vertical axis.

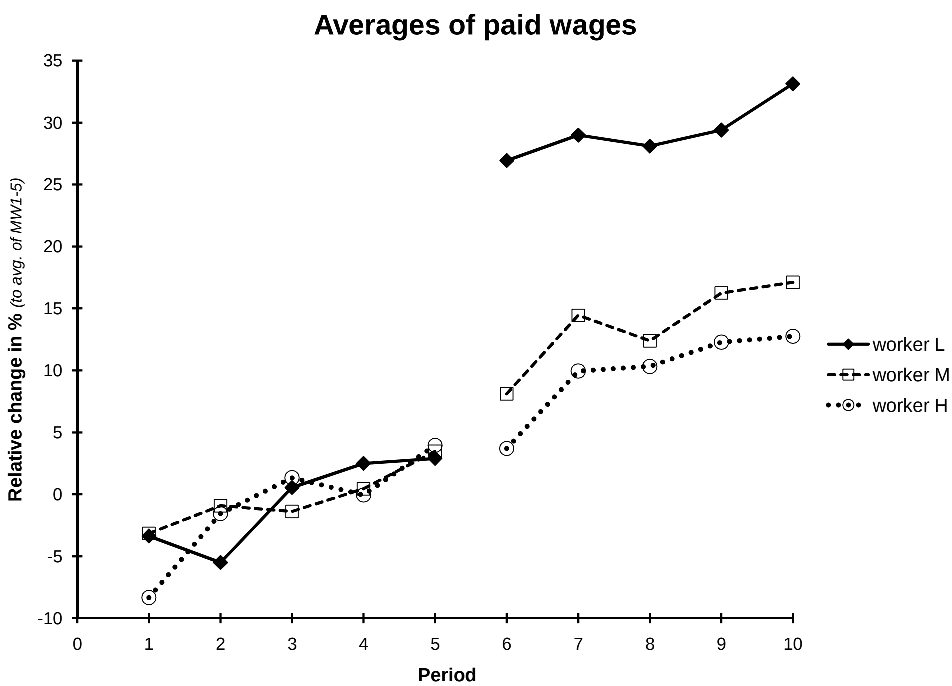


Figure 2: Treatment MW, relative changes in paid wages

The relative changes before the introduction of the minimum wage are quite moderate for all workers and lie mainly between -5 % and +5 %. As discussed before, wages increase during MW1-5 which is reflected in Figure 2 by the positive slopes of the hypothetical lines connecting $rel_{i,1}$ and $rel_{i,5}$. The minimum wage forces wages for $L$ to largely increase in MW6-10. Consequentially, from period 6 on the relative change for worker L lies between +27 % and +33 % and is thus much higher than during periods 1 and 5. Except for a little bump from periods 7 to 8, relative changes increase for

[40]We will use MW1-5 and p1-5 synonymously here.

later periods again, i.e., average successful wage offers were higher at the end of the experiment than shortly after introducing the minimum wage. This trend for what is called *seniority wages* in literature was already visible on the more aggregate level in Figure 1. It could be a result of the higher hiring figures discussed in Section 6.1 or *adaptation effects* could play a role, i.e., workers' aspired wages might have continually increased (see Section 2.2) and employers might have anticipated this. We will pick up this thought when discussing threshold wages below.

Relative wage changes for the medium productive workers $M$ are higher in each of the periods 6 to 10 (between about +8 and +17 %) than in each of the periods 1 to 5. There is small jump from the last period without minimum wage to the first afterwards, i.e., the minimum wage spillover is clearly visible. Again, there is an increase in wage offers from period 6 to 10 (with a bump at period 8).

There are two minor differences for workers $H$: a) the wage increases in MW6-10 are a little lower than for workers $M$ and range between +4 and +13 % and b) successful wages, and thus relative changes, are almost equal in periods 5 and 6, before they quite sharply increase in period 7 and afterwards.

Now, to conclude this subsection let us quickly broaden the view to all wage offers instead of focusing on paid wages as before. Table 3 gives these data (again for thresholds as well).

| | MW1-5 | $m$ | MW6-10 | *chg* | # of obs. |
|---|---|---|---|---|---|
| $w_L$ | 53.35 | 69.03 | 72.94 | 38.46 % | 34, 34, 34 |
| $w_M$ | 93.86 | – | 109.88 | 19.93 % | 34, 34, 34 |
| $w_H$ | 137.79 | – | 158.91 | 19.56 % | 34, 34, 34 |
| $t_L$ | 47.31 | 69.03 | 70.54 | 88.43 % | 34, 34, 34 |
| $t_M$ | 86.96 | – | 102.20 | 22.98 % | 34, 34, 34 |
| $t_H$ | 147.32 | – | 154.31 | 8.07 % | 34, 34, 34 |

Table 3: Treatment MW, all wage offers and wage thresholds

There are only minor differences to paid wages given in Table 2: The average over all wage offers is, of course, a little lower than in the subgroup of eventually successful wage offers in MW1-5 (about 6 to 9 percent), but this difference almost completely vanishes in MW6-10, which is not surprising given the increased hiring figures mentioned before. Consequentially, the percentages of the relative changes are a little higher this time. The increase for worker $L$ is about 38.5 percent and again twice as high as for worker $M$ (about 20 percent). However, the increase for worker $H$ is only marginally lower now with about 19.5 percent. Performing the same tests as above for paid wages, i.e., checking benchmark levels, wage spillovers and the increase above the minimum wage, gives qualitatively identical results.[41]

## 6.3 The minimum wage treatment: Threshold wages

Averages for workers wage thresholds were already given in the tables before. Since thresholds do not directly determine the contracted wages when they are lower than offers, we think it is more interesting to focus on all wage thresholds (Table 3), rather than limiting the view to those that lead to employment. Again qualitative differences between these two data sets are negligible and will be given in footnotes occasionally.

First of all, notice that thresholds in MW1-5 follow the same order as wages. According to Table 3 they are lowest for the low productive worker with $t_l = 47.31$, followed by those for the medium productive worker, $t_M = 86.96$, and are highest for the most productive one, $t_H = 147.32$. The fractions of the respective pies demanded thus lie between 40 and 50 percent. Just like for wages, the average minimum wage lies between the thresholds for $L$ and $M$. After the introduction of the minimum wage in MW6-10 the thresholds increase to $t_l = 70.54$, $t_M = 102.20$ and $t_H = 154.31$, respectively. One-sided dependent sample t tests tell us that the increases for $L$ and $M$ are highly significant ($p < .001$) and the increase for worker $H$ is almost significant on the 5%-level ($p \approx .050$).[42] This suggests that the minimum wage spillovers we observe are an echo of workers' rising wage demands and are not just founded in wrong assessments of workers' behavior by principals.[43]

[41] Tests results for the one sample t tests again the 40 %-prediction are: worker L: $p < .001$; worker M: $p < .001$; worker H: $p = .009$. One-sided dependent sample t tests comparing the wage average in MW1-5 with that in MW6-10 give us $p < .001$ for all workers. The $p$-value of the dependent sample t test comparing the wage of worker $L$ in MW6-10 with the minimum is $p < .001$.

[42] The more exact $p$-value is $p = .0502$.

[43] The results are similar for the sub-sample of thresholds that lead to employment. Here, $p$-values are $p < .001$ for $L$ and $M$ and $p = .002$ for workers $H$ (same tests as before).

We also calculated averages of relative changes again. The thresholds increase for 88.43 percent for worker $L$, 22.98 percent for $M$ and 8.07 percent for $H$, i.e., the order is qualitatively the same, yet more pronounced than for (paid) wages. We visually present these findings in Figure 3 that is constructed analogically to Figure 2.

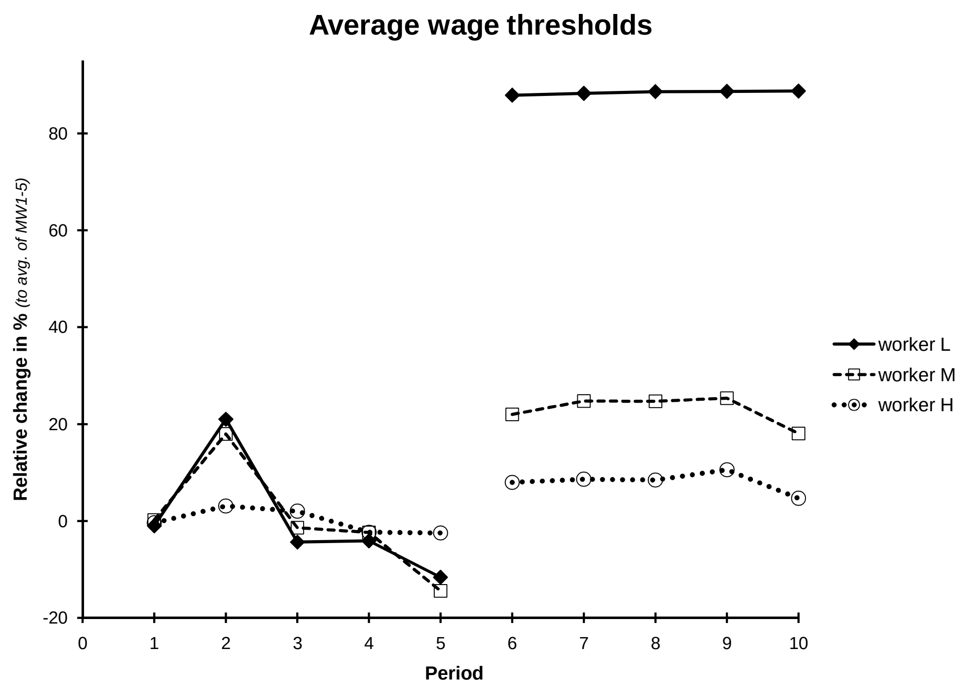


Figure 3: Treatment MW, relative changes in wage thresholds

Except for a peak in period 2 and modest decreases in periods 5 and 10, thresholds are rather stable during MW1-5 and MW6-10. The spillover effects are clearly visible. Since thresholds do not increase during MW1-5 and MW6-10, respectively, *adaptation effects* on behalf of the workers as a cause for the seniority wage structure observed for wages are unlikely.

As for paid wages before, the figure suggests that relative changes for workers $M$ are larger than for workers $H$. Due to the dependencies in our data, there is no statistically sound method to test this last difference. However, we think it is fair enough to summarize that the comparisons of relative wage and threshold changes give some support to our own and other authors' theoretical and empirical conjectures that the relative income effect is more important for those workers whose earnings are (comparatively) nearer to the minimum wage (workers $M$) than for workers whose wages are even higher (workers $H$).

Comparing the average wage thresholds for workers $L$ to the minimum wage is also interesting. The minimum wage is on overage 85.45 percent higher than the threshold wages during MW1-5. Additionally, we calculate the relative change between the minimum wage and the threshold wages in MW6-10 for all 34 groups. On average wage thresholds are only about 2 percent higher than the minimum wage, which is also reflected in the averages given in Table 3 ($m = 69.03$ and $t_L = 70.54$). This is even more interesting when keeping in mind that we explicitly disallowed thresholds to be lower than the minimum wage to prevent them from being meaningless. However, even this small difference is significant using a dependent sample t test ($p < .001$). In summary, the fairness perception effect exists for thresholds, but is of little magnitude only. Apart from this, *Hypothesis III* is confirmed again. Since FFZ2006 did allow workers to name threshold wages lower than the minimum wage, the authors could not compute the relative change and we can not compare our results to theirs.

***Result 4**: Wage thresholds in MW1-5 are highest for workers H, followed by those for workers M and L. In MW6-10, thresholds increase for all workers, and workers L demand only a little more than the minimum wage.*

We now want to finish discussing treatment MW by comparing the wage thresholds with the revenue relations. Let us define

$$tp_{i,j} = \frac{t_i/w_j}{R_i/R_j} \qquad \text{and} \qquad tp_{i,-i} = \frac{t_i/w_{-i}}{R_i/R_{-i}}$$

with $i, j \in \{L, M, H\}$, $i \neq j$, and $w_{-i}$ ($R_{-i}$) giving the average of wages (revenues) of all workers except worker $i$. For $tp_{i,j}$ (or $tp_{i,-i}$) values larger than 1 indicate that worker $i$'s threshold wage in comparison to worker $j$'s wage (or all other workers' wages) is larger than the respective revenue difference, i.e., values larger 1 mean that worker $i$ demands *"more than he deserves"* in comparison the revenue differences. Values smaller 1 indicate the opposite. In economic and psychology literature (see Frank (1984a) for a brief introduction) it is often argued that people tend to demand more for themselves than objective criteria would allow. Table 4 gives all averages $tp_{i,j}$ and $tp_{i,-i}$ for all workers $i$. The second row defines for which reference worker (group) the value $tp$ is calculated.

| worker (group) j | MW1-5 | | | | MW6-10 | | | |
|---|---|---|---|---|---|---|---|---|
| | $L$ | $M$ | $H$ | $-i$ | $L$ | $M$ | $H$ | $-i$ |
| $tp_{L,j}$ | – | 1.08 | 1.17 | 1.12 | – | 1.31 | 1.40 | 1.35 |
| $tp_{M,j}$ | .89 | – | 1.09 | .99 | .71 | – | 1.00 | .89 |
| $tp_{H,j}$ | 1.27 | 1.38 | – | 1.32 | .72 | .94 | – | .85 |

Table 4: Treatment MW, wage thresholds and revenue relations

Before the introduction of the minimum wage, workers $L$ and $H$, indeed, demand more than their revenue fractions. For worker $L$, for example, the divergence is $tp_{L,H} = 1.17$, i.e., his wage threshold in relation to the standing offer to $H$ is 17 percent larger than the revenue relation. A two-sided one sample t test shows that this is significantly different from 1 ($p = .044$), while the modestly lower value for his demands in comparisons to both other workers, $tp_{L,-i} = 1.12$, becomes insignificant ($p = .086$, same test).

The values for worker $H$ are a little misleading, since they are heavily influenced by one extreme outlier with $tp_H > 10$ that was more than six times larger than the second-highest value. Without this group the values are only a little different from 1: $tp_{H,L} = .99$, $tp_{H,M} = 1.11$, and $tp_{H,-i} = 1.05$. But even when not excluding the outlier, the differences between all $tp_H$ and 1 given in Table 4 are statistically insignificant due to the large variances.[44]

Workers $M$ almost exactly demand what they deserve in comparison to both other workers in MW1-5: for them $tp_{M,-i} = .99$ is, of course, insignificantly different from 1 (two-sided one sample t test: $p = .856$). It is interesting, however, to note that this aggregate result conveys the rather large differences between their demands with respect to the wages of workers $L$ and $H$. While medium productive workers demand more than they deserve in comparison to workers $H$, $tp_{M,H} = 1.09$ (not differing from 1, same test, $p = .282$), they want less than they deserve with regard to worker $L$, $tp_{M,L} = .89$ (almost significantly different from 1, same test, $p = .061$). This suggests that for workers $M$ the wage of worker $L$ is insofar less important as he is willing to get underpaid in comparison to him as long as he is overpaid with regard to worker $H$.

In MW6-10 the observations for workers $L$ are not that meaningful due to

[44] One sample t test as before, $p$-values are: for $t_{H,L}$: $p = .334$; for $t_{H,M}$: $p = .175$; for $t_{H,-i}$: $p = .252$.

the minimum wage. But here, a similar effect as for workers $M$ now occurs for $M$ and $H$. For workers $M$, the wage relation to $H$, $tp_{M,H} = 1.00$ is much larger than that to the worker $L$, $tp_{M,L} = .71$ and the high productive workers are now much more willing to accept an underpayment with regard to worker $L$ than to worker $M$ ($tp_{H,L} = .72$ and $tp_{H,M} = .94$) which could have been expected since the medium productive worker is most similar to him.

## 6.4 The control treatment

We reported minimum wage spillovers for workers $M$ and $H$. However, for these workers we did not only find that the wage averages of MW6-10 were larger than that of MW1-5, but we also presented visual evidence – in Figures 1 and 2 – that wages increased during MW1-5 and MW6-10. This might leave the reader with the question whether the wage spillovers may not originate in the introduction of the minimum wage that triggers *relative income effects* as our theoretical model argued, but are rather an artefact due to the a general tendency for increasing wages in experiments like ours. Similar trends did not occur for wage thresholds. Nevertheless, we did a control treatment CTR in which the first five periods CTR1-5 were played equally to treatment MW, but then no minimum wage was introduced and the same five periods were played again (CTR6-10).

If the minimum wage is not triggering relative income effects that cause the minimum wage spillovers, we should observe equally high wage increases from CTR1-5 to CTR6-10 as we did before for MW1-5 and MW6-10. On the contrary, if wage spillovers are due to the minimum wage, the increases should be higher in MW than in CTR. We thus hypothesize in this section that wage increases in treatment CTR are lower than those in treatment MW.

The hiring and payoff averages already given in Table 1 confirm the expectation that the first five periods of MW and CTR do not differ that much. For example, hiring averages are 2.11 in treatment MW and 2.07 in treatment CTR. When additionally splitting the hiring averages to all three workers, we find that a little more workers $M$ are hired in MW than in CTR (.79 in MW and .71 in CTR), but less of type $H$ (.62 in MW and .69 in CTR). Repercussions of this are visible in payoffs, but none of this slight differences is significant according to two-sided two sample Welch-Satterthwaite t tests

(*WS tests*).[45] The same holds for paid wages: in CTR1-5 they are $w_L = 58.89$, $w_M = 103.36$, and $w_H = 154.35$, in MW1-5 they are $w_L = 57.20$, $w_M = 99.65$, and $w_H = 149.71$. These differences are statistically insignificant.[46]

Let us now briefly describe results for CTR6-10 and their differences to those in CTR1-5. Table 5 presents the same data for paid wages in CTR as Table 2 did before for MW with the exception that the minimum wage column is, of course, left out. Instead a last column is added that gives the relative changes for MW, again.

| | CTR | | | | MW |
|---|---|---|---|---|---|
| | CTR1-5 | CTR6-10 | *chg* | # of obs. | *chg* |
| $w_L$ | 58.89 | 57.92 | 9.64 % | 29, 29, 29 | 29.37 % |
| $w_M$ | 103.36 | 106.54 | 7.91 % | 28, 29, 28 | 14.44 % |
| $w_H$ | 154.35 | 162.24 | 3.08 % | 28, 30, 28 | 10.93 % |

Table 5: Treatment CTR, paid wages

First of all, notice that although the paid wages for worker $L$ slightly decrease from $w_L = 58.89$ in CTR1-5 to $w_L = 57.92$ in CTR6-10 the relative wage change is positive with 9.64 percent. This is not a typo, but due to one extreme outlier with an increase of more than 300 percent. Since differences between CTR and MW are large anyhow and not in our main interest, we do not bother detailing what would change if we would exclude this outlier. Furthermore, a one-sided Wilcoxon paired sample test refutes the hypothesis that wages increase for workers $L$ from CTR1-5 to CTR6-10 ($p = .467$).[47]

The medium productive workers' average wages are 103.36 in CTR1-5 and increase to 106.54 in CTR6-10. This increase is significant according to a one-sided Wilcoxon paired sample test ($p = .025$). For worker $H$ the increase from 154.35 in CTR1-5 to 162.24 in CTR6-10 is slightly insignificant using the same test ($p = .068$). These intermediate results suggest that wages for $M$ and $H$ are also increasing in CTR.

[45] The $p$-values for all variables in Table 1 range from $p = .404$ for $Pay_H$ up to $p = .968$ for $WF$. Data on request.

[46] Mann-Whitney U-tests, $p$-values are: $p = .829$ for $w_L$, $p = .409$ for $w_M$, and $p = .694$ for $w_H$. Results are similar when looking at all wage offers instead. Data on request.

[47] We choose the one-sided hypothesis here and below, since we did so for MW before.

Are these wage increases in CTR at least smaller than in MW? For answering the question, we start by discussing differences for worker $L$ that are, of course, rather extreme due to the influence of the minimum wage in treatment MW. It thus suffices to look at the aggregate averages of relative wage changes given in Table 5 that are 29.37% for MW and only 9.64% for CTR. The hypothesis that both changes are equal is refuted in favor of the alternative that wage increases are larger in MW using a one-sided two sample Mann-Whitney U-test (*U-test*) ($p < .001$).

Visually depicting the relative changes in paid wages in treatments CTR and MW for workers $M$ and $H$ is helpful. This is done in the upper half of Figure 4. The lower half of Figure 4 deals with wage thresholds and will be discussed a few paragraphs later.

Relative wage changes in MW and CTR for workers $M$ and $H$ are nearly indistinguishable in periods 1 to 5, i.e., they vary between -5 % and +5 % and are increasing over time, although the latter trend is less pronounced for workers $M$ in CTR than in MW. However, for both workers the differences between treatments MW and CTR are clearly visible in periods 6 to 10.

In each of the periods 6 to 10, the relative wage change for workers $M$ in treatment MW is more than twice as high as in treatment CTR. Furthermore, the wage increase during CTR6-10 from about +4 % to +7.5 % is a little less pronounced than that during MW6-10 from about +8 % to about +17 %. On aggregate level the wages of workers $M$ increase for 14.44 % in treatment MW, but only for 7.91 % in the control treatment. This difference is significant according to a one-sided U-test ($p = .012$).

In period 6, relative wage changes for workers $H$ are only a little higher in MW (+3.70 %) than in CTR (+2.03 %). Afterwards wages and thus relative changes largely increase in MW, but eventually decrease a little in CTR so that changes are at least 3 times as high in MW in each of the periods from 7 to 10. According to a one-sided U-test, the difference between relative wage change averages in MW (10.93 %) and CTR (3.08 %) is only slightly insignificant with a $p$-value of $p = .055$.

Overall, these results suggest that the wage spillovers are larger in treatment MW and CTR. This implies that the wage spillovers in treatment MW originate in the introduction of the minimum wage that trigger relative income effects, and are not just an artefact caused by a tendency for wages to increase over time. The results do not differ much when broadening the view

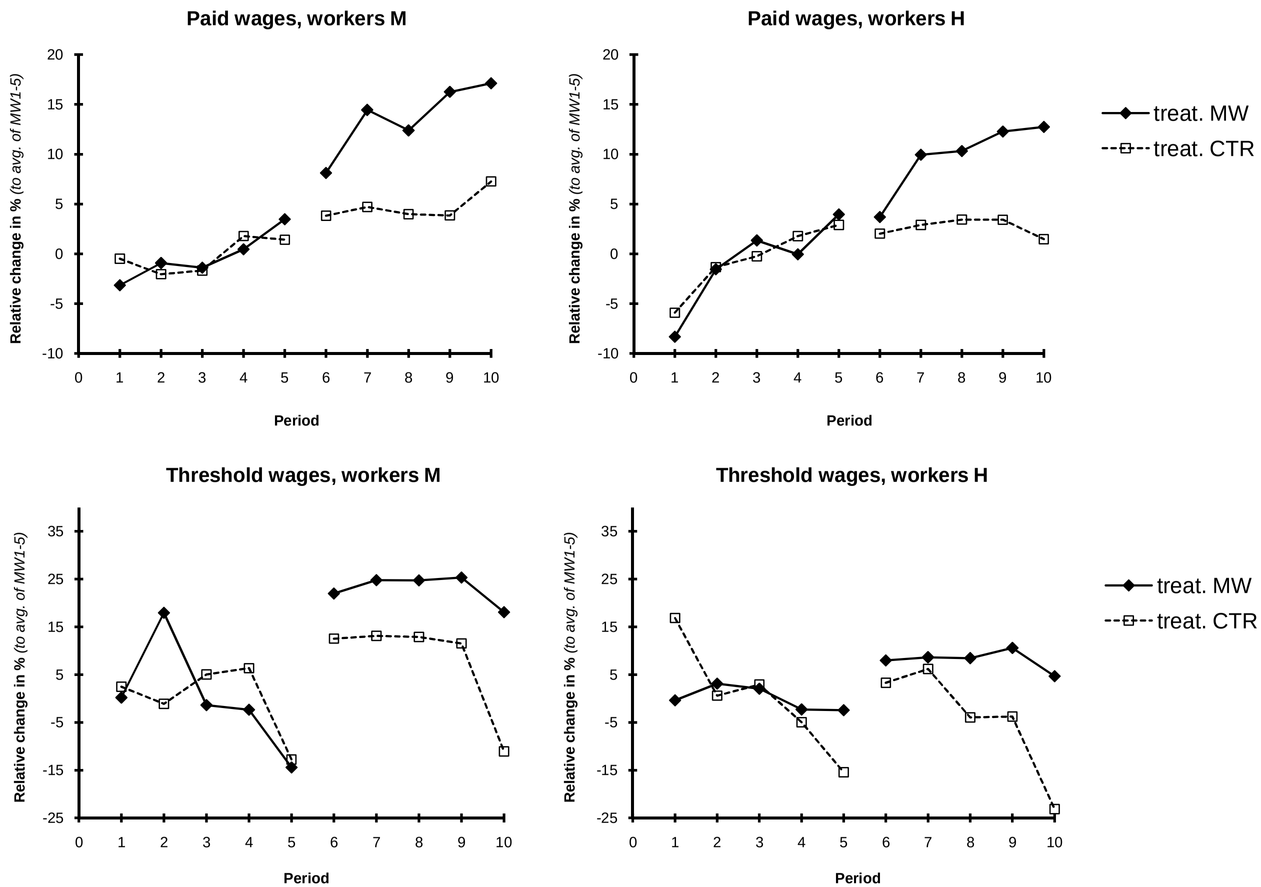


Figure 4: Treatments MW and CTR, relative changes in paid wages and wage thresholds

to all wage offers.[48]

Let us conclude this section by comparing differences in threshold wages in CTR and MW. Table 6 gives averages for the whole group of all wage thresholds for CTR just as Table 3 did for MW. Additionally, changes for MW are given in the last column.

| | CTR | | | | MW |
|---|---|---|---|---|---|
| | CTR1-5 | CTR6-10 | *chg* | # of obs. | *chg* |
| $t_L$ | 52.77 | 52.86 | 1.76 % | 30, 30, 30 | 88.43 % |
| $t_M$ | 95.75 | 101.05 | 7.80 % | 30, 30, 30 | 22.98 % |
| $t_H$ | 140.83 | 137.50 | -4.27 % | 30, 30, 30 | 8.07 % |

Table 6: Treatment CTR, wage thresholds

Trends are even clearer than for paid wages: Threshold wages for workers $L$ are almost identical in CTR1-5 and CTR6-10 with an average increase of only 1.76 %, while due to the minimum wage they inevitably largely increase in MW (88.43 %).

The moderate increase of 7.80 % for thresholds of workers $M$ in CTR is much smaller than the 22.98 %-increase in MW. This difference is significant according to a one-sided WS test ($p = .003$). Threshold wage averages for workers $H$ decrease from CTR1-5 to CTR6-10 for -4.27 % and are thus lower than the already only modest increase of 8.07 % in treatment MW. This difference is also significant using the same test again ($p = .016$).

These results suggest that not only wage spillovers in MW are due to the minimum wage and relative income effects, but this minimum wage also changes workers threshold wages much more lasting than time does.

Figure 4 visualizes these insights for workers $M$ and $H$ and since results

[48] Relative wage changes for workers $L$ ($M$) are 38.46 % (19.93 %) in MW, but only 9.99 % (11.20 %) in CTR; one-sided WS test: $p < .001$ (p = .064). At first glance, the difference for workers $H$ is rather small with 19.56 % in MW and 16.13 % in CTR. However, the high relative wage change for CTR is mainly due to an extreme outlier–case in which the principal offers only 42, on average, to his worker $H$ in CTR1-5 and thus never employs him, but offers 148 in CTR6-10. The relative wage change in this group is almost 6 times as high as the second highest relative change, while the analog factor is only 1.6 in MW. When excluding the outlier, the average relative change drops from 16.13 % to 7.98 % and the difference to the 19.56 %-increase in MW is significant (one-sided U-test: $p = .024$).

are qualitatively unchanged when restricting attention to successful wage thresholds only[49], we conclude:

***Result 5****: In p1-5, results for CTR and MW are almost identical. Increases in wages and threshold wages are larger in MW than in CTR.*

# 7 Conclusion

Minimum wages are a labor market institution regularly discussed and implemented across the world. While the public debate often centers around questions of proportionateness of society's wage distribution and dangers of financial and social exclusion of people with low wages (see, e.g, The Australian (2009), Irish Times (2009a), or Washington Post (2009)), scientific studies, both theoretical and empirical, predominantly focus on direct fiscal and employment effects of minimum wages. Our study does investigate these fiscal and employment effects. Instead, it analyzes the indirect effects of minimum wages, particularly the repercussions of minimum wages on the wages of workers who earned more than this minimum wage before its introduction. In cases in which wages of those workers increase after introducing a minimum wage, literature speaks of a minimum wage spillover. The question whether such minimum wage spillovers exist or not should be important for lawmakers and their advisors, not only when considering introducing a minimum wage, but also when changing the height of an existing minimum wage.

We are confident that we enriched the knowledge about minimum wages by a) theoretically analyzing minimum wage spillovers in a model that focuses on relative income preferences and heterogeneously qualified workers, and by b) experimentally testing our theoretical predictions.

We started by evaluating literature and singled out the best established cause for minimum wage spillovers, namely peoples' preferences for a favorable relative income position. Two concrete classes of utility functions that capture relative income preferences were proposed in literature. In our relative income model, we derived main results without committing to one of this specific classes of functions and were able to show that a set of rather general assumptions about relative income preferences suffices to qualitatively

[49]The $p$-values of one-sided U-tests are: $p < .001$ for $L$, $p = .004$ for $M$, and $p = .043$ for $H$.

analyze minimum wage spillovers. The model predicted that minimum wage spillovers occur and suggested that they originate in workers' relative income preferences.

Our experimental design followed the relative income model and thereby excluded some of the other causes for minimum wage spillovers discussed in theoretical and empirical literature like substitution effects, for example. The experiment is thus, on principle, not only capable of testing for minimum wage spillovers, but also of attributing them with high certainty to one specific cause, namely relative income preferences.

Our experimental results essentially confirmed the theoretical predictions: minimum wage spillovers occurred and we presented evidence that they originated in relative income preferences.

We are aware that by concentrating on relative income preferences only, one might overemphasize the magnitude of minimum wage spillovers in comparison to a real world environment in which other effects also might play a role. However, our findings do not suggest that minimum wage spillovers are only statistically significant, but of no practical relevance. On the contrary, we observe that the increases in wages of workers who earned more than the minimum wage before its introduction, i.e, the minimum wage spillovers, are almost half as high as the increases for workers whose wages have to rise, since they earned less than the minimum wage before its introduction. This clearly indicates rather strong minimum wage spillovers and we conclude that they should be considered by lawmakers when introducing or modifying minimum wage laws.

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# A Instructions

The original instructions were written in German. In the following, we thus give translated instructions. Additionally, formatting is changed to save some space. Given below are instructions for employers in treatment MW. Instructions in the original formatting and language or for other participants and treatments can be obtained on request.

**Instructions:**

You are participating in an experiment consisting of two parts. In the following these two parts will be named "part 1" and "part 2".

In this experiment, you can earn money, which will be paid out in cash immediately after the experiment. Your earnings depend on your own decisions and those of other participants. Every participant makes his decisions on his own at his computer box. Your anonymity will be guaranteed even after the end of the experiment. Communication between participants is not allowed. Please turn off your mobile phone and read the following instructions carefully. Please stay silently at your seat at the end of the experiment. We will call you individually and anonymously with the help of your box number and pay you off. We will have to exclude you from the experiment and all payments if you violate these rules.

In both parts of the experiment you form a group of four with three other participants. The composition of the group stays the same in both parts of the experiment. This means that in part 2 of the experiment you form a group with the same participants as in part 1.

Earnings are calculated in GE (Experimental Currency Unit) during the experiment. At the end of both parts of the experiments, the total earnings are calculated and converted into Euro at a fixed exchange rate. **This exchange rate is 100 GE = 80 Euro-Cent.**

Additionally to the earnings of the two parts of the experiments, participants once receive a fixed participation fee that does not depend on decisions. **This participation fee is: 500 GE.**

You are now handed out the instructions for the first part of the experiment. You will receive the instructions for the second part, after the first part is finished.

**Part 1:**

You form a group of four with 3 other participants. Three of you are employees ($AN_1$, $AN_2$, $AN_3$), one is the employer (AG). The role assignment was carried out randomly in the beginning of the experiment by the drawing of the box numbers. **Your role is that of an employer**.

In the following, employers and the employees interact for 5 periods. In each of these 5 periods, the employer offers wages to the employees who individually decide whether they want to be employed or not. If an employee is hired, he will produce a good for the employer. Before explaining the procedure of each of the 5 periods in detail, it is necessary to give the following information regarding the possibly produced goods. If, later on, $AN_1$ is hired by his employer, he will – automatically and without further decisions – produce a good which is immediately sold by the employer. The fixed selling price of this good is $R_1 = 100$ GE. Similar rules apply for $AN_2$. If he is hired, he will also automatically produce a good which is sold directly. The selling price of this good is also fixed and is $R_2 = 200$ GE. Analogically, the product possibly produced by $AN_3$ is sold for $R_3 = 300$ GE. **Each** of the 5 periods mentioned before is subdivided into **three stages** in the following way:

- Stage I: **Wage offers**
  The employer AG offers a wage to each employee AN, for which he (AG) is willing to employ him (AN). The wage offer to $AN_i$ is denoted by $w_i$ (with $i = 1, 2, 3$).
  The employer is allowed to offer different wages, i.e., that, for example, the wage offer to $AN_1$ ($w_1$) does not have to be be identical to the wage offer to $AN_3$ ($w_3$).
  However, the wage offers are not allowed to be lower than 1 and are also not allowed to be higher than the value of the good $AN_i$ produces. Furthermore, only integers are allowed as wage offers. Overall, each of the three wage offers has to fulfill: $1 \leq w_i \leq R_i$ with $w_i$ being an integer. Altogether a total wage offer profile, $(w_1, w_2, w_3)$, results that describes a wage offer to each of the three employees.

- Stage II: **Employment decision**
  Based on $(w_1, w_2, w_3)$ each worker $AN_i$ is told only the wage offers to the both other workers, i.e, he does **not** know his own wage offer at first. Then, he names the limit $t_i$ for his wage $w_i$ above (or equal to) which he is willing to be employed. It has to fulfill: $t_i \leq R_i$.
  An example for $AN_2$: He learns $w_1$ and $w_3$ and then chooses his wage limit $t_2$.
  After this he learns his actual wage offer $w_2$. If his limit $t_2$ is less or equal to the wage offer $w_2$, he will be hired by the employer (for the

wage $w_2$, see stage III). If his limit $t_2$ is higher than the wage offer $w_2$, he will not be hired in this period.

- Stage III: **Production, selling and earnings**
  If $AN_i$ is not being hired, nothing will be produced and sold and thus he and the employer will earn 0 GE from this potential hiring relationship. If $AN_i$ is hired, the good will be produced and sold an $AN_i$ will earn the offered wage $w_i$. The employer will earn the difference between the sales price and the paid wage, $R_i - w_i$. The employer's total earnings are the sum of the earnings from the hiring relationships with all workers. An example: If $AN_1$ and $AN_2$ are hired, but $AN_3$ is not, then $AN_1$ will earn $w_1$, $AN_2$ will earn $w_2$ and $AN_3$ will earn 0. The total earnings for the employer from the hiring relationships with the three workers follow as: $(R_1 - w_1) + (R_2 - w_2) + 0$.

In each period, all employees decide unaware of the decisions of the other employees. This means that, e.g., $AN_1$ does not know if $AN_2$ is hired or not before his own decision. However, each employee gets to know which employees had been hired und which not in the later course of each period.

After these three stages I to III the first periods ends. Then, another 4 periods are taking place with the same rules. The earnings of the 5 periods are summed up. After these 5 periods the second part of the experiment follows. You will receive new instructions for this part. Before we start the experiment, you have to answer some control questions at your computer box.

**Part 2:**

Just like in the first part of the experiment you form the same group of four with the same participants. Your role has also not changed. In the second part, another 5 periods take place that again consist of three stages I to III.

Before the first of the following 5 periods, additionally, a lower bound $m$ will be set once and for all. This lower bound is set for each of the 5 following periods. The exact value of $m$ will be given on your computer screen. This lower bound than applies to all wages, i.e., the employer AG has to offer a wage of at least $m$ to each worker $AN_i$. Overall, each of the three wage offers now has to fulfill: $m \leq w_i \leq R_i$. Besides this the same rules for wage offers, employment decisions and earnings as in part 1 apply. The employees, however, have to name a limit at least as high as the lower bound $m$ now, i.e.: $t_i \geq m$. Your total earnings are the sum of your earnings in parts 1 and 2 of the experiment plus the participation fee.

# B Wage ordering

Under which circumstances does the intuitive wage profile **(A.6.1)** $w_L^* < w_M^* < w_H^*$ hold? We have to rely on more specific assumptions to answer this question. We start by introducing a second *reservation utility assumption*: **(A.1.a)** $r_L < r_M < r_H$. It states that the reservation utilities' ranking mirrors the ranking of productivity differences. We think this assumption is less strict than it might look at first glance, since it specifically does not require reservation utilities to be less divergent than marginal revenues. It does, however, require comparability of agents' utility functions.[50] However, **(A.1.a)** alone does not fully determine the wage profile. We also need some kind of similarity in preferences which will be clearer with an example: assume only a low and a medium productive player interact ($i, j \in \{L, M\}$; $i \neq j$). The RCU function of worker $i$ shall be given by

$$u_i = w_i^{1-\alpha_i} \cdot \left(\frac{w_i}{w_j}\right)^{\alpha_i} \tag{11}$$

Now suppose we want to check whether the principal can set the wages to $w_L = w_M$. We first equate $u_L$ to $r_L$ and $u_M$ to $r_M = r_L + d$ (with $d > 0$) and solve the two equations defined by (11) for $r_L$ which leads to:

$$w_L^{1-\alpha_L} = w_L^{1-\alpha_M} - d \, . \tag{12}$$

With similar RCU functions Johansson-Stenman et al. (2002) estimated $\alpha$ for different income groups. They did not find significant differences in mean values of $\alpha$. Though this may be different on individual level and the estimations were not explicitly based on different skill levels, we could use this best heuristic available to us, assuming $\alpha$ to be quite similar for $L$ and $M$. Then, it is immediately obvious that (12) can never hold for all $d$ significantly larger than zero. This implies that the principal can not set

[50] Alternatively, one can re-interpret the reservation utilities as pie shares participants commonly demand in ultimatum games. FFZ2006 use the heuristic of about 30 to 40 percent of the total pie size to predict firms' offers. Since pies are unequal in our game, one could generalize this by expecting reservation utilities to be larger for players who bargain over larger pies.

$w_L$ equal to $w_M$. Furthermore, $w_L > w_M$ is also impossible, since this would would further increase the left, and further decrease the right side of equation (12). An even stronger support for the result that $w_L = w_M$ can not hold, is given by the ACU function parameter estimates reported by Johansson-Stenman et al. (2002). The authors found that $\alpha$ was increasing for higher income levels, which, if transferred to an ACU analogon of (12) leads to a further increase of the right side of the equation.

To sum things up: With this expanded set of assumptions, concrete RCU (or ACU) functions suggest that the equilibrium wage profile likely mirrors the productivity differences, i.e., $w_L^* < w_M^* < w_H^*$ holds.

# C Comparative statics

The first-order conditions (FOC) of the *Lagrangian function* $L(w_M, w_H, \lambda_M, \lambda_H; m)$ are denoted as follows: FOC no. 1: $\partial L/\partial w_M = 0$; no. 2: $\partial L/\partial w_H = 0$; no. 3: $\partial L/\partial \lambda_M = 0$; no. 4: $\partial L/\partial \lambda_H = 0$. They implicitly define four equations $F^p(w_M, w_H, \lambda_1, \lambda_2; m)$ with $p$ being the same number as in the corresponding FOC. This, in turn, describes all four endogenous variables depending on the exogenous minimum wage $m$ only: $w_M^{**} = f^1(m)$, $w_H^{**} = f^2(m)$, $\lambda_M^{**} = f^3(m)$, $\lambda_H^{**} = f^4(m)$. Differentiating again regrouping, and some defining then leads to:

$$\begin{bmatrix} \frac{\partial F^1}{\partial w_M} := A & \frac{\partial F^1}{\partial w_H} := B & \frac{\partial F^1}{\partial \lambda_M} := C & \frac{\partial F^1}{\partial \lambda_H} := D \\ \frac{\partial F^2}{\partial w_M} := E & \frac{\partial F^2}{\partial w_H} := F & \frac{\partial F^2}{\partial \lambda_M} := G & \frac{\partial F^2}{\partial \lambda_H} := H \\ \frac{\partial F^3}{\partial w_M} = C & \frac{\partial F^3}{\partial w_H} = G & \frac{\partial F^3}{\partial \lambda_M} = 0 & \frac{\partial F^3}{\partial \lambda_H} = 0 \\ \frac{\partial F^4}{\partial w_M} = D & \frac{\partial F^4}{\partial w_H} = H & \frac{\partial F^4}{\partial \lambda_M} = 0 & \frac{\partial F^4}{\partial \lambda_H} = 0 \end{bmatrix} \begin{bmatrix} \frac{dw_M}{dm} \\ \frac{dw_H}{dm} \\ \frac{d\lambda_M}{dm} \\ \frac{d\lambda_H}{dm} \end{bmatrix} = \begin{bmatrix} -\frac{\partial F^1}{\partial m} := I \\ -\frac{\partial F^2}{\partial m} := J \\ -\frac{\partial F^3}{\partial m} := K \\ -\frac{\partial F^4}{\partial m} := L \end{bmatrix}$$

or in simpler vector form: $M \cdot N = O$.

With Cramer's Rule, the desired comparative static results are $dw_M^{**}/dm =$

$|M_1|/|M|$ and $dw_H^{**}/dm = |M_2|/|M|$, where $|M_i|$ denotes the determinant of vector $M$ with the i-th column replaced by vector $O$.

Due to the fact that the four lower right cell entries all equal zero, all second-order derivatives (in $A$, $B$, $E$, and $F$), vanish and some further simplifications yield

$$\frac{dw_M^{**}}{dm} = \frac{G \cdot L - H \cdot K}{D \cdot G - C \cdot H} \qquad \text{and} \qquad \frac{dw_H^{**}}{dm} = \frac{D \cdot K - L \cdot C}{D \cdot G - C \cdot H},$$

which directly gives (5) and (6). *q.e.d.*

# D Total differential, utility of worker $L$

For the RCU functions defined by (8) the two comparative static derivatives (after some cancellations) are:

$$\frac{dw_M^{**}}{dm} = \frac{\beta_M \beta_H + \alpha_M}{1 - \beta_M \alpha_H} \cdot \frac{w_M}{w_L} \quad \text{and} \quad \frac{dw_H^{**}}{dm} = \frac{\alpha_M \alpha_H + \beta_H}{1 - \beta_M \alpha_H} \cdot \frac{w_H}{w_L}.$$

Substituting this and all other terms into (7) and further cancellations lead to:

$$\frac{du_L}{dm} \geq 0 \Leftrightarrow \frac{1 - \alpha_L(\alpha_M + \beta_M \beta_H) - \beta_L(\alpha_M \alpha_H + \beta_H) - \alpha_H \beta_M}{1 - \beta_M \alpha_H} := \frac{N}{D} \geq 0\,. \quad (13)$$

Repeating the same steps for the ACU functions defined by (9) leads to exactly the same intermediate result. Since the denominator of (13) is larger than zero for either $\beta_M \neq 1$ or $\alpha_H \neq 1$ (which we implicitly assume to avoid further complexities), the numerator $N$ determines the sign of (13). Substituting $\beta_L = 1 - \alpha_L$, $\beta_M = 1 - \alpha_M$, $\beta_H = 1 - \alpha_H$ leads to $N = 0$. Furthermore, one immediately derives that $N > 0$ holds if any $\beta_i$ is smaller $1 - \alpha_i$. *q.e.d.*

The approach to directly investigate the sign of (7) does not lead to an unifying categorization for RCU and ACU functions.[51] But even adding factors $x_{i,j}$ into the brackets in (8) does not change results for RCU functions. For example, the converters $x_{i,j} = R_j/R_i$ would constitute productivity differences as agents' new aspirations level. However, every set of converters (not only the example named above) leads to (13) again.

[51]Simple calculations only yield that as long as the derivative $\partial u_i/\partial w_i$ is larger than the absolute value of $\partial u_i/\partial w_j + \partial u_i/\partial w_k$, the total differential is larger than zero, but this is only a sufficient condition that solely the ACU necessarily functions fulfill.