Reference Dependence and the Role of Information Frictions †

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Abstract

Decades of research highlight the importance of social preferences in strategic interactions. However, most studies assume full information and stable conditions. We relax both by introducing endowment shocks and information frictions into a labor market experiment. Workers evaluate wages relative to a reference wage that depends on economic conditions and adjusts instantaneously to information, but sluggishly and asymmetrically to experience. Firms form accurate beliefs about how shocks and information reshape effort responses and act on their beliefs. We find self-interest and reference dependence rationalize behavior previously attributed to other-regarding preferences. Counter-intuitively, information frictions do not always benefit the informed party.

JEL classifications: J2, J3, E32
Keywords: reference dependence, information frictions, beliefs, wage rigidity, labor market, business cycle

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1 Introduction

Ample experimental evidence convincingly demonstrates that other-regarding preferences lead people to deviate from the self-interested outcomes predicted by standard economic theory (Camerer, 2011). A significant stream in this literature models experimental labor markets under full information and stable economic conditions to study how variation in structural parameters influences wages, effort, and employment (Charness and Kuhn, 2011). A general finding is that reciprocity and fairness motives prop up wages and effort above the Nash equilibrium prediction (Fehr et al., 1993, 1998). Such other-regarding preferences motivate many behavioral theories of labor market dynamics.[1]

However, the assumptions of full information and stable economic conditions may not be benign. Economic volatility, information structure, or both may affect how market participants convey and perceive others' intentions. For example, a worker may be more willing to accept wage cuts during economic downturns triggered by shocks unrelated to the firm's performance (i.e. inflation in inputs, negative transitory shocks, etc.). Similarly, workers may expect wage hikes in times of economic prosperity.

These examples convey the main intuition of our paper, wherein we propose that a worker evaluates wages with respect to a reference wage that depends on the firm's economic conditions. Because of this relationship between reference wages and economic conditions, information structure can play a crucial role in wage-effort dynamics. Understanding this is important since most real-world employment relationships feature at least some degree of information asymmetry.[2]

[1]Examples of theories include the fair wage-effort hypothesis (Akerlof, 1982; Akerlof and Yellen, 1988, 1990), reference dependence (Tversky and Kahneman, 1979), adverse selection in quits and hires (Weiss, 1980, 1990), and reciprocity and fairness (Rabin, 1993). For evidence on labor market dynamics, see (Bewley, 1995, 1999; Altonji and Devereux, 2000; Agell and Lundborg, 2003; Dickens et al., 2007; Babecky et al., 2010; Kaur, 2019; Jo, 2019).

[2]See Cullen and Perez-Truglia (2018) and Cullen and Perez-Truglia (2022) for evidence of infor-

This paper relaxes these assumptions by introducing information frictions and economic shocks into a bilateral gift exchange game, yielding a 2×2 between-subjects design. In this design, we match subjects into stable pairs and randomly assign one to act as a firm and the other as a worker and have them interact for 20 periods. In each period, the firm receives an endowment that it splits between the worker's wage and savings. The worker responds to the wage offer by choosing a costly level of effort. At the end of each period, both the firm and worker learn of their own and their counterpart's payoff. Halfway through each session we either increase or decrease (*positive* and *negative*) the firm's endowment by one third. Sometimes the workers knows of this shock (*full information*) and sometimes they do not (*asymmetric information*).

We also introduce a novel approach to belief elicitation that allows us to study how the firm's beliefs about the worker's effort response function evolves with experience, in response to shocks, and under different information conditions. Importantly, we also elicit the full effort response function via strategy method so that we can evaluate the accuracy of the firm's beliefs.

We find that under full information, wages adjust in the direction of endowment shocks, and firms and workers share shocks equally. On average, firms increase wages following a positive shock by about half the size of the shock and decreases wages following a negative shock by about the same magnitude. Belief elicitation reveals firms do this because they know fully-informed workers expect wages to adjust following endowment shocks. Because workers' expectations adjust upon learning of the shock, post-shock wages offer little surprise and effort remains relatively stable.

Introducing information frictions significantly changes wage dynamics following endowment shocks. Wages increase, on average, by about half as much following a posi-

mation frictions within a firm.

tive shock and fall by about 20% less following a negative shock whenever firms know that workers are uninformed. Thus, information frictions moderate wages and better align them with the theoretical predictions of a self-interested, profit-maximizing firm. Belief elicitation reveals that, on average, firms expect workers' effort response functions to remain unchanged following the shock. Together, these facts suggest that firms raise wages for informed workers due to self interest (i.e. because workers expect wage hikes) rather than other-regarding preferences.

Because uninformed workers' wage expectations do not adjust following endowment shocks, wage changes come as a surprise and lead to much stronger effort responses, which lead to a significant change in profit shares. Despite significantly smaller wage hikes, effort increases by about as much as under full information. And despite the average wage falling by 20% less, effort decreases by about four times as much. Thus, information frictions benefit firms following a positive shock and harm firms following a negative shock. Counter-intuitively, it is not always the more informed party who benefits from information frictions.

Wage expectations adjust with subsequent experience. However, adjustment is sluggish relative to a full-information setting and adjustment dynamics depend on the direction of wage surprises. Succinctly, we find that wage expectations are much more strongly anchored in response to negative wage surprises than to positive wage surprises. In positive asymmetric treatments, the initial wedge between wage expectations and offers vanishes by period 15. This is in sharp contrast to full information conditions, where adjustment is immediate. For negative asymmetric shocks, wage expectations remain above wage offers in all the post-shock elicitation periods. Hence, we find subjects are less willing to adjust expectations downward following unexpected wage cuts than upward following unexpected wage hikes.

Finally, in a structural exercise, we demonstrate that there is no downside to introducing state-dependent reference wages into the worker's utility function. Using only pre-shock data, we estimate a model with an adjustable reference wage and then obtain predictions for the post-shock periods. As a comparison, we benchmark our predictions against a model with a constant reference wage that does not react to endowment shocks. Our model significantly outperforms the benchmark model when forming out-of-sample predictions of worker behavior and at predicting firms' post-shock beliefs following negative shocks. In addition, our model significantly outperforms the benchmark model at prediction post-shock wages. In general, this exercise highlights the benefits of incorporating information frictions into models of reference dependence.

Previous work has studied how information can influence wages and efforts in experimental settings.[3] Charness and Kuhn (2007) show in multi-worker firms that revealing within firm wages does not lead to lower levels of effort, and Gächter et al. (2013) shows in a multi-worker gift exchange game that intra-group comparisons can influence reciprocity. Rubin and Sheremeta (2016) use a gift exchange experiment to show that that random productivity shocks reduce wages and effort. Davis et al. (2017) replicate this finding. In our context, shocks corresponds to aggregate economic conditions and not to productivity signals or within firm comparisons.

Our results are consistent with the few available experimental studies that examine how information about available surplus influences allocations. Some evidence from dictator games suggests that people strategically exploit asymmetric information in their favor when making pro-social decisions (Dana et al., 2006, 2007). Varying in-

[3]The idea of modeling labor markets as partial gift-exchanges has extensive experimental backing. Examples using chosen effort are Fehr et al. (1993); Fehr et al. (1998) and Charness (2004). Examples using real-effort tasks are Cohn et al. (2015); Greiner et al. (2011) and Hennig-Schmidt et al. (2010).

formation in ultimatum games shows that relative payoffs and fairness enter players' utility functions (Mitzkewitz and Nagel, 1993; Kagel et al., 1996; Schmitt, 2004; Croson, 1996).

Exactly which circumstances make wage cuts painful is important to understand. Experiments are particularly useful in this pursuit. Buchanan and Houser (2020) find in a stylized gift-exchange game that the wage-effort relationship responds to nominal but not real wage cuts. Chen and Horton (2016) find that workers in online labor markets naturally form reference points and quit tasks when they encounter wage cuts. However, workers are not upset if they provide a reasonable explanation for wage cuts.

Several other studies demonstrate reference-dependent behavior among workers. DellaVigna et al. (2017) provide evidence from a natural experiment in Hungary that workers anchor their expectations around recent paychecks. Shvartsman and Diriwächter (2017) show that reported job satisfaction in Germany increases when workers receive a wage increase. This complements the experimental evidence that effort is higher when workers receive wage increases. We contribute to this literature by showing that firms beliefs about workers responses can provide an additional mechanism to explain reluctance to cut wages, as Bewley (1995, 1999) survey evidence suggested.

Recent evidence from DellaVigna et al. (2022) shows that workers hired to work on behalf of charities are insensitive in productivity to unexpected positive and negative 'gifts' (i.e. wage shocks) from the employer. However, they find evidence that workers are more willing to do extra work in response to positive gifts and suggest evidence that positive reciprocity may be stronger than negative reciprocity. In our setting, absent the intrinsic motivation of working for a charity, we find the opposite: workers drastically reduce effort in response to unexpected wage cuts and do not increase effort following unexpected wage hikes. Taken together, this suggests that workplace context and the nature of work can play an important role in wage-effort dynamics.

Finally, we contribute to an active literature on reference dependence. Kőszegi and Rabin (2006) endogenized reference points theoretically by assuming expectations can form a reference point. This assumption found support in the laboratory Abeler et al. (2011) and in the field Crawford and Meng (2011). More recently, Thakral and Tô (2021) have shown that reference points adjust dynamically in response to accumulated income, with agents placing more weight on recent earnings. This observed recency bias prevents instantaneous adjustment of reference, which would produce behavior consistent with neoclassical theory.

We contribute to this literature by exploring the relationship between economic shocks, information, and reference points. We show that reference points can adjust instantaneously in response to information about an impending economic shock. However, similar shocks lead to sluggish adjustment of the reference point under severe information frictions where only a wage history can change the workers reference point. Finally, we show there may be asymmetry in the speed at which reference points adjust that depends on the direction of wage surprises. Whereas recent wage experiences are enough to adjust reference points to unexpectedly high wages, we see that reference points fail to adjust to unexpectedly low wages.

In the next section we describe our conceptual framework where we highlight the role of information asymmetries. Section 3 describes our experimental design on how we elicit beliefs and effort responses. Section 4 contains our main analysis and results. We show the results of our structural exercise in section 5. Finally, section 6 concludes.

2 Theoretical Framework

We now introduce a stylized labor market model to illustrate how information frictions and economic shocks can influence wage-effort dynamics. The key intuition is that workers have reference-dependent preferences that depend on available information about firms' economic conditions, which can reshape the effort response function *if* the worker is aware of the change. Previous models employ similar logic by allowing for effort to respond to the introduction of minimal wages (Brandts and Charness (2004); Falk et al. (2006); Owens and Kagel (2010)), a rise in inflation levels or a threat to firm profits (Kahneman et al. (1986); Kaur (2019)). We then use predictions from this simple theoretical model to develop behavioral hypotheses for our experiment.

2.1 Basic set up

Consider a labor market with a single firm and single worker formed into a stable firm-worker pair that interacts for N periods. The firm receives an endowment R at the beginning of each period and sets a wage $w \in [\underline{w}, ..., R]$. The worker provides costly effort $e \in [0, \overline{e}(w)]$, where $\overline{e}(w)$ is the maximum possible effort that yields non-negative utility. For now, we assume that both the worker and firm have symmetric information regarding economic conditions, R.

We consider a profit-maximizing firm with no altruistic motives whose profit function depends on the endowment, the wage, and the worker's effort:

$$\pi_i(w, e) = (R - w)e. \tag{1}$$

The worker's utility function incorporates monetary incentives, reference-dependence, and other-regarding preferences. This yields a modified version of the effort response function introduced in (Akerlof and Yellen (1990, 1988)) and similar in spirit to Dickson and Fongoni (2019):

$$U_j\left(e, w, \tilde{R}\right) = w - c(e) + M\left(w, \tilde{R}, w_0(\tilde{R})\right) \cdot e \tag{2}$$

where $c(e)$ is a strictly convex cost function of effort. The first component $w - c(e)$ captures the monetary incentive of the worker while the last component M is the 'morale function,' which captures three distinct features comprising the worker's reference dependence and other-regarding preferences.

First, the worker forms a reference wage $w_0(\cdot)$ that depends on her beliefs, $\tilde{R}$, about the firm's economic conditions, R. When both parties have full information about economic conditions, $\tilde{R} \equiv R$. We assume $w_0(\cdot)$ is order-preserving so that a higher endowment always warrants a higher wage. Formally, all else equal, $\forall(R,\ R')$ where $R > R'$, $w_0(R) > w_0(R')$.

Second, the worker evaluates the offered wage w in relation to the reference wage $w_0(\cdot)$. Wages above the reference wage induce positive reciprocity while wages below the reference wage induce negative reciprocity. This produces a gain or loss in the worker's utility, respectively.

Finally, the worker considers wages relative to the firm's endowment. Suppose a worker receives a wage larger than her reference wage. Intuitively, our model says the worker will more strongly reward this wage coming from a poorer firm than a richer firm. This adds an additional channel through which changes in (information about) economic conditions impact the worker's effort choices.

Given these preferences, the functional form of M resembles a gain-loss function:

$$M\left(w, R, w_0(R)\right) = \alpha_j \left(\frac{\mu + w - w_0(R)}{R}\right)^{\beta_j}$$

where μ represents the reference utility value when the worker receives the reference wage, $w = w_0(R)$. We also allow $M(\cdot)$ to depend on parameters $\alpha_j,\ \beta_j \geq 0$ to account for individual traits of reciprocal behavior (Cox et al. (2006); Buchanan and Houser (2019)). When $\alpha = 0$,the worker does not respond reciprocally to wages and our model yields the classical Nash equilibrium prediction of minimum wages and effort. If $\beta_j = 1$ the reciprocal component of equation 2 becomes linear, which implies effort responds equivalently to both wage surprises and shortfalls of equivalent magnitude. If $\beta_j > 1$ then workers reward positive wage surprises more strongly than they punish wage shortfalls, and vice versa if $\beta_j < 1$.[4]

2.2 Effort response and wage setting

We solve the model via best response analysis. Under the assumption that $c(e)$ is strictly convex, $U(\cdot)$ is strictly concave in e and the worker can always find a utility-maximizing level of effort e for any offered wage. Assuming the cost function $c(e) = 0.5e^2$, the worker's optimal effort response to a wage w and some reference wage $w_0(R)$ is:

$$e_i^*\left(w, R, w_0(R)\right) = \alpha_j \left(\frac{\mu + w - w_0(R)}{R}\right)^{\beta_j} \tag{3}$$

which is increasing in wages, decreasing in the reference wage, and decreasing in beliefs about the firm's endowment.[5]

Substituting $e_i^*(w, R)$ into the firm's profit function and solving for the optimal wage yields the firm's best-response function:[6]

[4]A noteworthy addition to the model could be the introduction of loss aversion in the spirit of Kahneman (1979), Tversky and Kahneman (1991). This could be captured by different values of α_j that correspond to wages that are either above or below the reference wage. While we think that loss aversion is an important factor in workers' effort response (see Dickson and Fongoni (2019); Buchanan and Houser (2019)), we prefer keeping our model parsimonious.

[5]We assume $\mu \geq w_0(R) - \underline{w}$ to ensure non-negative effort responses.

[6]Our experimental results suggest that firms do form accurate beliefs about the effort response function, understand how a change in the endowment reshapes the effort response function, and form accurate beliefs about the worker's expected wage.

$$w^*(e^*) = \frac{\beta_j R + w_0(\tilde{R}) - \mu}{1 + \beta_j} \tag{4}$$

Notice first that Equation 4 is decreasing in μ. This is because, all else equal, higher values of μ yield a larger effort response for any wage w. Second, Equation 4 is increasing in the firm's endowment R and the worker's belief about the endowment $\tilde{R}$ through $w_0(\cdot)$. Intuitively, this says wages will always adjust in the direction of the endowment shock. Firms share positive shocks in order to elicit a reciprocal effort response from workers and share negative shocks expecting only a proportional decrease in effort. Further, firms understand that $w_0(R)$ is order preserving – the worker will expect a wage increase following a positive shock ($w_0(R)$ shifts up) but will tolerate a wage cut following a negative shock ($w_0(R)$ shifts down). These two channels highlight the relevance of information – or absence thereof – regarding economic conditions in determining optimal wages.

2.3 Endowment shocks and the role of information frictions

Using equations 3 and 4, we can now illustrate the dynamics of the model in response to an endowment shock under both full and asymmetric information conditions.

Suppose there is an exogenous expansionary (recessionary) shock to R that is known to both the firm and worker. This shock puts upward (downward) pressure on wages via R and $w_0(R)$. Thus, both the worker's reference wage and the optimal wage adjust in the direction of an endowment shock under full information. In this scenario, a change in R changes the optimal wage $w^*(e^*)$ by $\frac{\partial w^*}{\partial R} = \frac{\beta_j + w_0'(R)}{1+\beta_j}$.

Hypothesis 1: Under full information, a positive (negative) shock to the firm's endowment leads to an increase in the (decrease) wage offered by the firm.

Now let us consider the worker's effort response to a given wage w. Changes in the endowment R impact effort levels through two channels: $w_0(R)$ and the scaling factor R. When R increases, both imply a decrease in the effort level for any given wage. This yields the following hypothesis:

Hypothesis 2: Under symmetric information, a positive (negative) shock to the firm's endowment leads to the worker providing less (more) effort, relative to pre-shock effort levels, for each wage in the wage distribution.

Suppose instead that only the firm knows about the exogenous expansionary shock. In this case, the worker's belief about economic conditions are not necessarily accurate so that $\tilde{R} \neq R$. Now, the worker's effort response function is:

$$e_i^*(w, \tilde{R}) = \alpha_j \left(\frac{\mu + w - w_0(\tilde{R})}{\tilde{R}} \right)^{\beta_j} \tag{5}$$

which depends on (inaccurate) beliefs about economic conditions, $w_0(\tilde{R})$.

The expansionary shock shifts R to R', where $R' > R$, which leads to an increase in $w^*(\cdot)$ directly through the change in the endowment. However, the worker does not adjust her belief about R to its new level so that $R = \tilde{R} < R'$. As a result, $w_0(R) = w_0(\tilde{R}) < w_0(R')$. Since equation 4 is strictly increasing in $w_0(\cdot)$, the optimal wage w^* under asymmetric information is lower that its analog under full information. Intuitively, this means that a profit-maximizing firm devoid of other-regarding preferences will retain more of a positive endowment shock whenever information about that shock is asymmetric. Similar logic shows that a negative shock under asymmetric information will lead to a smaller wage cut than what would occur following an equivalent shock under full information. This yields the following hypothesis:

Hypothesis 3: Information frictions moderate wage changes following an endowment shock.

When the worker is unaware of the endowment shock, her effort response function remains unchanged. Because of this, the worker will react more strongly to a given wage increase than she would under full information since $\frac{w-w_0(R)}{R} < \frac{w-w_0(\tilde{R})}{\tilde{R}}$ when $R' > R$.[7] This leads to the following hypothesis:

Hypothesis 4: Workers respond more strongly to wage changes following an endowment shock under asymmetric information than full information.

Overall, this simple model reveals that information structure can play a critical role in determining allocations following economic shocks. Our experimental design, which closely mimics the intuition of this model, provides a direct test for these hypotheses.

Throughout this section we have assumed that the firm engages in best response analysis – a common feature of principle-agent models – even in the presence of economic shocks. Our experimental design offers a novel approach to test the validity of this assumption about accurate contingent reasoning. Further, our design allows us to test whether or not subjects assigned to the role of firm act on these beliefs (i.e. employ best-response analysis when making decisions).[8]

3 Experimental Design

Our experimental design extends the classic gift-exchange game in three important ways. First, firms face either a positive or negative permanent shock to their endowment. Second, we introduce information frictions by varying workers' awareness of the shock. Finally, we elicit firms' beliefs and workers' effort strategies both before and after the shock occurs.[9] The confluence of these extensions allows us to distin-

[7]This assumes $\alpha_j > 0$, which is akin to assuming at least some degree of other-regarding behavior.

[8]We find strong evidence that firms form accurate beliefs about workers' effort response functions and correctly predict how endowment shocks reshape effort response functions (or not) under both asymmetric and full information.

[9]In an unpublished manuscript, Armouti-Hansen et al. (2020) use a similar elicitation method.

guish between self-interest and other-regarding motives in firms' wage choices and to understand the role of information frictions in wage-effort dynamics.

The firm receives an endowment of R at the beginning of each period and makes a wage offer w using a simple input box. We inform the worker of w, then allow the worker to choose costly effort $e \in \{0, ..., \overline{e}(w)\}$, where $\overline{e}(w)$ is the largest effort level that does not yield a negative payoff for the worker. We provide the worker with a slider tool that displays payoff information for both the firm and worker based on hypothetical effort levels to help them make this choice. We provide examples of both the firm's and the worker's decision screens in the appendix (see section D).[10] Both players then receive feedback on their respective payoffs and the firm also learns about the worker's effort. Following information revelation, the experiment proceeds to the next period.

After 10 rounds of baseline play where $R = 12$, we introduce a permanent session-level endowment shock: $R = 16$ following a positive shock and $R = 8$ following a negative shock. Shocks are common knowledge in the full information treatment. However, only firms learn of the shock in the asymmetric information treatment.[11] To ensure that firms understand information structure in our asymmetric information treatments, we add a short comprehension test regarding firms' beliefs about workers' knowledge of the shock.[12] Variation in these two factors, shock direction and information structure, yields a 2×2 between-subjects design summarized in Table 1.

[10] In the positive asymmetric treatment, we do not provide the worker with the firm's payoff information as this information will reveal the shock. We do not find any significant differences in pre-shock behavior across information conditions, suggesting that this feature did not impact effort choices. However, providing full payoff information in gift-exchange games leads to effort choices that yield more equitable payoff distributions. Thus, if present, this effect attenuates our main results.

[11] We provide screenshots of all relevant screens in appendix D.

[12] We screen out confused subjects using results from this quiz. We find no differences in confusion across treatment conditions (6 subjects in positive shock and 4 in negative shock, p.value=0.267).

Table 1: Summary of Design Treatments

Treatments	Shock Information	Shock	Participants
Positive	Firms and Workers	$R = 12 \rightarrow R = 16$	56
Negative	Firms and Workers	$R = 12 \rightarrow R = 8$	66
Pos. Asymmetric	Only Firms	$R = 12 \rightarrow R = 16$	56
Neg. Asymmetric	Only Firms	$R = 12 \rightarrow R = 8$	72

We elicit the firm's beliefs of her own worker's effort response, and her worker's corresponding effort response function by implementing the strategy method in periods 5, 10, 11, and 15. This allows us to understand how beliefs evolve as a function of experience during baseline play, how beliefs respond to shocks, and how the structure of information surrounding the shock effects beliefs. We do this by asking what effort the participant playing the role of firm expects from the worker at each possible wage.

In these same periods, we also elicit the worker's wage expectation for the current period and use the strategy method to elicit the worker's corresponding effort response function after first asking her wage expectation in that period. We provide example screenshots for both tasks in appendix D.

We incentivize the worker during elicitation periods by implementing her effort response function and paying her \$5 for a correct wage belief. We incentivize the firm's beliefs by paying \$5 if the effort guess of a randomly selected wage from the wage distribution is within .25 units of the actual effort response for that wage.

During elicitation periods, both the firm and the worker can explore all hypothetical choices before providing a response. Similar to how the worker chooses effort in non-elicitation periods, both the firm and the worker can use a slider to understand how a potential effort level for each wage translate into payoffs. After the first elicitation period, we remind each subject of their own choices in the previous elicitation period. Thus, any changes in beliefs or effort reflect actual updates and not a lack of recollection. We provide instructions on screen for subjects during all elicitations.

Before moving to results, we briefly address two possible design concerns. First, we circumvent hedging in elicitation periods by randomly paying subjects for either the accuracy of beliefs or for choices. [13] Second, one may wonder if employing the strategy method during elicitation periods induces an artificially high degree of monotonicity in effort responses. However, Maximiano et al. (2007) shows in a multi-worker gift-exchange game that the strategy method has a negligible effect, if any, on subject behavior. This finding is especially true in low-complexity environments.[14]

3.1 Procedures and Implementation

We recruited a total of 250 undergraduate student subjects from Texas AM University via the recruitment system ORSEE (Greiner (2015)). We programmed all experimental software using oTree (Chen et al. (2016)).

Each session began by reading experimental instructions aloud and administering comprehension quizzes. We deliver instructions in two parts. First, we provided subjects a brief set of instructions outlining basic components of the game like experimental length, formation of pairs, and anonymity (see C.1), and then administered a first comprehension quiz. We then provided a second set of instructions detailing game play and payoffs (see C.2) followed by a second comprehension quiz.

Following the second quiz, we randomly assign participants to the role of either firm or worker and form firm-worker pairs and familiarize them with the experiment via

[13]For example, a firm that suspects a worker will not reciprocate but wants to offer a high wage with the hope of reciprocation may guess that the worker will provide low effort at this wage.

[14]See Cason and Mui (1998); Brandts and Charness (2000); Oxoby and McLeish (2004); Bosch-Domènech and Silvestre (2005).

three unpaid practice periods. Following practice periods, we randomly form new firm-worker pairs that remain stable for the subsequent 20 paid periods.

Subjects completed a short socio-demographic survey and the end of the experiment. Following this survey, we released subjects and paid them privately. The average payment in our sessions was $25 and each session lasted approximately 90 minutes.

4 Results

We find that information frictions play a fundamental role in determining the allocation of exogenous economic shocks in our experimental labor markets. Following a positive endowment shock, firms reduce the magnitude of pass-thru by more than half if workers are unaware of the shock. This suggests that a significant portion of pass-thru of the positive shock under full information is not due to other-regarding preferences but instead results from sophisticated self interest.

Information frictions only slightly moderate pass-thru of negative shocks relative to positive shocks. This turns out to be quite costly for firms, because workers respond to wage cuts under information frictions by drastically reducing effort. This is true despite the fact that subjects in this treatment experience wage cuts of a similar magnitude to their full-information counterparts.

Firms' beliefs about workers' effort response functions reveal several interesting facts. First, firms' beliefs are highly accurate in all treatments. Second, these beliefs adjust instantaneously and incorporate information conditions in a reasonable way. Third, there is a logical coherence between beliefs about the effort response function, wage expectations, and wage choices. Finally, we learn that firms can form accurate beliefs about wages that never actually arise within the respective firm-worker pair. This sort of extrapolative learning is a necessary component of the best-response analysis common in theory and employed by subjects in our experimental setting.

Together, our findings about beliefs and wage-effort dynamics indicate that self interest plays a fundamental role in explaining firms' wage choices and that intentions-based models, rather than outcomes-based models, best explain workers' effort choices.

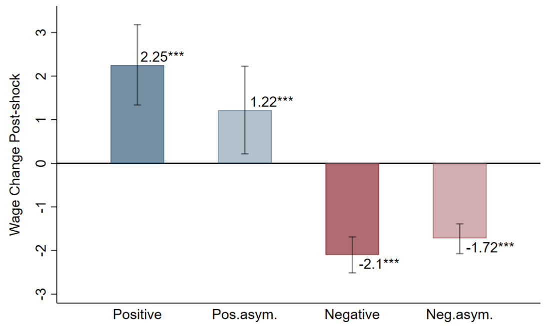
Finally, we show via structural estimation that modifying a behavioral labor market model to consider wages relative to the endowment increases out-of-sample predictive power by more than 50 percent. This further supports our claim that intentions-based models better represent effort choices than do outcomes-based models.

4.1 Wage-Effort Dynamics

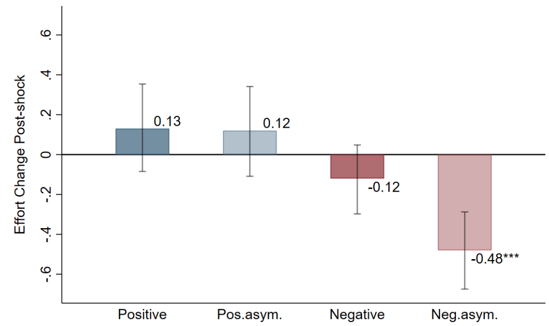
We first consider wage-effort dynamics. Figure 1 shows that both wages and effort adjust as a consequence of the endowment shocks.Under full information, average wages increase by about 2.25 units following a positive exogenous economic shock. This wage increase – slightly more than half of the shock – yields a small, albeit statistically insignificant, response in effort. Negative shocks induce an average wage cut of 2.1 units, which prompts a small, statistically insignificant decrease in effort. Both wage changes are highly significant, in line with Hypothesis 1.

These changes in wages and effort are consistent with firm-level beliefs about workers' effort response functions. To see this, consider figure 2a, which shows how endowment shocks reshape firm's beliefs about worker's responses.[15] Firm beliefs reveal that, under full information, firms expect less effort for a given wage after a positive shock and more effort following a negative shock. Put another way, firms in our full-information treatments are obligated to share a positive shock to maintain effort levels and are allowed to share a negative shock without reprisal from the worker.

[15] We show this data in levels in our appendix. For beliefs, see Figure C. For effort response functions, see Figure D.



(a) Pre/Post Wage Change



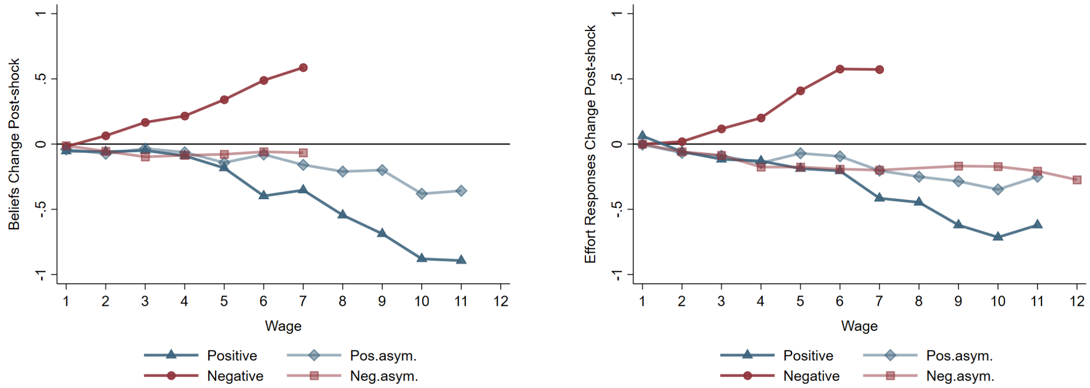
(b) Pre/Post Effort Change

Figure 1: Wages and Effort Responses to Shocks

Beliefs about how shocks reshape effort responses are quite accurate, which we see by comparing figures 2a and 2b. This suggests that subjects sorted randomly into the role of a firm in our experiment correctly predicted that their worker counterparts cared about intentions underlying a wage choice. This is true despite firms predicting changes in effort at wages they have not paid their worker.

The fact that the effort-response function adjusts (2b) following these shocks is consistent with our theoretical framework and supports Hypothesis 2. This suggests that workers consider more than just the level wage when making effort decisions. Instead, our results suggest that workers care about the wage relative to the firm's endowment. Firms anticipate this and adjust wages accordingly following endowment shocks, which supports the assumption of accurate contingent reasoning in both classical and behavioral models of principle-agent interactions.

Introducing information frictions moderates the reaction of wages to endowment shocks and also impacts how workers respond to wage cuts. These results provide support for Hypothesis 3. Wages increase by only 1.22 units on average following the positive shock, which is a bit less than half of the wage hike following an equiv-



(a) Pre/Post Beliefs Change **(b)** Pre/Post Effort Responses Change

Figure 2: Beliefs and Effort Responses to Shocks

alent endowment shock under full information. Workers do not exhibit a significant response to this muted wage hike. Following a negative shock, firms cut wages by 1.7 units, which is about 20% less severe than the wage cut under full information.[16] Despite this smaller wage cut, workers exhibit a large and highly significant reduction in effort of .48 units. This effort cut is four times larger than the average effort cut under full information.

Hypothesis 4 states that workers would be more responsive to wage changes under information frictions. This is clearly true following negative shocks, where effort cuts are four times as large under information frictions even though wages fall by 20% less. The positive shock case is more nuanced. In the positive treatments, although wage increases are half as large, they induce the same effort change from the workers. In other words, firms can increase wages by half as much to induce a similar effort response under information frictions.

Firm beliefs about effort response in 2a reflect a clear understanding that information

[16]This difference in wage cuts across information conditions is not statistically significant. See table 3.

Table 2: Wages and effort choices before/after shock

	(1) Wage offer (pos. shock)	(2) Wage offer (neg. shock)	(3) Effort Choice (pos. shock)	(4) Effort Choice (neg. shock)
Mean of dep. var.	6.975***	6.772***	1.608***	1.290***
	(0.385)	(0.240)	(0.166)	(0.099)
Post	2.303***	-2.070***	0.126	-0.123
	(0.469)	(0.211)	(0.109)	(0.087)
Asym.info	-0.573	-0.879**	-0.172	0.045
	(0.556)	(0.385)	(0.271)	(0.152)
Post×Asym.info	-1.140*	0.309	0.001	-0.360***
	(0.677)	(0.273)	(0.156)	(0.132)
Last Round	0.180	-0.395*	-0.156	-0.256***
	(0.459)	(0.211)	(0.134)	(0.079)
Male	-0.626	0.059	-0.019	0.215*
	(0.404)	(0.302)	(0.180)	(0.128)
Nash Eq.	-1.433	-0.917**	-0.573	-0.663***
	(1.073)	(0.448)	(0.408)	(0.164)
Observations	1000	1300	1000	1300

Notes: Results from a random-effects linear regression. The regression also includes a control for the last round and if the participant indicated being a male. Nash equilibrium is a dummy equal to 1 if the worker selected effort equal to 0 for all possible wages in at least one elicitation. We excluded pairs where the firm did not pass the asymmetric test. Clustered standard errors at the individual level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

frictions conceal shocks from workers.[17] Whereas firms expect shocks to reshape the effort response function under full information, firms correctly predict a static effort response function under information frictions. This difference in beliefs, coupled with choice data, gives critical insight into the motives underlying firm behavior.

What we see is that firms facing full-information conditions correctly believe that workers will demand higher wages. Perhaps coincidentally, they pay higher wages. We then see that firms facing information frictions believe that uninformed workers

[17] We show firms' beliefs and workers' effort response functions in levels for each elicitation period for all treatments in the appendix.

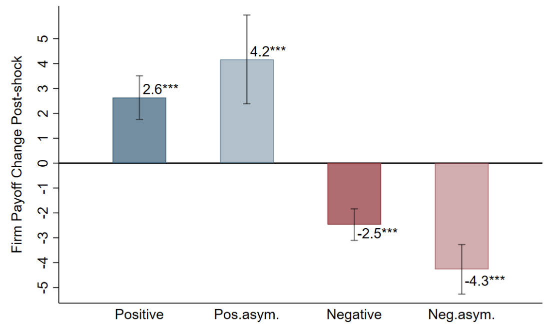
will not demand higher wages following the positive endowment shock. If firms were truly other regarding then we would expect equivalently high wage hikes following a positive shock under both information conditions. Instead, we see that the firms who believe workers will not demand higher wages significantly reduce the pass through of positive endowment shocks. Taken together, this suggests a sophisticated form of self interested firm that increases wages under full information only because they know the worker will demand higher wages.

4.2 Payoffs and the Distribution of Endowment Shocks

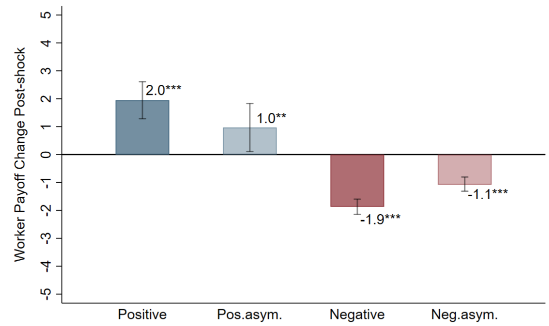
Our primary finding in this subsection is that information structure matters for determining allocations of shocks. Interestingly, it isn't always the more informed party who benefits from information frictions in our experiment. To see this, consider figure 3, which shows two things. First, information frictions benefit firms following a positive shock and harm firms following a negative shock. Second, the opposite is true for workers whose payoffs increase less following positive shocks but fall less following negative shocks whenever information is asymmetric.

Under symmetric information, firms and workers split endowment shocks almost equally. Because of this, positive endowment shocks increase payoffs for both firms and workers about equally and negative endowment shocks decrease payoffs about equally.

Making information about shocks asymmetric greatly benefits firms following positive endowment shocks. Information frictions allow firms to capture a much larger share of the shock without negatively impacting worker effort. This is because workers in asymmetric information treatments do not adjust their reference wage following the shock, which implies that their effort response functions remain unchanged (Table 4 and figure 2, respectively).



(a) Firm Payoff Change



(b) Worker Payoff Change

Figure 3: Firms and Workers Payoffs Changes to Shocks

Firms correctly predict this (figure 2), and significantly reduce pass-thru of the positive endowment shock (figure 1). Though wages increase less when information is asymmetric, effort responses are equivalent to the full information setting. This causes firm profits, on average, to increase by about twice as much relative to the full information setting. In contrast, workers' payoffs increase little - if at all - when information is asymmetric. Taken together, this means firms increase their profits by about four times as much as workers following a positive shock.

Information frictions harm firms following negative endowment shocks. The average firm's payoff falls by about 72% more under asymmetric information. Though firms correctly infer that the worker's stated effort response function is static across the shock due to asymmetric information (figure 2), they still share the shock.[18] Wage cuts cause wages to fall significantly below the worker's reference wage, which were also static due to asymmetric information. This leads to drastic and punitive effort cuts that severely impact firm profits.

[18]This aligns with Equation 4 where wages always adjust in the direction of endowment shocks.

Table 3: Firms and workers payoffs before/after shock

	(1) Firm payoff (pos. shock)	(2) Firm payoff (neg. shock)	(3) Worker payoff (pos. shock)	(4) Worker payoff (neg. shock)
Mean of dep. var.	6.788***	5.498***	5.224***	5.631***
	(0.734)	(0.383)	(0.298)	(0.168)
Post	2.495***	-2.482***	1.999***	-1.841***
	(0.440)	(0.316)	(0.345)	(0.142)
Asym.info	-0.021	1.453**	-0.476	-0.962***
	(1.180)	(0.682)	(0.428)	(0.317)
Post×Asym.info	1.850*	-1.775***	-1.095**	0.730***
	(0.995)	(0.601)	(0.544)	(0.204)
Last Round	-0.974	-0.783***	0.370	-0.215
	(0.796)	(0.226)	(0.422)	(0.190)
Male	0.724	1.029**	-0.552	-0.273
	(1.063)	(0.503)	(0.454)	(0.259)
Nash eq.	-3.213	-2.590***	-0.618	-0.245
	(2.510)	(0.721)	(0.801)	(0.375)
Observations	1000	1300	1000	1300

Notes: Results from a series of random-effects linear regressions. The regressions also includes controls for the last round and gender. Nash equilibrium is a dummy equal to 1 if the worker selected effort equal to 0 for all possible wages in at least one elicitation. We exclude pairs where the firm did not pass the asymmetric test. Standard errors clustered at the individual level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

On the other hand, workers benefit from information frictions following a negative shock; the average worker payoff falls by only about 57% of what it does under under full information. This happens because punitive effort cuts greatly reduce the cost of effort. Coupled with a slightly higher average wage, this leads to the higher payoff relative to the full information setting. However, asymmetric information is less beneficial to workers when the endowment shock is positive; average payoffs increase by about half of what they do under full information.

Table 3 provides estimates of payoff differences for workers and firms following positive and negative shocks interacted with information frictions. Our main coefficients of interest are the interaction terms between post periods and asymmetric information, which capture the differential reaction to endowment shocks. As previously discussed, firms payoffs increase 1.85 units more after a positive shock (column 1) when we introduce information frictions. With respect to negative shocks (column 2), we find a highly significance decrease (-1.8 units) in firms profits in the presence of asymmetric information. Interestingly, these interactions flip sign when we focus on the workers' payoffs (columns 3 and 4). Now, workers experience a lower payoff increase when they are unaware of the positive shock (-1.1 units) and higher payoff following a negative shock (0.7 units). Nonetheless, in neither case are these effects large enough to reverse the sign of the overall wage change. The net effect of the post and the interaction term is always of the same sign as the post coefficient.

4.3 Optimal Wages and Beliefs Accuracy

Next, we explore whether firms form accurate beliefs about optimal wages and whether they act on these beliefs. Overall, we find that firms act as profit maximizers: they do form accurate beliefs and make beliefs-consistent decisions. This provides suggestive support that people actually do adhere to the sort of best-response analysis commonly used to solve principle-agent problems in theory.

Table 4 reports three key pieces of information. We report in column 1 the wage that maximizes firm profits based on firms' beliefs about workers' effort response functions. Column 2 reports the wage that will actually optimize firm profits based on workers' elicited effort response functions. Finally, column 3 reports the wage that a firm actually offers. Rows labeled 'Pre' report the averages of these values over all firms using data from rounds 5 and 10 and 'Post' from rounds 11 and 15. We denote positive shocks with (+), negative shocks with (-), and indicate asymmetric information results alongside shock directions.

Firms' beliefs are mostly accurate: optimal wages based on firms' beliefs closely match optimal wages based on workers' effort responses in all treatments prior to the permanent endowment shocks. And although endowment shocks shift effort responses, firms anticipate this and adjust beliefs accordingly so that beliefs about the optimal wage never diverge significantly from the actual optimal wage.[19] The one exception we observe comes in our negative asymmetric information treatment where firms do not anticipate workers retaliating unexpected wage cuts with punitive effort cuts. Thus, the average firm's belief about the optimal wage is too low relative to the actual average profit maximizing wage.

Firms' actions are consistent with their beliefs. Comparing columns 1 and 3 of Table 4 confirms that firms offer wages that are optimal according to their beliefs. Differences between these columns are never statistically significant. This is true even in our one treatment (negative, asymmetric) where the firm hold incorrect post-shock beliefs about the profit maximizing wage.

4.4 Dynamic Reference Dependence and Information Frictions

This subsection studies the adjustment process of wage expectations.[20] Two key insights emerge. First, we find that wage expectations adjust instantaneously and accurately in response to information about economic shocks, which aligns with Abeler

[19]Note that even if beliefs and effort responses do not change, optimal wages are still impacted by changes in endowment, as seen in equation 4

[20]One can think of wage expectations as a reference point, akin to Kőszegi and Rabin (2006)).

Table 4: Expectations and wage optimality

	(1) Optimal wage wrt beliefs	(2) Optimal wage wrt responses	(3) Wage offer	(4) *F-test*
Pre (+)	6.35	6.25	6.66	0.62
Post (+)	8.53	8.62	8.89	0.85
Pre (+Asym.)	6.04	6.40	5.97	0.69
Post (+Asym.)	6.61	7.06	7.31	0.53
Pre (-)	6.81	7.46	6.81	0.20
Post (-)	4.56	4.96	4.59	0.27
Pre (-Asym.)	5.54	6.23	5.68	0.23
Post (-Asym.)	3.89	4.95	3.93	0.01**

Notes: Optimal wage with respect to beliefs is the average of optimal wages according to firms beliefs. Similarly, Optimal wage with respect to responses is the average of the optimal wages based on workers response function. Wage offer is the wage offered by the firm in the elicitation rounds. We exclude pairs where the firm did not pass the asymmetric test. Pre-shock and post-shock rounds are pooled respectively. We report the F-test of the equality of columns 1 to 3. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

et al. (2011).[21] Second, when information is asymmetric, wage expectations can still adjust based on post-shock experience (in line with Thakral and Tô (2021)). However, adjustment is sluggish relative to a full-information setting and adjustment dynamics depend on the direction of wage surprises.

Under full information, workers' wage expectations are accurate in both pre- and post-shock periods. These expectations are stable on either side of the shock but adjust between periods 10 and 11. We show this in Table 4, which reports average wages, average wage expectations, and their difference for each elicitation period in

[21] Abeler et al. (2011) manipulate the rational expectations of subjects and show this impacts wage-effort dynamics via a reference wage. We show that information about changes in economic conditions, coupled with previous worker-firm experience, is enough to instantly shift wage expectations.

all treatments. This is true even though workers have not experienced any post-shock wage offers, which highlights the importance of information about the firm's endowment in establishing wage expectations and effort responses. The stability of wages and expectations between rounds 5 and 10 allay any concern that the updating in wage expectations between rounds 10 and 11 are a continuation of pre-shock trends.

Discrepancies occur in asymmetric information treatments because information frictions prevent wage expectations from adjusting on impact of the shock. Since wages adjust in the direction of endowment shocks, workers receive an unexpected wage hike following a positive shock and an unexpected wage cut following a negative shock.

We find that experience alone in the positive asymmetric treatment eventually leads workers to form accurate expectations about wage offers. Immediately following the shock, average wages adjust by more than one point (from 6.13 to 7.36, column 1) while wage expectations remain relatively constant. Thus, average wage expectations are significantly below average wages ($p = 0.042$, column 3). However, experiencing higher wages for several periods causes expectations to adjust upward so that by round 15 average wages (7.27) and wage expectations (7.04, column 2) are no longer significantly different ($p = 0.701$). This demonstrates the ability of expectations to adjust via experience alone following economic shocks despite workers' complete lack of information regarding the shock.

We do not observe this same adjustment following wage surprises in negative shock sessions. Average wages (4.03, column 4) and wage expectations (5.4, column 5) are significantly different following a negative shock ($p < 0.01$, column 6). Despite workers and firms interacting for several post-shock periods together, and workers consistently receiving wages below their expectations, we find that significant differences between wages and wage expectations persist through round 15 ($p < 0.01$). Importantly, average wages in this treatment are stable across post-shock rounds. This means that the difference between wages and wage expectations is driven by the failure of expectations to adjust rather than by an adjustment of wages.

Table 5: Average wage offers and wage expectations [in elicitation rounds]

	Positive Asymmetric			**Negative Asymmetric**		
	(1) Wage Offer	(2) Expected Wage	(3) Difference	(4) Wage Offer	(5) Expected Wage	(6) Difference
Round 5	5.81	5.54	0.27	5.68	5.87	-0.19
Round 10	6.13	5.59	0.54	5.68	6.18	-0.5
Round 11	7.36	6.04	1.32**	4.03	5.4	-1.37***
Round 15	7.27	7.04	0.23	3.84	5	-1.16***
Pairs	22	22	-	32	32	-
	Positive Full Info.			**Negative Full Info.**		
Round 5	6.64	6.71	-0.07	6.78	6.42	0.36
Round 10	6.67	6.75	-0.08	6.84	7.21	-0.37
Round 11	8.57	8.5	0.07	4.39	4.81	-0.42*
Round 15	9.21	8.78	0.43	4.78	4.72	0.06
Pairs	28	28	-	33	33	-

Notes: Wage offer is the wage offered by the firm in the elicitation rounds. Expected wage is the wage that workers expect to receive in each elicitation rounds. We exclude pairs where the firm did not pass the asymmetric test. We report the t-test of the difference in means in columns 3 and 6. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Overall, this constitutes strong evidence that expectations adjustment is not symmetric in the presence of information frictions. People are willing to adjust expectations upward to meet unexpected wage surprises but expectations are more strongly anchored and sluggish to adjust whenever wage surprises are negative. This asymmetric adjustment aligns with Bewley (1999, 2007), which show via survey evidence that a primary component of downward nominal wage rigidity is an expressed concern from managers that lowering wages will destroy worker morale and reduce effort.

Similarly, our evidence is consistent with the idea of wage ratcheting observed in Kaur (2019), where positive shocks generate persistently higher nominal wages but negative shocks do not lead to nominal wage cuts. In her setting, individuals believe nominal wage cuts are unfair and lead to effort reductions. Our evidence on expectation adjustment shows that wage hikes lead to quick upward updating while the opposite is not true for wage cuts under information frictions. Arguably, this rapid updating might anchor workers expectations and reduce tolerance for wage cuts in the future.

We next explore the impacts of information frictions on effort choices via the misalignment of wages and expectations. To do this, we first classify firm-worker pairs into three groups (Above, Below, or Equal) according to their wage offers relative to wage expectations in round 11. Using these classifications, we look for heterogeneous effects in effort choices using the same specification as in our previous analysis. We report results from this exercise in Table 6 where our main coefficients of interest are Post×Above and Post×Below, which report how effort responds to the surprise component of wages that are above or below the worker's wage expectation. We first consider results from our positive shock treatments. Whenever workers do not expect wage hikes following a positive shock they strongly reciprocate wage increases (1.137 units, column 2). This effect is not present under full information where workers expect wage increases following positive shocks. Instead, we see that workers strongly punish wages that fall short of their new, higher wage expectations whenever they know of the positive endowment shock (−1.266 units, column 1). This suggests that a rationale for firms to increase wages under full information is avoiding retaliatory effort cuts when expectations are not met, rather than to elicit a higher effort via reciprocal motives. In contrast, when information frictions mask firm's intentions, workers who receive a wage above expectations elicit a higher effort response.

Table 6: Effort responses and wage expectations in round 11

	(1) Effort Choice (pos. shock)	(2) Effort Choice (pos. asym. shock)	(3) Effort Choice (neg. shock)	(4) Effort Choice (neg. asym. shock)
Mean of dep. var.	1.440***	1.402***	1.330***	1.274***
	(0.242)	(0.326)	(0.120)	(0.179)
Post	0.559***	-0.737***	-0.253**	-0.099
	(0.093)	(0.263)	(0.127)	(0.115)
Post×Above	0.023	1.137***	0.138	0.082
	(0.186)	(0.325)	(0.209)	(0.447)
Post×Below	-1.266***	0.319	-0.176	-0.446***
	(0.178)	(0.330)	(0.223)	(0.146)
Male	0.222	0.133	0.183	0.292
	(0.283)	(0.465)	(0.201)	(0.224)
Nash eq.	0.536***	-0.678	-0.876***	-0.726***
	(0.152)	(0.449)	(0.324)	(0.248)
Observations	308	242	363	352

Notes: Results from random-effects linear regressions that include controls indicating gender and if a worker ever played Nash equilibrium in an elicitation period. *Above* indicates wage offers above, *Below* wage offers below and *Equal* corresponds to pairs with offers equal to workers' expectation in round 11. Standard errors clustered at the individual level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

In the negative shock treatments, we find that workers strongly punish wage cuts if they are unexpected and lead to shortfalls relative to expectations (-0.446, column 4). However, this same effect is not present in the negative, full information treatment (-0.176, column 3). This suggests that workers are more lenient with wage short falls whenever they expect (and can rationalize) wage cuts. It's worth remembering that the average wage is indeed quite similar in the post-shock rounds of both negative shock treatments. We can see that the large decrease in effort following the endowment shock in our negative asymmetric information treatment (-0.48, figure 1) is driven largely by workers retaliating against unexpected wage cuts (-0.44).

Taken together, our analysis in this section suggests that information frictions are more costly in terms of efficiency following negative shocks because sluggish adjustment of expectations leads to prolonged bouts of punitively low effort. Once wages increase and the reference wage adjusts, any additional effort garnered by wages in excess of the original reference wage could vanish.

5 Estimating the Model and Evaluation

This section outlines an estimation exercise wherein we quantify the out-of-sample predictive power of our model (given by equations (1) and (2)) relative to a baseline model that still incorporates a reference wage but does not respond to economic shocks

$$e^*(w) = \alpha \left(\frac{w-a}{b}\right)^{\beta} \tag{6}$$

We first use data from both pre-shock elicitation rounds to structurally estimate the parameters of both models. Next, we use these estimated sample parameters to predict post-shock effort levels and wages, and then compare these predictions to actual wage and effort choices. We compute a mean squared predicted error (MSPE) for each subject using the difference between actual and predicted behavior to quantify the out-of-sample predictive power of each model. Our analysis suggests that allowing a behavioral model of labor market dynamics to account for information frictions leads to significant increases in predictive power for behavior on both sides of the market.

5.1 Post-Shock Effort Predictions

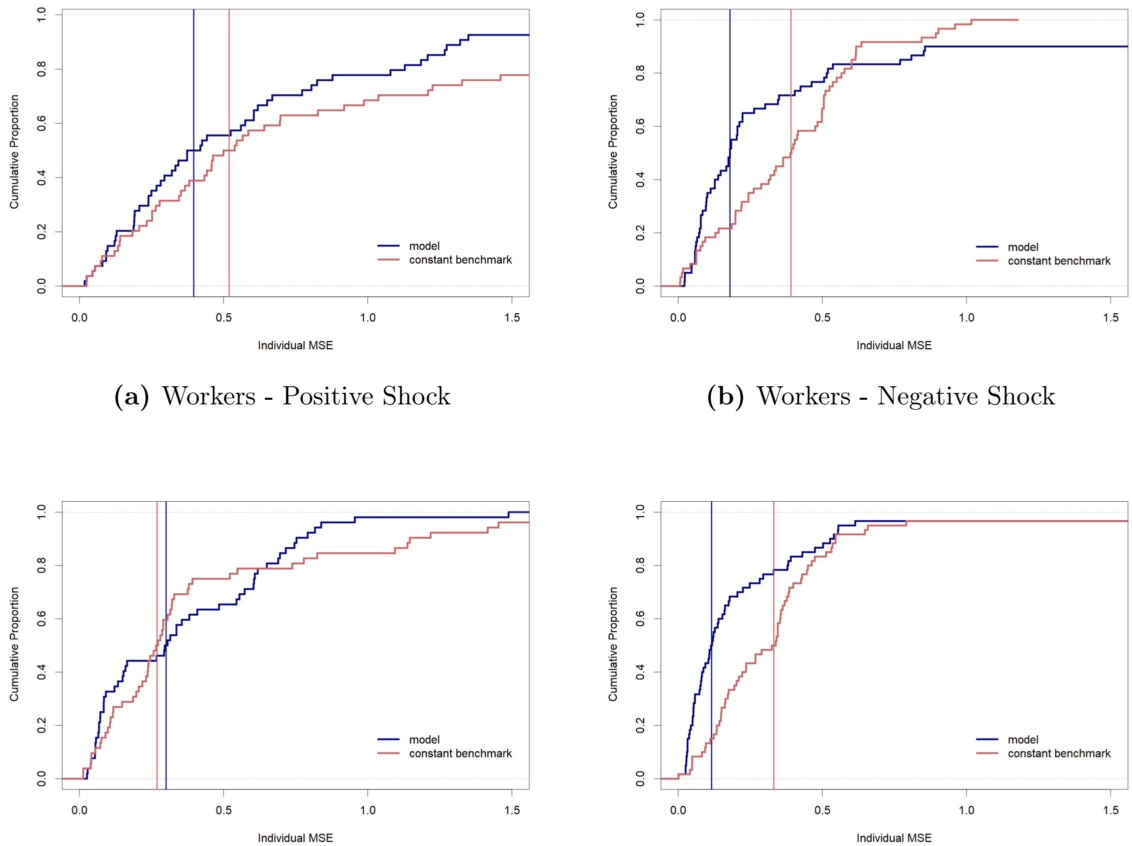
We summarize results of effort predictions in figure 4, which displays cumulative distribution functions (CDFs) of individual-level MSPEs for workers (a and b) and firms (c and d) using the benchmark model (red solid line) and our model (blue solid line). The corresponding vertical lines denote the medians of the two distributions.[22]

Figure 4 provides compelling evidence that our model outperforms the benchmark model in predicting both firms' beliefs about worker effort and workers' actual effort response functions. Our model reduces the median individual MSPE of effort response predictions by 24% following a positive endowment shock (panel a) and by 54% following a negative shock (panel b) relative to the benchmark model (one-sided Wilcox test p.values are 0.078 and 0.012 respectively). Likewise, our model reduces the median individual MSPE of predictions about firm beliefs by 65% after a negative shock (panel d) relative to the benchmark model (one-sided Wilcox test p.values is $<$0.001). However, we find that both models predict firm beliefs equally well following a positive endowment shock (panel c, one-sided Wilcox test p.value is 0.409).

5.1.1 Post-Shock Wage Prediction

Next, we use our estimates for the firms in the pre-shock periods to obtain a prediction for wage offers in the post-shock periods and compare this to observed wage offers. Table 7 shows that our model does remarkably well in predicting shifts in wage offers – there is no significant difference between observed wages (column 1) and wages predicted by our model (column 2) in any of our four treatments.

[22] We evaluate medians rather than means to ensure that a few extreme outliers are not driving our results.



(a) Workers - Positive Shock

(b) Workers - Negative Shock

(c) Firms - Positive Shock

(d) Firms - Negative Shock

Figure 4: This figure shows CDFs of mean squared prediction errors (MSPEs) in rounds 11 and 15 for workers (panels a and b) and firms (panels c and d). Red dashed CDFs correspond to the benchmark model. Solid blue CDFs correspond to our relative wage model. Red vertical lines shows the median of the MSPEs from the benchmark model and the blue vertical line the median of the MSPEs from the relative wage model.

Figure 4 shows that accounting for changes in economic conditions matters for two reasons. First, our model allows reference wages to adjust when economic conditions change whereas the benchmark model does not. Intuitively, we account for the idea that workers will share shortfalls and expect to share windfalls whenever they are exogenous. Second, effort accounts for wages relative to the firm's endowment. This captures the idea that a person's degree of altruism can depend on the perceived wealth of an firm and hence, why information about that wealth matters.

Table 7: Predicted wage comparison [in post-shock rounds]

	(1) Wage offer	(2) Model prediction	(3) Model deviation	(4) Benchmark prediction	(5) Benchmark deviation	(6) Performance difference
Positive	9.06	9.08	0.01	8.47	-0.60	0.59***
Positive asym.	7.86	7.41	0.11	-	-	-
Negative	4.74	4.78	0.03	5.45	0.70	0.67***
Negative asym.	4.06	4.26	0.20	-	-	-

Notes: This table compares predicted wages for our model (2) and a benchmark model (4) to actual wage offers (1). Columns (3) and (5) report deviations from actual wages. Column (6) reports the result of a statistical test for differences in model deviations. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

We find that firms correctly predict both of these channels, which is why our model better predicts firm's beliefs about effort response functions. Because firms act on these beliefs, our model also outperforms the benchmark model in predicting wages. More subtly, what we learn from figure 4 is that information structure helps determine *how* changes in economic conditions impact wage-effort dynamics.

Finally, we want to emphasize that there is no tradeoff for using our model instead of the benchmark model. Predictions from our model are always at least as good as those from the benchmark model – usually, they are much better. More generally, it likely always makes sense to adapt behavioral models of the labor market to account for changes in economic conditions and relative information sets.

6 Conclusion

This paper explores the role of information frictions in a labor market setting. We first illustrate theoretically how information frictions can significantly impact wage-effort dynamics. Our key intuition is that workers evaluate wages relative to a reference wage, which itself depends on economic conditions. Because of this relationship, information frictions regarding economic conditions play a significant role in determining how wage-effort dynamics evolve in response to economic shocks. We then incorporate permanent endowment shocks, information frictions, and belief elicitation into a gift-exchange game to demonstrate these insights empirically.

Under full information, endowment shocks are shared almost equally between agents. Following a positive endowment shock, workers demand higher wages but do not increase their average effort and when the endowment decreases, workers are willing to accept wage cuts and keep effort constant. Firms anticipate this, forming highly accurate beliefs and adjusting wages accordingly in the same direction as the endowment shock. This leads to an equitable sharing of shocks - whether positive or negative - and roughly equivalent changes in payoffs.

Introducing information frictions significantly moderates the pass through of endowment shocks. Despite smaller wage cuts, workers reduce effort four times more than under full information. In this particular case, the less-informed party (i.e., the workers) benefit from information frictions.

Our results suggest workers evaluate wages according to a state-contingent reference wage. These adjust instantaneously in response to news about endowment shocks so that subsequent wage changes are not a surprise and lead to little, if any, changes in effort. However, this dynamic reverses whenever endowment shocks and wage changes surprise uninformed workers. When surprises are positive, the uninformed worker's effort responds about twice as strong as the uninformed workers. If the surprise is negative, the uninformed worker cuts effort four times more than the informed worker.

Experience alone can remove the wedge between wage expectations and wages. However, adjustment depends critically on the direction of wage surprises. Expectations fully adjust by our second post-shock elicitation in round 15 following positive wage surprises. In contrast, workers are more reluctant to adjust their reference wage in response to negative wage surprises. Because of this, wages and wage expectations still remain highly significantly different in our second post-shock elicitation round. This is true despite the fact that, in both instances, average wages remain relatively stable across post-shock elicitation rounds. This asymmetric adjustment helps rationalize both wage ratcheting and downward nominal wage rigidity as empirical regularities.

Accounting for economic shocks and information frictions almost always improves the out-of-sample predictive power of the analogous behavioral labor market model. An implication is that models of reference dependence should allow for information frictions, especially when concerned with the dynamics of reference dependence.

An implication of our results is that differences in institutional features that create firm-level heterogeneity in information frictions may themselves lead to differences in wage frictions. For example, wage dynamics might differ between public and private firms, since the later retain discretion and the former are compelled to reveal information. These features may also be cultural and lead to peer-to-peer information gaps. For example, recent work documents the reluctance to discuss wages between coworkers (Cullen and Perez-Truglia, 2018). Our results on the asymmetric adjustment of reference wages rationalizes this reluctance since only low-paid workers are likely to revise their reference wages. This aligns with evidence on pay secrecy and effort provision from Nosenzo (2013) and Cullen and Perez-Truglia (2022).[23]

Importantly, the asymmetric adjustment of wage expectations that we observe suggests that even short-lived fluctuations can yield long-term effects on wages. The fact that informed workers will tolerate wage cuts while uninformed workers will not highlights the importance of the economic context underpinning a firm's wage decisions.

[23] Charness and Kuhn (2007) provide evidence that revealing wages may not lead to lower effort.

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Appendix

A Additional Tables and Figures

Table A0: Beliefs and effort responses changes in post-shock periods (full information)

	(1)	(2)	(3)	(4)
	Beliefs diff.	Beliefs diff.	Effort Resp. diff.	Effort Resp. diff.
	(pos. shock)	(neg. shock)	(pos. shock)	(neg. shock)
Mean of dep. var.	0.215*	-0.100	0.180	-0.155*
	(0.110)	(0.097)	(0.116)	(0.091)
Wage	-0.087***	0.106***	-0.066***	0.118***
	(0.013)	(0.021)	(0.016)	(0.019)
Observations	228	264	228	264

Notes: Results from a random-effects linear regression. We exclude wages that exhaust the endowment. Rounds 5 and 10 are pooled together, similarly with rounds 11 and 15. The regression also includes a control for the maximum wage. Clustered standard errors at the individual level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A1: Beliefs and effort responses changes in post-shock periods (asymmetric information)

	(1)	(2)	(3)	(4)
	Beliefs diff.	Beliefs diff.	Effort Resp. diff.	Effort Resp. diff.
	(asym.pos.shock)	(asym.neg.shock)	(asym.pos.shock)	(asym.neg.shock)
Mean of dep.var.	0.038	0.082	0.044	0.028
	(0.104)	(0.078)	(0.096)	(0.084)
Wage	-0.016*	-0.003	-0.007	-0.009
	(0.009)	(0.014)	(0.010)	(0.006)
Observations	216	288	216	432

Notes: Results from a random-effects linear regression. We exclude wages that exhaust the endowment. Rounds 5 and 10 are pooled together, similarly with rounds 11 and 15. The regression also includes a control for the maximum wage. Clustered standard errors at the individual level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

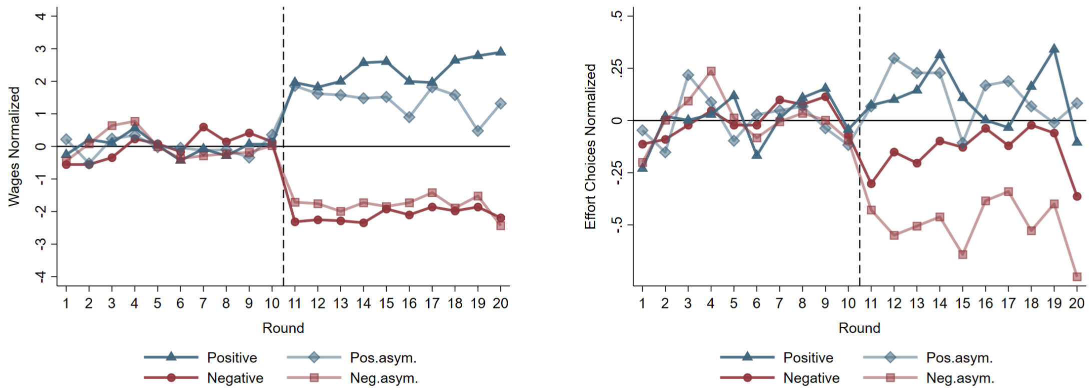
Table A2: Firms profits and wage expectations

	(1) Firm Payoff (pos. shock)	(2) Firm Payoff (pos. asym. shock)	(3) Firm Payoff (neg. shock)	(4) Firm Payoff (neg. asym. shock)
Mean of dep. var.	6.058***	8.840***	5.563***	6.903***
	(0.654)	(1.993)	(0.396)	(0.647)
Post	3.370***	6.015***	-2.574***	-4.318***
	(0.832)	(2.256)	(0.496)	(1.234)
Post×Above	0.058	-1.123	0.212	-0.592
	(0.949)	(2.439)	(0.706)	(1.593)
Post×Below	-1.946	-6.224**	0.076	0.145
	(1.190)	(3.045)	(0.584)	(1.332)
Last Round	-2.356**	0.784	-0.899***	-0.663**
	(1.099)	(1.064)	(0.309)	(0.335)
Male	2.095***	-2.646	0.851*	1.125
	(0.740)	(2.144)	(0.448)	(0.919)
Nash eq.	-1.945**	-4.918*	-2.717***	-2.558**
	(0.850)	(2.876)	(0.877)	(1.113)
Observations	560	440	660	640

Notes: Results from a random-effects linear regression. The regression also includes a control for the last round and if the participant indicated being a male. Nash equilibrium is a dummy equal to 1 if the matched worker selected effort equal to 0 for all possible wages in one elicitation. We excluded pairs where the firm did not pass the asymmetric test. Type *Above* is a dummy that corresponds to pairs with wage offers above workers' expectation in round 11. Type *Below* to those with wage offers below and *Equal* corresponds to pairs with offers equal to expectations. Clustered standard errors at the individual level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Figure A: Average wage and effort response by treatment

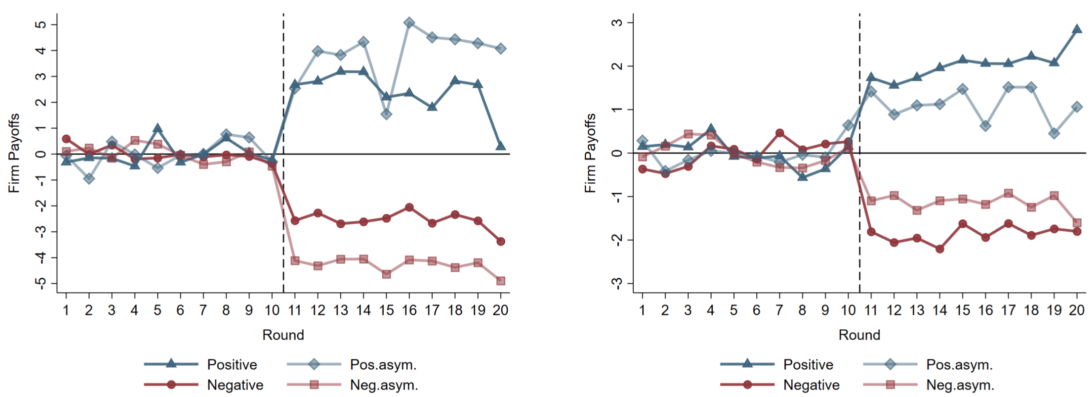
(a) Wages **(b)** Effort Choices



Notes: This figure shows the average wage (a) and effort choice (b) for each round. We normalize each variable by subtracting the pre-shock average.

Figure B: Average payoffs by treatment

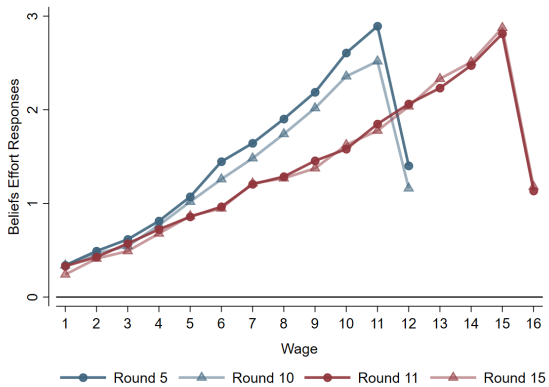
(a) Firm Payoff **(b)** Worker Payoff



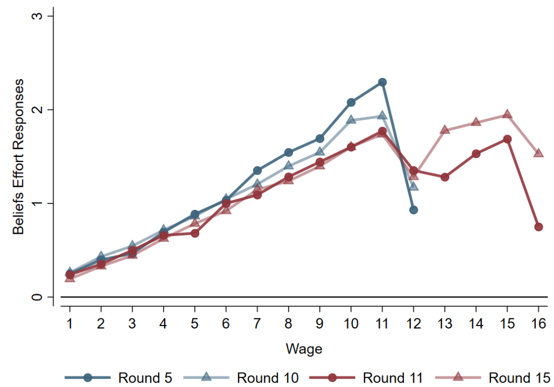
Notes: This figure shows the average firm (a) and worker (b) payoff for each round. We normalize each variable by subtracting the pre-shock average.

Figure C: Firms' beliefs about effort responses by elicitation round

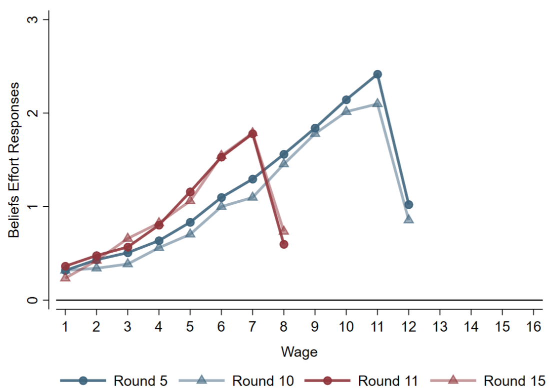
(a) Positive Treatment



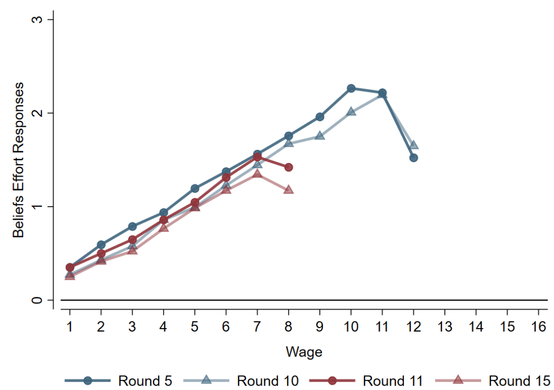
(b) Positive Asymmetric Treatment



(c) Negative Treatment

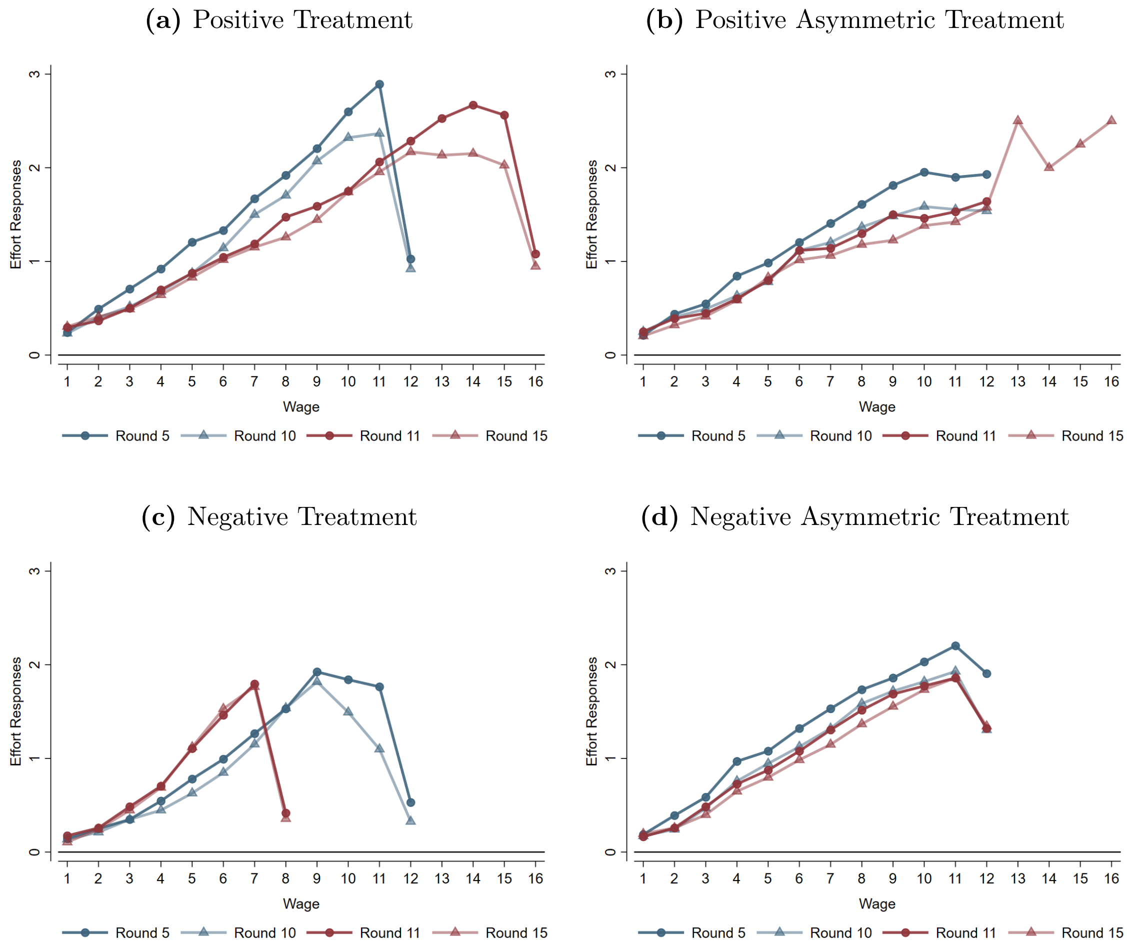


(d) Negative Asymmetric Treatment



Notes: This figure shows the average belief about effort responses for each possible wage. Drops corresponds to wage offers that exhaust the firm's endowment.

Figure D: Workers' effort responses by elicitation round



Notes: This figure shows the average effort response for each possible wage. Drops corresponds to wage offers that exhaust the firm's endowment.Note that for post-shock rounds in Panel (b) the range is 16 since firms can decide to reveal the shock to workers and in that case, workers must elicit effort responses for the additional wages.

B Structural Estimation

This section outlines an estimation exercise wherein we quantify the out-of-sample predictive power of our model (given by equations (1) and (2)) relative to a baseline model where effort responds to neither information frictions nor economic shocks. We do this in two steps. First, we use data from both pre-shock elicitation rounds to structurally estimate the parameters of both models. Second, we use these estimated sample parameters to predict post-shock effort levels and wages, and then compare these predictions to actual wage and effort choices. We compute a mean squared predicted error (MSPE) for each subject using the difference between actual and predicted behavior to quantify the out-of-sample predictive power of each model. Overall, our analysis suggests that allowing a behavioral model of labor market dynamics to account for information frictions leads to significant increases in predictive power for behavior on both sides of the market.

$$ln(e^*(w,R)) = ln(\alpha) + \beta\ ln\left(\frac{\mu + w - w_0(\tilde{R})}{\tilde{R}}\right) \tag{7}$$

$$ln(e^*(w,R)) = ln(\alpha) + \beta\ ln\left(\frac{w - a}{b}\right) \tag{8}$$

B.1 Identification and Estimation

We first focus on the worker's problem. Log-linearization of equation (3) yields the following equation:

$$ln(e^*(w,R)) = ln(\alpha) + \beta\ ln\left(\frac{\mu + w - w_0(\tilde{R})}{\tilde{R}}\right) \tag{9}$$

Because we directly observe w and $\tilde{R}$, to be able to estimate $\alpha,\ \beta$ in equation (9) via ordinary least squares (OLS) we need measures of both μ and $w_0(\tilde{R})$. Since neither of those is directly observable, we first assume $\mu = 0$. This assumption biases our estimates of α (i.e. the intercept) but it does not affect β (i.e. the slope) since μ is a constant that shifts the effort response function but does not impact its curvature. Biasing α does not reduce the goodness of fit of either model and we can still estimate wage offers since the optimal wage does not depend on α. This leaves only the issue that we do not directly observe $w_0(\tilde{R})$.

One possibly solution is to proxy $w_0(\tilde{R})$ using wage expectations gathered from workers during elicitation rounds. However, this proxy leads to many instances in our data where $w - w_0(\tilde{R}) < 0$ for which the log of the ratio is undefined in $\mathbb{R}$. To circumvent this issue, we instead proxy $w_0(\tilde{R})$ using the wage $\overline{w}_0(\tilde{R})$ such that $e^*(w, R) = 0$ whenever $w \leq \overline{w}_0(\tilde{R})$. For $\overline{w}_0(\tilde{R})$ to be a valid proxy, it should react to endowment shocks in a way consistent with our theoretical assumptions about $w_0(\tilde{R})$. We provide evidence of this in table 4, which shows that our proxy measure reacts to endowment shocks in the same direction as fair wages under full information and does not change under asymmetric information.

While we obtain $\overline{w}_0(\tilde{R})$ directly from pre-shock data, we need to be able to estimate this value following an endowment shock. This means we must assume a functional form for $\overline{w}_0(\tilde{R})$ in order to produce post-shock estimates of wages, beliefs, and effort that do not rely on post-shock data. Thus, we further assume $\overline{w}_0(\tilde{R}) = \gamma\tilde{R}$, which says that our proxy of the reference wage is simply a constant fraction of the endowment. Note that if this is a misspecification of $\overline{w}_0(\tilde{R})$ then it will penalize our model while leaving unaffected the benchmark model.

In our benchmark model the worker's effort response function does not react to endowment shocks or incorporate information frictions. We model this by replacing

$w_0(\tilde{R})$ and $\tilde{R}$ with two constants. For simplicity, we let these two constants match the pre-shock values of $\overline{w}_0(\tilde{R})$ and $\tilde{R}$, respectively.[24]

$$ln(e^*(w,R)) = ln(\alpha) + \beta\ ln\left(\frac{w-a}{b}\right) \tag{10}$$

Intuitively, this benchmark model implies that neither changes in the endowment nor information regarding those changes impact a worker's effort response function. The models are otherwise identical.

Table 4: Reference wage proxy [in elicitation rounds]

	(1) **Pre-shock proxy**	(2) **Post-shock proxy**	(2)-(1) **Diff.**
Positive	1.24	2.13	0.88**
Positive asymmetric	1.38	1.47	0.08
Negative	1.50	0.92	-0.58*
Negative Asymmetric	1.04	1.21	0.16

Notes: This table shows the average wage for which workers choose a zero effort level in the elicitation rounds. $\overline{w}_0(R)$ is defined as the wage such that $e^*(w,R) = 0$ whenever $w \leq \overline{w}_0(R)$. Rounds 5 and rounds 10 are pooled together. Similarly for rounds 11 and 15. As in the remaining of our structural exercise, we exclude pairs with an all-zero effort elicitation. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

We start by estimating individual-level values of α and β using pre-shock elicitation data for workers (from effort response function) and firms (from belief elicitation) separately.[25] We then predict post-shock values for wages, beliefs, and effort with

[24] Though the values of a, b do not influence the out-of-sample predictive power of this benchmark model, this approach to selecting their values ensures that pre-shock values of α, β are consistent across the two models that we consider.

[25] In many instances, all effort responses or beliefs are 0 in a given elicitation. We drop these observations from the estimation since logs are undefined. In addition, we do not take into account the responses for when the wage offer exhausts the endowment for the same reason. For a discussion

both models using these parameter estimates. Comparing the resulting distributions of individual-level MSPEs determines which model provides better out-of-sample predictions.

Before proceeding to the results of this exercise, we also note that we perform this estimation exercise using only subjects from our two full information treatments. This is because the two models make almost identical predictions under asymmetric information - a prediction fully supported by our data - since the endowment remains unchanged from the worker's perspective following the endowment shock.[26]

B.2 Post-Shock Effort Predictions

We summarize results of effort predictions in figure 4, which displays cumulative distribution functions (CDFs) of individual-level MSPEs for workers (a and b) and firms (c and d) using the benchmark model (red solid line) and our model (blue solid line). The corresponding vertical lines denote the medians of the two distributions.[27]

Figure 4 provides compelling evidence that our model outperforms the corresponding benchmark model in predicting both firms' beliefs about worker effort and workers' actual effort response functions. Our model reduces the median individual MSPE of effort response predictions by 24% following a positive endowment shock (panel a) and by 54% following a negative shock (panel b) relative to the benchmark model. Likewise, our model reduces the median individual MSPE of predictions about firm beliefs by 65% after a negative shock (panel d) relative to the benchmark model. However, we find that both models predict firm beliefs equally well following a positive

about how to deal with logs and zeros in regression models see Young and Young (1975) and Bellego et al. (2021).

[26]The only differences arises from two pairs in the positive asymmetric condition that reveal the shock to their counterpart. We report results using only subjects from our asymmetric in figure A for interested readers.

[27]We evaluate medians rather than means to ensure that a few extreme outliers are not driving our results.

endowment shock (panel c).

B.2.1 Post-Shock Wage Prediction

Next, we use our estimates for the firms in the pre-shock periods to obtain a prediction for wage offers in the post-shock periods and compare this to observed wage offers. Our proxy $\overline{w}_0(\tilde{R})$ almost certainly introduces downward bias in our wage predictions since the levels are likely lower than actual reference wages. However, we can recover firm's actual beliefs of worker's reference wage $\hat{w}_0(\tilde{R})$ if we assume that the firm set wages optimally given their beliefs (this is supported by evidence in section **??**. Given this assumption, we can then use our estimates of β and pre-shock wage offers to recover the firm's beliefs from equation (1) and its benchmark analog.[28] Finally, we assume the same functional form as before $\hat{w}_0(\tilde{R}) = \gamma\tilde{R}$ so we can do out-of-sample predictions for changes to the endowment.

Table 7 shows that our model does remarkably well in predicting shifts in wage offers – there is no significant difference between observed wages (column 1) and wages predicted by our model (column 2) in any of our four treatments.
Figure 4 shows that accounting for changes in economic conditions matters for two reasons. First, our model allows the worker's reference wage to adjust in response to changes in economic conditions whereas the benchmark model does not. Intuitively, we account for the idea that workers will share shortfalls and expect to share windfalls, at least whenever each are exogenous to the firm. Second, effort accounts for wages relative to the firm's endowment. This captures the idea that a person's degree of altruism can depend on the perceived wealth of an firm and hence, why information about that wealth matters.

We find that firms correctly predict both of these channels, which is why our model better predicts firm's beliefs about effort response functions. Because firms act on

[28]The benchmark equation only differs in that $w_0(\cdot)$ is substituted by a constant.

these beliefs, our model also outperforms the benchmark model in predicting wages. More subtly, what we learn from figure 4 is that information structure helps determine *how* changes in economic conditions impact wage-effort dynamics.

Finally, we want to emphasize that there is no tradeoff for using our model instead of the benchmark model. Predictions from our model are always at least as good as those from the benchmark model – usually, they are much better. More generally, it likely always makes sense to adapt behavioral models of the labor market to account for changes in economic conditions and relative information sets.

C Instructions

This subsection of the appendix provides the instructions used in our experiment. There was one minor difference in the instructions used for symmetric and asymmetric information sessions. This difference - where we not what information workers receive at the end of a Decision Period - is highlighted in red text. This difference, which corresponds to a difference in end-of-period information for workers across information conditions, was necessary to create our desired information frictions. Importantly, our baseline periods of play across information conditions confirms that this difference did not meaningful affect workers' effort decisions.

We provided instructions in two phases. First, we provided subjects with a one-page document meant to outline the basics of the game they would play, how their decisions would affect their earnings, and how we would construct their final payoffs. We followed this with a basic comprehension quiz, delivered on-screen. Subjects could not proceed without answering all questions in the comprehension quiz correctly. Next, we provided subjects with more detailed information the the two types of periods they would experience. We again followed this set of instructions with an on-screen comprehension quiz.

C.1 Instructions - Basic Information Sheet

Basic Information

Formation of Pairs:

We will randomly assign you to one of two roles for this experiment: employer or worker. You will be informed about your role at the beginning of this experiment.

Once we assign you to one of these two roles we will then randomly form employer-worker pairs. Your role (employer or worker) will not change during this experiment. Additionally, the composition of worker-employer pairs will not change during the paid portion of this experiment. That means that you will always make decisions with the same worker/employer during the paid portion of this experiment

Anonymity:

This is an anonymous game. No other participant will know your identity during this experiment. Your counterpart will know your role (whether you are an employer or worker) and will see your decisions. However, your counterpart cannot link these decisions to you personally. No other participant (other than your counterpart) will know your role or be able to view your decisions.

Experiment Length:

- This experiment lasts for 20 paid periods. A period ends after both players (worker and employer) make all relevant choices.
- However, you will play 3 additional trial periods to get used to the game. Trial periods are not paid. It is important that you take these seriously so that you understand the game. This will help you maximize your earnings during paid periods. After the 3 trial periods, the 20 paid periods will begin automatically

Description of the 20 periods

There are two types of periods during the paid portion of this experiment:

- *Decision Periods:* workers and employers make some decisions.
- *Questionnaire Periods:* first, players will respond to some questions; then, they will proceed to making their decisions. You will start the experiment by playing a Decision Period and you will be notified when you are playing a Questionnaire

Period.

Payment for this experiment:

- We will pay you in cash at the end of this experiment.
- The computer will randomly select one Decision Period and one Questionnaire Period out of the 20 periods. We will pay you for these two randomly selected periods. This is in addition to your $10 show-up fee.
- Thus, your final payment will include your earnings for the two randomly selected periods and the show-up fee.

C.2 Instructions - Description of Periods

1.Description of a Decision Period

Steps

Each *Decision Period* proceeds as follows:

1. The employer receives an endowment and then sets a wage for the worker
2. The worker learns the wage offered and then selects a level of effort in response
3. Both subjects learn their payoff for that period
4. The game proceeds to either another Decision Period or to a Questionnaire Period

Roles and Actions

- **Employer:**
  - A subject assigned to the role of employer' initially receives an endowment of \$12. The employer will use the per-period endowment to pay a wage to the worker for that period.
  - The wage must be some number between \$1 and the total endowment in increments of \$1. Thus, an employer could pay a wage of \$1,\$2,\$3, , etc.
  - Whatever portion of the endowment the employer keeps is multiplied by the effort provided by the worker and then paid to the employer.
  - Formally, the employer will earn:

$$\text{Employer's payoff} = (\text{Endowment} - \text{Wage}) * \text{Effort}$$

  - **An Example:** Suppose that the employer decides to pay the worker a wage of \$4. Further, suppose that the worker selects effort of 1.5. With these hypothetical values, the employer earns $(124) * 1.5 = 8 * 1.5 = \$12$.

- Note that only what is left of the initial endowment is multiplied by the level of effort chosen by the worker. Thus, paying the whole endowment as a wage would yield a payoff of zero for the employer no matter the level of effort the worker selects in response.
- At the end of each period, the employer will learn both the worker's effort level and his/her own payoff.
- The employer cannot accumulate money throughout periods. This means the employer can use only his/her endowment to set a wage in each period.

- **Worker:**
  - A subject assigned to the role of 'worker' will receive a wage offer in each period from the employer.
  - In each period, after receiving the employer's wage offer, the worker will select a level of costly effort for that period. The higher the effort, the higher is the cost of effort.
  - The level of effort can be: [0, 0.25, 0.5, 1, 1.25, 1.50,..., max effort]. Note that a worker cannot select a level of effort that will cause a negative payoff.
  - Workers have the following payoff function:

    $$\text{Worker's payoff} = \text{Wage} - \text{Cost of Effort}$$

    The cost of effort is computed according to the following function and displayed before confirming the effort choice:

    $$\text{Cost of effort} = .5 * e^2$$

  - Suppose an employer offers a wage of \$6 and the worker exerts an effort level of 2 in response.Then the worker earns $6 - (0.5 * 2^2) = 6 - 2 = \$4$

- At the end of each period, the worker will learn his/her own payoff. Note: For symmetric information treatments, subjects also learned the employers payoff, which we informed them of here.
- The worker cannot accumulate money throughout periods. That is, each period the worker will receive a wage offer and go through the steps described above.

2. Description of a Questionnaire Period

Steps

Each *Questionnaire Period* proceeds as follows:

1. Both the worker and the employer respond to some questions
2. Both the worker and the employer make their Decisions
3. Payoffs of the worker and the employer for that period are displayed
4. The game proceeds to either another Questionnaire Period or to a Decision Period.

Further details on points 1 and 2 will be given during the game and displayed on screens.Instructions are role specific. We display these instructions during each questionnaire period. However, the instructions for a questionnaire period are the same for all questionnaire periods.

The software will notify you when you are playing a Questionnaire Period. You will start the game by playing a Decision Period.

3. Final remarks:

If you have any further questions, please raise your hand and an experimenter will visit your station to answer your question privately.

4. Summary of Basic Instructions:

- We will randomly assign you to one of two roles: employer or worker. Your role will not change during the experiment.
- We randomly assign one worker to one employer. This is the employer-worker pair. These pairs do not change during the experiment.
- The game lasts for 20 periods (plus 3 trial periods) and they are distinguished into Decision Periods and Questionnaire Periods.
- In Each Decision period, the employer receives an endowment and uses this endowment to pay a wage to the worker.
- Once the worker receives a wage offer, the worker will respond by selecting a level of costly effort.
- Employer earnings for each period are (Endowment - Wage)*Effort. -Worker earnings for each period are (Wage - Cost of Effort).
- The employer receives a new endowment in each period, and the employer and the worker cannot accumulate money across periods.
- The employer selects a new wage each Decision Period. The worker selects a new level of costly effort each Decision Period.
- During Questionnaire Periods, both players respond to some questions displayed on their respective screens. The software will always notify you when you are playing a Questionnaire Period.
- 1 Decision Period and 1 Questionnaire Period will be randomly chosen and the payoffs in these periods, plus your show-up fee, form you final payment.

D Screen Shots

Comprehension Quiz

Please, respond to the following questions concerning the instructions that you just read.

- **Question 1. :**

How many **period types** are there?	0	

- **Question 2. :**

How many *Decisional Periods* will be paid?	0	
How many *Questionnaire Periods* will be paid?	0	
How many periods will be paid overall?	0	

Number of right answers: 0

(a) First comprehension quiz

Comprehension Quiz

Please, respond to the following questions concerning the instructions that you just read.

- **Question 3. :**

What is the **initial endowment** of the employer?		
What is the **payoff** of the **employer** for a wage = 12 and effort = 4?		
What is the **payoff** of the **employer** for a wage = 12 and effort = 0?		
What is the **payoff** of the **employer** for a wage = 0 and effort = 0?		
What is the **payoff** of the **worker** for a wage = 12 and effort = 4?		
What is the **payoff** of the **worker** for a wage = 12 and effort = 0?		

Number of right answers: 0

(b) Second comprehension quiz

Figure 5: Beliefs and Effort Responses to Shocks

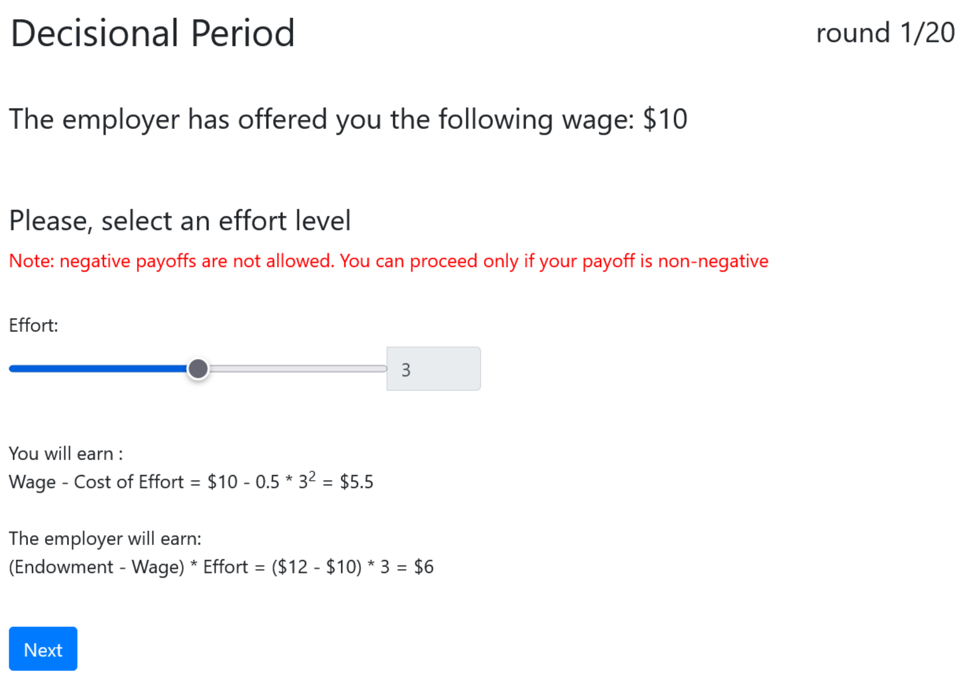


Figure 6: Worker's effort selection screen

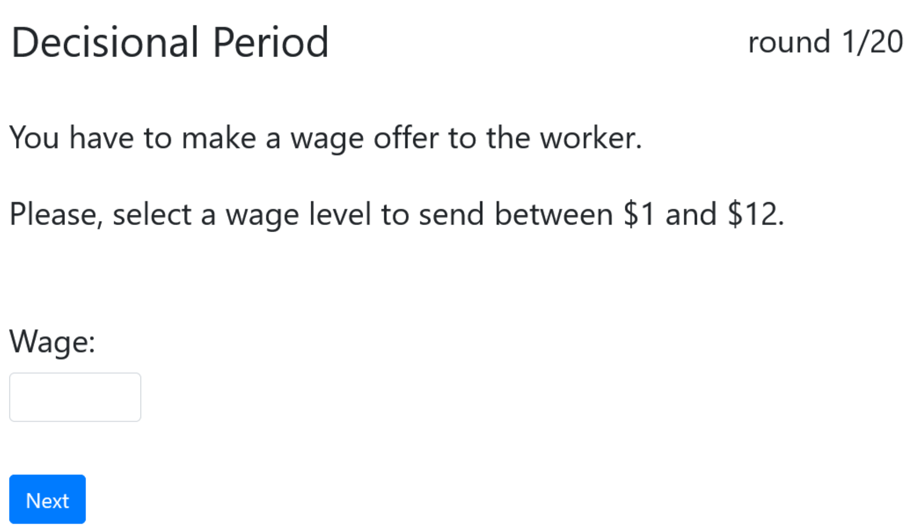
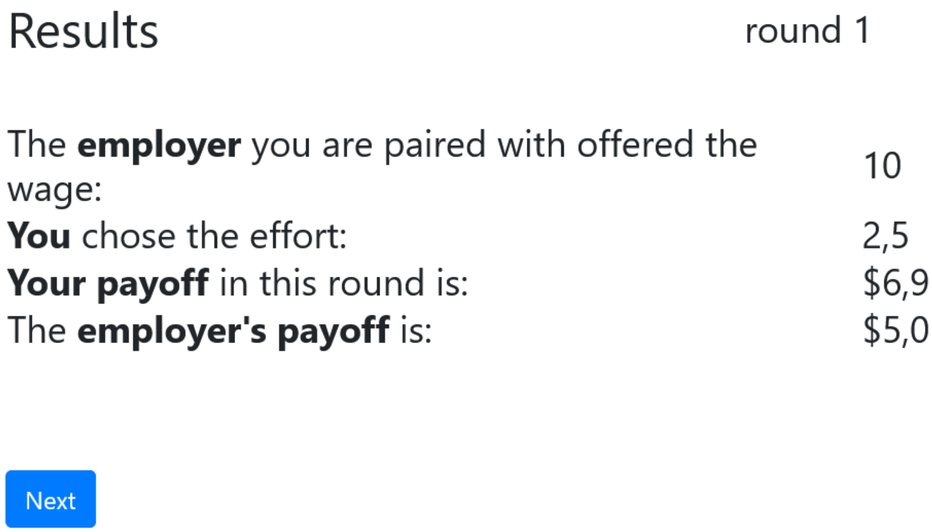
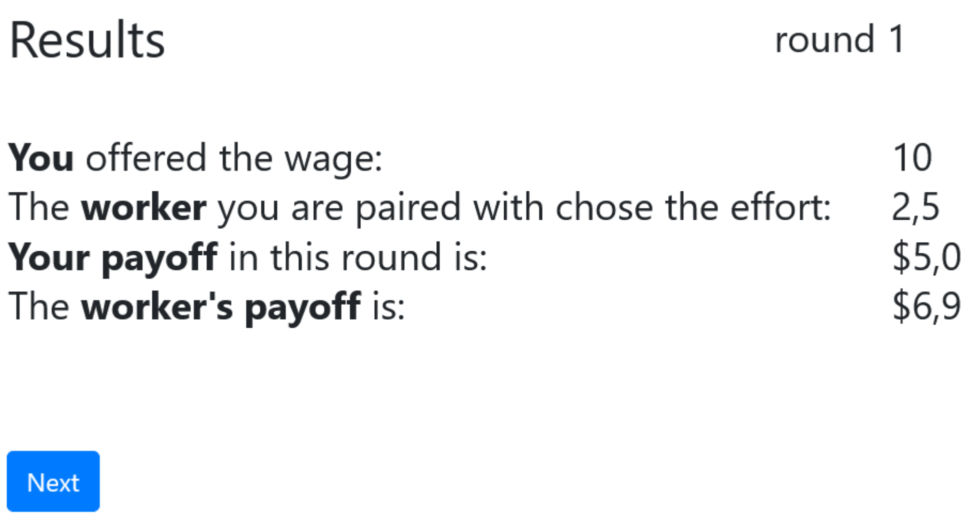


Figure 7: Worker's effort selection screen



(a) Firm's end-of-period information



(b) Worker's end-of-period information

Figure 8: End-of-period information

Change in Employer's Endowment

The employers' per-period endowment has changed from $12 to $8.

This change will last for the remainder of this experiment!

Please, note:

- The employer’s payoff is now ($8 – Wage)* Effort.
- Therefore, the **highest** wage offer possible is now $8 rather than $12.
- This screen is being displayed **only** to **employers** in this experiment.
- Workers **do not learn** about this change.

Click on the button below to proceed.

Next

(a) Negative shock under asymmetric information

Change in Employer's Endowment

The employers per-period endowment has changed from $12 to $8.

This change will last for the remainder of this experiment!

Please, note:

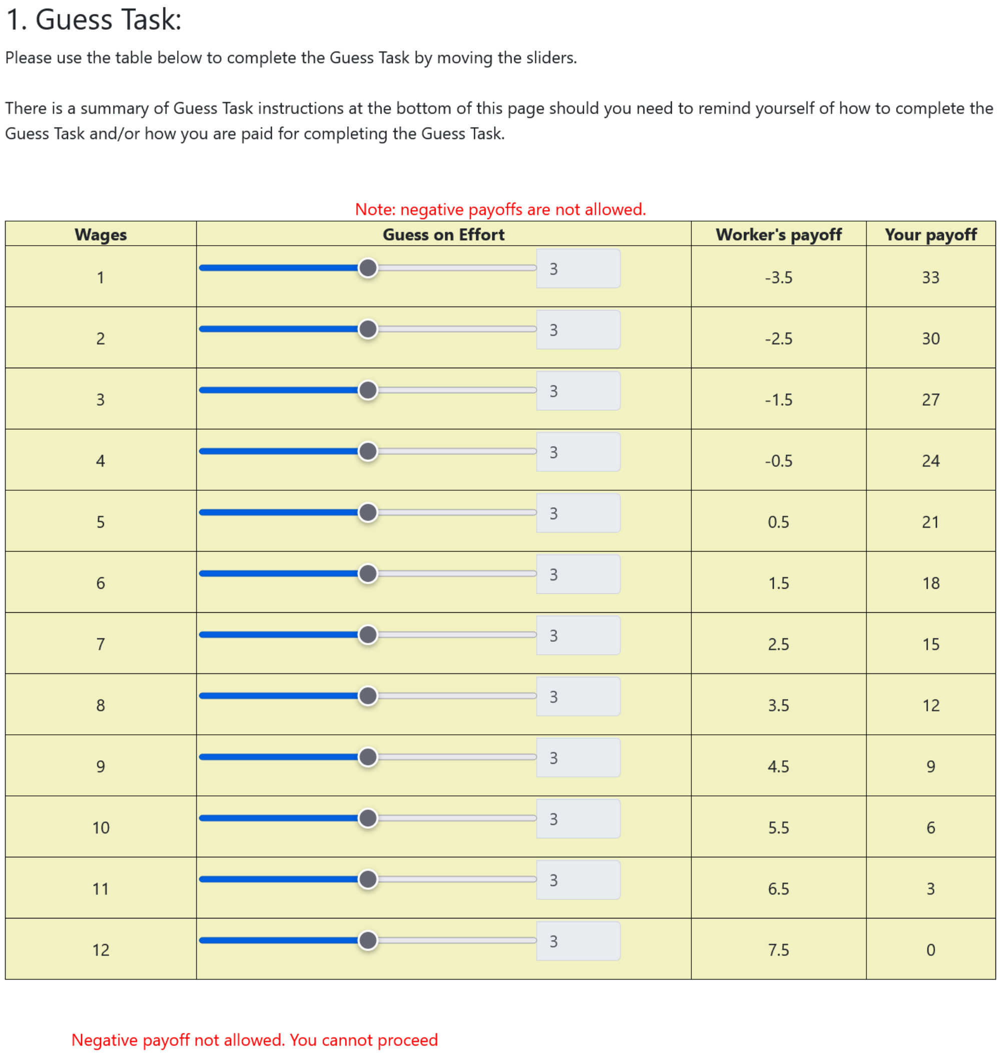
- The employer’s payoff is now ($8 – Wage)* Effort.
- Therefore, the **highest** wage offer possible is now $8 rather than $12.
- This screen is being displayed to all employers and workers in this experiment.

Click on the button below to proceed.

Next

(b) Negative shock under full information

Figure 9: Examples of endowment shock announcement



1. Guess Task:

Please use the table below to complete the Guess Task by moving the sliders.

There is a summary of Guess Task instructions at the bottom of this page should you need to remind yourself of how to complete the Guess Task and/or how you are paid for completing the Guess Task.

Note: negative payoffs are not allowed.

Wages	Guess on Effort	Worker's payoff	Your payoff
1	3	-3.5	33
2	3	-2.5	30
3	3	-1.5	27
4	3	-0.5	24
5	3	0.5	21
6	3	1.5	18
7	3	2.5	15
8	3	3.5	12
9	3	4.5	9
10	3	5.5	6
11	3	6.5	3
12	3	7.5	0

Negative payoff not allowed. You cannot proceed

Figure 10: Example of the belief elicitation screen seen by subjects sorted into the role of employer in periods 5,10,11 and 16

Figure 11: Example of the effort function elicitation seen by subjects sorted into the role of worker in periods 5,10,11 and 16

2. Strategy Task:

You will use the table below to provide your effort choice for each possible wage the employer could send you in this round. Note that in this task you will not known in advance the offered wage (as in previous Decisional Periods). That is:

- The employer will make a wage offer as usual, but this time it will not be displayed until the end of this task. You will learn the wage offer only after completing this task.
- You have to complete the table below with your effort response for each hypothetical wage level

How you earn money for the Effort Provision Task

- To compute your payoff for this task, the effort level corresponding to the wage offered by the employer will be chosen as effort response.

Example

- suppose you have completed the table below.
- Now, suppose that the employer offers a wage of \$6 and that you agreed previously to provide effort 1.5 for a wage offer of \$6 (that is the line 6 of table).
- Your payoff is computed as usual : Wage - Cost of Effort = (\$6 - 0.5 * 1.5 ^{2}) = \$4.9 in this example.

------------------------- Please, indicate your effort choices in the table below by moving the sliders.------------------

Note: negative payoffs are not allowed. You can proceed only if your payoff is non-negative

Hypothetical Wages	Your Effort	Your payoff	Employer's payoff
1	0.75	0.7	8.3
2	0.75	1.7	7.5
3	0.5	2.9	4.5
4	0.5	3.9	4
5	3	0.5	21
6	3	1.5	18
7	3	2.5	15
8	3	3.5	12
9	3	4.5	9
10	3	5.5	6
11	3	6.5	3
12	3	7.5	0

Next