Economics Bulletin

Volume 32, Issue 3

Inequity aversion in a model with moral hazard

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Abstract

In this paper we solve a parametric moral hazard model that incorporates risk and inequity aversion. In the model, the worker's effort is not contractible but the employer can link the worker's compensation to the revenue, a measure probabilistically related to the effort. The model can account for some regularities observed in the experimental data such as loss avoidance. It also suggests that inequity aversion may amplify variability of the worker's compensation. Data from a within-subject experiment is used to estimate the unobservable parameter of inequity aversion. Experimental results generally support the model's predictions. In the setting considered, the estimate of the inequity aversion parameter implies that about 30 percent of the change in the revenue range is passed into the worker's incentive payment.

Citation: Kirill Chernomaz, (2012) "Inequity aversion in a model with moral hazard", *Economics Bulletin*, Vol. 32 No. 3 pp. 2500-2510.
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Submitted: June 03, 2012. **Published:** September 09, 2012.

1 Introduction

This study focuses on the effect of equity considerations in a standard moral hazard model used in Keser and Willinger (2000, 2007). The employer offers a contract to the worker to carry out a task which can yield low (R_l) or high (R_h) revenue. The contract is a pair of wages (w_l, w_h) such that w_l (w_h) is paid when the revenue is R_l (R_h). If the worker accepts the contract, he is hired and chooses between two levels of effort e: high ($e = 1$) or low ($e = 0$). The worker's cost of effort is c_e such that $c_1 > c_0$. The effort is not observable by the employer but is positively correlated with the revenue. Thus, $\pi_1 \equiv \Pr(R_h | e = 1) > \Pr(R_h | e = 0) \equiv \pi_0$. Under standard utility assumptions, the optimal contract involves a positive incentive payment $\Delta w \equiv (w_h - w_l) > 0$. Additionally, w_h and w_l are independent of R_l or R_h and $w_l \leq c_0$, i.e. the worker choosing $e = 1$ may experience a loss.

Keser and Willinger (2000, 2007) experimentally test the model outlined above. They find that e.g. the predicted relation $w_l \leq c_0$ does not hold in the data. To better explain the observed behavior they put forward three principles of contract design: (a) loss avoidance: the employer should offer a wage that covers the worker's effort costs (in particular, $w_l \geq c_0$); (b) the incentive payment is non-negative ($\Delta w \geq 0$); and (c) the net profit of the employer is no lower than the net earnings of the worker. The principles organize the data well although less so when the cost of effort is increased. Nevertheless, they are a better predictor of the subjects' behavior compared to the standard model with a very general formulation of the worker's risk aversion.

Using a variant of the utility formulation in Fehr and Schmidt (1999) we explicitly incorporate inequity aversion into the model and solve for the optimal contract (w_l^*, w_h^*) assuming both risk and inequity aversion. The model's predictions are consistent with the three principles. Thus, if the worker is sufficiently inequity-averse we have $w_l^* > c_0$. The model additionally predicts that, in contrast to the standard setting, w_l^* increases with R_l, w_h^* increases with R_h, and Δw increases with $\Delta R \equiv (R_h - R_l)$. The implication is that an increase in the variance of R due to changes in ΔR results in a more variable compensation for an inequity-averse worker. This prediction also stands in contrast with some of the reciprocity-based theories of principal-agent interactions which suggest that the incentive payment may not be necessary at all. Using data from a within-subject experiment we find support for the model's prediction and obtain an estimate of the parameter of inequity aversion. The estimate implies that about 30 percent of a change in ΔR is passed into Δw (compared to no effect as predicted by the classical theory).

Englmaier and Wambach (2010) study the effect of inequity aversion on optimal contracts in a model with continuous levels of revenue and effort. They find that the optimal wage $w^*(R)$ is an increasing linear function of R. This study is a special case allowing us to find a parametric expression for $w^*(R)$ and its slope for a particular utility specification.[1]

[1] In a related work, Itoh (2004) studies optimal contracts under risk neutrality considering cases with an inequity-averse agent, an inequity-averse principal, as well as with multiple agents. Dur and Glazer (2008) study the setting where the worker's effort is directly contractible. There is also a substantial strand of literature which focuses on implications of inequity aversion when workers are concerned with their standing relative to each other rather than the principal (e.g. Rey-Biel (2008) and Bartling (2011))

2 Theoretical model

The employer's objective is to maximize the expected profit:

$$E_e\Pi(w_l, w_h) = \pi_e(R_h - w_h) + (1 - \pi_e)(R_l - w_l), \tag{1}$$

where E_e is the expectation conditional on the worker's effort choice and $\pi_e \in \{\pi_0, \pi_1\}$ is the probability of the high revenue. The worker's preferences are given by a utility function that combines constant absolute risk aversion (CARA) with a simplified version of the Fehr and Schmidt (1999) inequity aversion formulation:

$$U(w, c, R - w) = u(w - c - \alpha((R - w) - w)) = u(w(1 + 2\alpha) - c - \alpha R), \tag{2}$$

where w is the worker's wage, c is the cost of effort, $R-w$ is the profit of the employer, $\alpha \geq 0$ is the weight that the worker puts on aversion to inequity, and $u(x) = -\exp(-\gamma x)$ with the coefficient of absolute risk aversion γ. Thus, the worker's utility is negatively affected by the difference between the employer's profit and his wage. With this specification the worker only experiences inequity-related disutility when his wages are less than the employer's profit $R - w$. Thus, we omit the empathy component of the full Fehr-Schmidt formulation (β), which applies to wages higher than the employer's profit. In equilibrium, the optimal wage is lower than the employer's profit for the parameter values used in the experiment.

The employer's objective is to select the profit-maximizing contract (w_h, w_l). In doing so she has to take three things into account (see Figure (1) for an illustration). First, the worker will not accept the contract if it does not provide at least the reservation level of utility: $E_eU(w, c_e, R - w) \geq U(0, 0, 0)$, where $U(0, 0, 0)$ is the worker's reservation utility. This is the participation constraint (PC). If the employer decides to induce $e = 1$ (so that $c_e = c_1$) then using (2) the PC constraint becomes:[2]

$$w_h \geq \frac{\alpha}{(1 + 2\alpha)}R_h - \frac{1}{\gamma(1 + 2\alpha)} \ln\left[u\left(w_l(1 + 2\alpha) - \alpha R_l\right)\frac{(1 - \pi_1)}{\pi_1} - \frac{u(c_1)}{\pi_1}\right]. \tag{3}$$

Second, if the employer wants to induce $e = 1$, she needs to make sure that the contract provides the appropriate incentives. The worker's expected utility from $e = 1$ should be at least as high as the expected utility from $e = 0$: $E_1U(w, c_1, R-w) \geq E_0U(w, c_0, R-w)$. This is the incentive compatibility constraint (IC). Using (2) the IC constraint can be written as:

$$w_h \geq w_l + \frac{1}{(1 + 2\alpha)}\left\{-\frac{1}{\gamma}\ln\left(\frac{(1 - \pi_0)u(c_1) - (1 - \pi_1)u(c_0)}{\pi_1 u(c_0) - \pi_0 u(c_1)}\right)\right\} + \frac{\alpha}{(1 + 2\alpha)}(R_h - R_l). \tag{4}$$

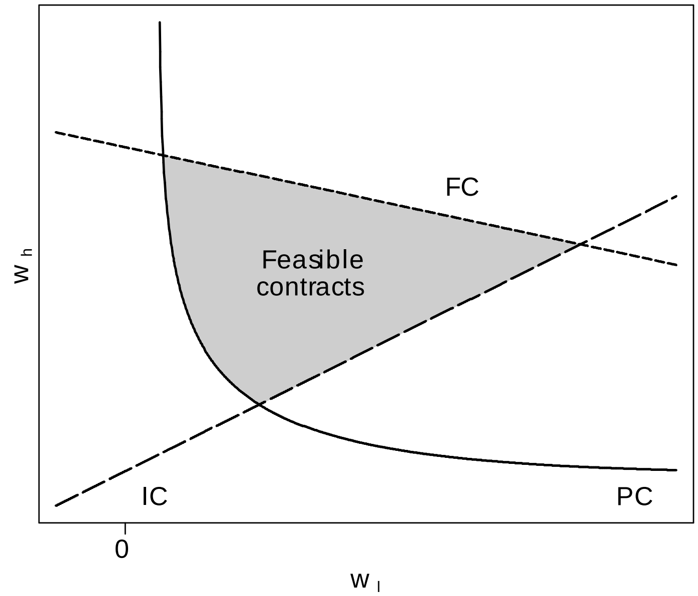
If the IC constraint is binding, from (4) the incentive payment $\Delta w = w_h - w_l$ is an increasing function of $\Delta R = R_h - R_l$. If the worker is inequity-neutral ($\alpha = 0$), Δw is independent of the employer's revenue.

Finally, the employer needs to decide whether or not inducing the high level of effort is worth the additional expense: $E_1\Pi(w_l, w_h) \geq \max_{(w_l, w_h)} E_0\Pi(w_l, w_h)$. This is the feasibility constraint (FC). After some manipulations it can be written as:

$$w_h \leq \frac{\left[(1 + 2\alpha)\pi_1 - (1 + \alpha)\pi_0\right](R_h - R_l) + aR_l + c_0}{\pi_1(1 + 2\alpha)} - \frac{(1 - \pi_1)}{\pi_1}w_l. \tag{5}$$

[2] Details on the derivation can be found in the supplemental materials.

Figure 1: Constraints and the set of feasible contracts.



The three constraints define the set of contracts that can profitably induce $e = 1$ ("feasible contracts"). It is illustrated in Figure (1). The objective of the employer can be viewed as selecting a contract from this set to maximize her expected profit (1). The iso-profit lines of the employer trying to induce $e = 1$ have the same slope as the feasibility constraint, $-\frac{(1-\pi_1)}{\pi_1}$, and the lines closer to the origin correspond to higher profits. Thus, the optimal contract(s) lies on the south-west boundary of the set. When the worker is risk averse, the PC constraint is strictly convex implying a unique optimal contract. It can be shown that the slope of the PC constraint is steeper than the slope of the iso-profit lines left of the intersection of the PC and the IC constraints. Therefore, the pair of wages (w_l^*, w_h^*) found at the intersection are the unique profit-maximizing wage contract. From (3) and (4) (w_l^*, w_h^*) is given by:

$$w_l^* = \frac{\alpha R_l}{(1+2\alpha)} - \frac{1}{\gamma(1+2\alpha)} \ln\left(-u(c_0) + \frac{\pi_0}{\pi_1 - \pi_0}(u(c_1) - u(c_0))\right) \tag{6}$$
$$w_h^* = \frac{\alpha R_h}{(1+2\alpha)} - \frac{1}{\gamma(1+2\alpha)} \ln\left(-u(c_1) - \frac{(1-\pi_1)}{(\pi_1 - \pi_0)}(u(c_1) - u(c_0))\right).$$

Thus, when the worker is averse to inequity, the optimal wages increase with the corresponding employer's revenue: $\frac{dw_l^*}{dR_l} = \frac{dw_h^*}{dR_h} = \frac{\alpha}{(1+2\alpha)} > 0$. Additionally, the optimal incentive payment $\Delta w^* = w_h^* - w_l^*$ can be expressed as a function of ΔR:

$$\Delta w^* = \beta_0 + \beta_1 \Delta R, \tag{7}$$

where $\beta_1 \equiv \frac{\alpha}{(1+2\alpha)}$ and β_0 is a constant independent of ΔR. The relationship in (7) implies that a fraction $\frac{\alpha}{(1+2\alpha)}$ of any change in the spread between the low and the high employer's revenue is passed to the worker. In other words, unless the worker is inequity-neutral, more variable employer revenue calls for a more variable worker compensation. From (6), it can also be shown that $w_l^* \leq c_0$ regardless of the degree of risk aversion if the worker is inequity-neutral ($\alpha = 0$). In contrast, when agents are averse to inequity, $w_l^* > c_0$ whenever $R_l > 2c_0$.

The model suggests a strategy for estimating the unobservable parameters using the binding IC constraint. Let $\Delta\hat{w}$ be a sample mean of Δw and $g(\gamma) \equiv -\frac{1}{\gamma} \ln \left\{ \frac{(1-\pi_0)u(c_1)-(1-\pi_1)u(c_0)}{\pi_1 u(c_0)-\pi_0 u(c_1)} \right\}$. From (4) we obtain the relation between $\Delta\hat{w}$, the parameter of risk aversion, γ, and the parameter of inequity aversion, α:

$$\Delta\hat{w} = \frac{1}{(1+2\alpha)} g(\gamma) + \frac{\alpha}{(1+2\alpha)} \Delta R. \tag{8}$$

Using two samples that differ only in the magnitude of ΔR, the two parameters can be estimated separately as follows. Let $\Delta\hat{w}_i$ be the mean of the incentive payment in the sample corresponding to ΔR_i, holding all other parameters constant. Then, using the fact that $g(\gamma) = \alpha(2\Delta\hat{w}_i - \Delta R_i) + \Delta\hat{w}_i$ is constant across the samples we obtain an estimate of α:

$$\begin{aligned} \alpha(2\Delta\hat{w}_1 - \Delta R_1) + \Delta\hat{w}_1 &= \alpha(2\Delta\hat{w}_2 - \Delta R_2) + \Delta\hat{w}_2 \\ \hat{\alpha} &= \frac{\Delta\hat{w}_2 - \Delta\hat{w}_1}{(\Delta R_2 - \Delta R_1) - 2(\Delta\hat{w}_2 - \Delta\hat{w}_1)}. \end{aligned} \tag{9}$$

Once the inequity aversion parameter $\hat{\alpha}$ is estimated, $\widehat{g} = \hat{\alpha}(2\Delta\hat{w}_i - \Delta R_i) + \Delta\hat{w}_i$ can be estimated as well. Even though $g(\gamma) = \widehat{g}$ cannot be explicitly inverted, it can be used to obtain an estimate of $\widehat{\gamma}$.

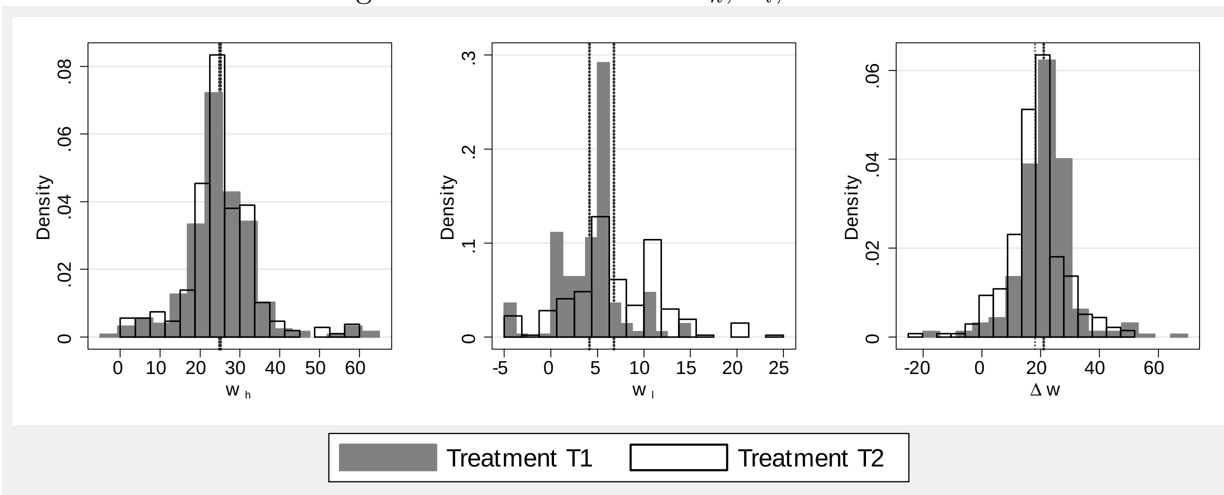
3 Experimental data analysis

3.1 Experimental setup

To estimate the parameter of inequity aversion we use data from a within-subject experiment. ΔR was varied across treatments by setting $R_l = \$10$ (treatment T1) and $R_l = \$20$ (treatment T2). Other parameters were held constant ($c_1 = \$4$, $c_0 = \$0$, $\pi_0 = 0.3$, $\pi_1 = 0.7$, and $R_h = \$60$). The within-subject design is aimed at keeping the unobservables constant as well. Four sessions (48 subjects) were conducted consisting of 1-2 independent sub-sessions for a total of 7 sub-sessions (with no interaction between subjects across sub-sessions). Subjects participated in 4 parts consisting of 6 rounds each. Employer/worker roles were randomly assigned in part 1 and switched in subsequent parts. Every round subjects were randomly matched into employer-worker pairs. To reduce the order effect, the treatment condition was switched every round. In addition, two sessions started with T1 and two sessions started with T2.

Standard procedures were followed: written instructions were distributed and read aloud, a short quiz was administered, after which subjects went through 5 training rounds experiencing both roles. In each round subjects started with a \$5 initial balance to accommodate negative wage offers (a lump-sum payment has no effect in the model). Each employer made a wage offer (w_l, w_h). The worker either rejected the offer (both earned \$5 initial balance) or accepted it and chose the level of effort. Based on the effort, the employer's revenue

Figure 2: Distributions of w_h, w_l, and Δw.



$R_i \in \{R_l, R_h\}$ was randomly determined. The employer earned $\$5 + R_i - w_i$ and the worker earned $\$5 + w_i$.

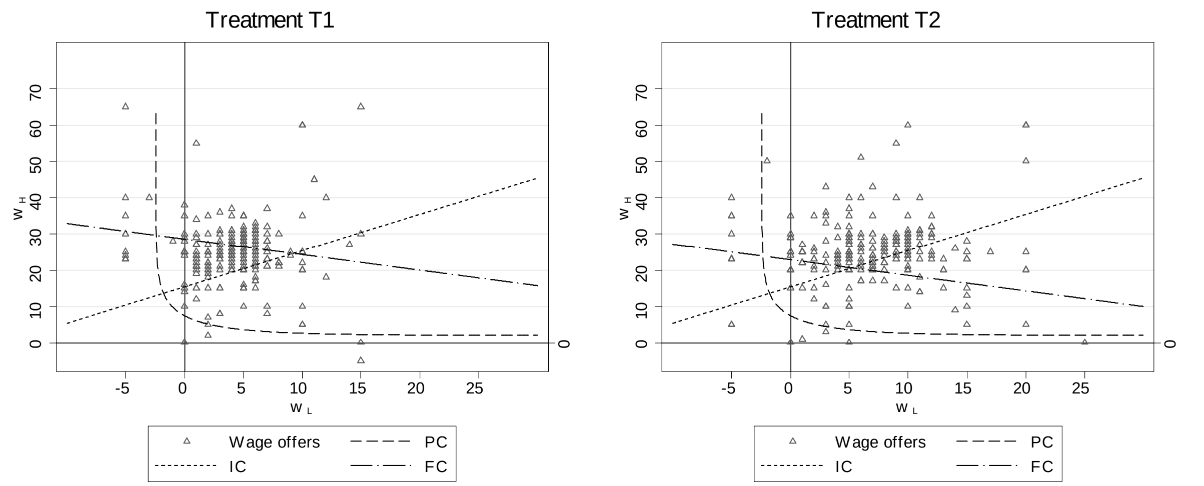
The experiment was implemented using zTree experimental software Fischbacher (2007). Subjects were recruited through email announcements from the general undergraduate population at San Francisco State University. Subjects' cash payments consisted of a show-up payment of \$8 and earnings from a randomly selected round. On average, subjects earned \$32 for an approximately 2-hour session.

3.2 Analysis of wage offers

The three panels in Figure (2) show the sample distributions of (left to right) w_h, w_l, and Δw. Solid grey bars corresponds to T1, and hollow bars correspond to T2. In the left panel, two dotted vertical lines around \$25 represent the sample means of w_h for the two treatments. The difference between the means is small and insignificant (\$25.2 in T1 vs. \$24.88 in T2). In the middle panel, the two dotted vertical lines corresponding to the means of w_l are clearly different (\$4.14 in T1 vs. \$6.76 in T2). Thus, w_l is increasing in R_l. This pattern holds not only on average for the whole sample, but also for all 7 independent sub-sessions. Using a one-tail binomial test we can reject the hypothesis that this is due to a random chance at 1% significance level (p-value = 0.0078). Additionally, in all 7 sub-sessions we have $w_l > c_0 = 0$. This observation cannot be explained by a standard model with or without risk aversion. Without inequity aversion, the optimal w_l should be negative regardless of the degree of risk aversion. On the other hand, if the workers are averse to inequity, positive w_l is optimal for a wide range of inequity aversion parameter values. For comparison, the optimal wages for inequity- and risk-neutral workers are $w_l^* = c_0 - \frac{\pi_0}{\pi_1 - \pi_0}(c_1 - c_0) = -3$ and $w_h^* = c_1 + \frac{(1-\pi_1)}{(\pi_1 - \pi_0)}(c_1 - c_0) = 7$.

From the right panel of Figure (2) it is clear that Δw is smaller in T2 than in T1 (18.12 vs. 21.06). Since ΔR is smaller in T2 it follows that Δw is increasing in ΔR. The result is significant with a p-value of 0.0078. A larger incentive payment in T1 is consistent with inequity aversion and cannot be explained with standard utility assumptions.

Figure 3: Data and theoretical constraints with inequity-neutral workers.



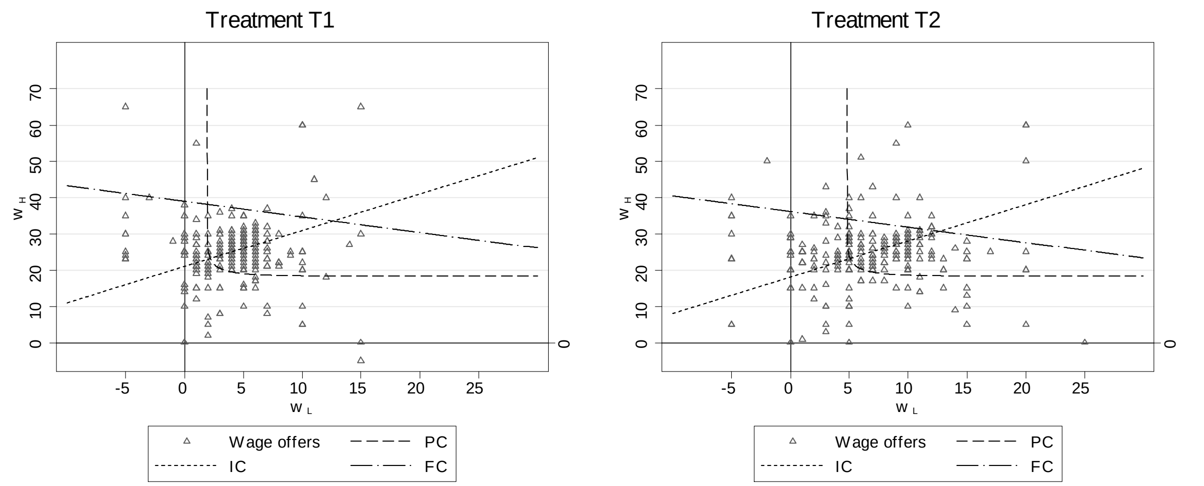
For comparison, with risk- and inequity-neutral worker the optimal incentive payment is (independently of R) $\Delta w^* = \frac{(c_1 - c_0)}{(\pi_1 - \pi_0)} = 10$.

Result 1 *Consistent with inequity aversion,*
(a) w_l *is increasing with* R_l*;*
(b) $w_l > c_0 = 0$ *in both treatments;*
(c) Δw *is increasing with* ΔR*.*

Figures (3) and (4) illustrate how the inequity aversion assumption improves the fit to the data. Figure (3) overlays the data over the theoretical constraints drawn under the assumption that the workers are inequity-neutral and risk-averse with $\gamma = 0.187$ (other parameter values are as used in the experiment).[3] The two panels correspond to the two treatments. Figure (3) shows that the optimal wage contract on the intersection of the IC and the PC constraints has $w_l^* < 0$ and is the same for both treatments. Despite the presence of a few outliers in the vicinity of that point, the bulk of the data is inconsistent with inequity-neutral workers. Note that the FC constraint is different between the treatments: in T2 it moves towards the origin, reducing the set of feasible contracts. Even if we presume that the data points correlate with the set of feasible contracts rather than the optimal contract, the movement of the data mass between the two treatments (rightward) is inconsistent with the movement of the feasibility constraint (down-left). Figure (4) depicts the same data but the constraints are drawn assuming inequity-averse workers with $\alpha = 0.7$. It shows that the assumption of inequity aversion is a better fit to the data. The IC and PC constraints intersect at a positive w_l, w_h is also higher, and, finally, the movement of the optimal point corresponds directionally with the movement of the data mass.

[3] The value of $\gamma = 0.187$ is implied by the data as described below.

Figure 4: Data and theoretical constraints with inequity-averse workers.



3.3 Estimation of unobservable parameters

From (9), the inequity aversion parameter is a non-linear function of $\Delta\hat{w}_2 - \Delta\hat{w}_1$, the difference between the incentive payment means in the two samples. We ran an OLS regression with Δw as the dependent variable and the treatment dummy (1 for T2 and 0 for T1) as the key independent variable. The coefficient of the treatment dummy is an estimate of $\Delta w_2 - \Delta w_1$. To control for high variability of the incentive payment the basic specification is augmented with a set of part fixed effects and a set of subject fixed effects.

Specification (1) in the first column of Table (1) reports the results of the basic regression. The estimate $\Delta\hat{w}_2 - \Delta\hat{w}_1$ (given by the coefficient of the dummy variable $T2$) is -2.93 and statistically significant. The implied estimate of the inequity aversion parameter is $\hat{\alpha} = .71$, and the rate at which the employer's revenue variability is passed to the worker is $\hat{\beta}_1 = 0.293$ (see (7)). Using the delta method, the standard error of $\hat{\alpha}$ is .402. Thus, the estimate $\hat{\alpha}$ is statistically significant (p-value=0.078). In specification (2) we drop the observations with $\Delta w < 0$ (11 observations), which significantly improves the precision of $\hat{\alpha}$. As a result, we omit these observations when estimating additional specifications.

As a robustness check, several other specifications are reported. Specification (3) includes the variable $time$ which is equal to the round within a particular part (1 to 6). There is some evidence that the incentive payment, Δw, increases towards the end of each part. However, the statistical significance of the result is weak. Specification (4) includes running frequencies of $e = 1$ ($freqE1$), R_h ($freqRh$), and the two events occurring simultaneously ($freqE1Rh$). The frequencies are calculated separately for each employer based on the history experienced by a particular subject up to round $t - 1$. The coefficient of $freqE1$ is not significant, i.e. the historic frequency of high effort does not influence the employers' decisions on its own. However, the positive and significant estimate of $freqE1Rh$ means that a relatively high frequency of $e = 1$ and R_h occurring at the same time tend to increase Δw. The negative estimate of $freqRh$ seems to suggest that a higher frequency of R_h by itself decreases Δw. Subjects may be inferring that they do not need to induce $e = 1$ if in their experience

Table 1: Estimation of the parameter of inequity aversion.

	(1)		(2)		(3)		(4)		(5)	
Variables	coef	p-val	coef	p-val	coef	p-val	coef	p-val	coef	p-val
$T2$	-2.93	0.000	-2.86	0.000	-2.89	0.000	-3.01	0.000	-2.98	0.000
$time$					0.29	0.110				
$freqRej_{t-1}$									-6.40	0.160
$freqE1Rh_{t-1}$							9.58	0.033	11.05	0.017
$freqE1_{t-1}$							-4.60	0.176	-5.74	0.100
$freqRh_{t-1}$							-12.05	0.001	-13.59	0.000
$const$	25.41	0.000	15.58	0.000	14.63	0.000	18.63	0.000	19.15	0.000
$\hat{\alpha}$	0.710	0.078	0.668	0.047	0.684	0.048	0.759	0.080	0.739	0.078
$\hat{\beta}_1$	0.293		0.286		0.289		0.301		0.298	
N	576		565		565		464		464	
R^2	0.34		0.37		0.37		0.42		0.43	
Subject FE	yes		yes		yes		yes		yes	
Part FE	yes		yes		yes		yes		yes	
$\Delta w < 0$	included		omitted		omitted		omitted		omitted	

the frequency of R_h is relatively high. Specification (5) includes the running frequency of rejections faced by an employer ($freqRej$). The sign of the coefficient suggests that a higher frequency of rejections reduces Δw. However, the result is not significant.

To summarize, there is some evidence that the employers' offers evolve throughout the experiment and may be affected by the history of play they experience. However, the estimate of the inequity aversion parameter seems fairly robust at about 0.7. The estimate of $\hat{\beta}_1$ is stable as well. Note that the estimate of the inequity aversion parameter is based on wage offers by the employers. Thus, we do not necessarily measure the true inequity aversion of the workers but rather as it is perceived by the employers.

Result 2 *The estimate of the inequity aversion parameter is $\hat{\alpha} \approx .7$. It implies that about 30 percent of a change in the employer's revenue range is reflected in the worker's incentive payment.*

Using the inequity aversion parameter $\hat{\alpha}$, we can obtain the parameter of risk aversion implied by data. Recall that $g(\gamma) = \alpha(2\Delta w_i - \Delta R_i) + \Delta w_i$, and can be calculated using $\Delta\hat{w}$ from either treatment and the estimate $\hat{\alpha}$: for example for $\hat{\alpha} = .71$, $\hat{g}(\gamma) = 15.454$. Despite the fact that $g(\gamma)$ is not analytically invertible, $\hat{g}(\gamma) = 15.454$ can be matched to $\hat{\gamma} = .1873$ employing a straightforward grid search. Using the estimates of the unobserved parameters and (6) the optimal wages in T1 are $w_l^* = 2.18$ and $w_h^* = 23.2$ while that in T2 are $w_l^* = 5.09$ and $w_h^* = 23.2$. These estimates are only about \$2 lower than the observed averages in the sample. The estimated parameter values can also better explain wage contract rejections. Rejections occurred in 45/576 cases (7.8%). From these 45 contracts, 41 (91.1%) should have been accepted if the workers were both inequity- and risk-neutral, and 35 (77.8%) should have been accepted if the workers were inequity-neutral but risk-averse (with $\hat{\gamma} = .1873$). In contrast, only 12 (26.7%) should have been accepted if we use both estimated parameters.

4 Summary

In this paper we solve a simple parametric model of moral hazard that incorporates inequity aversion on the part of the worker. The augmented model offers a superior fit to experimental data as it can explain wage offers and incentive payments that depend on the magnitude of the employer's revenues. The model is used to devise a strategy for estimation of the unobserved parameter of inequity aversion. Using data from a within-subject experiment the value of the inequity aversion parameter is estimated to be 0.7, which implies that about 30 percent of the change in the range of the employer's revenue is passed into the worker's incentive payment. The implication of the model is that the worker's inequity aversion may amplify the volatility of the worker's compensation as the incentive payment is linked to the magnitude of ΔR. This result is notable in light of the standard prediction that the employer finds it beneficial to partially insure the worker against revenue fluctuations despite the fact that it lowers the worker's incentives. One can also envision that additional insurance against revenue fluctuations can be the basis for trust-reciprocity dynamic between an employer and a risk-averse worker. A less volatile compensation is of value to the worker and may cause the worker to reciprocate with a higher effort level despite weaker incentives. In such a case, the volatility of the worker's compensation would be reduced. In the setting of this paper no such tendency is observed, or at least the considerations of equity have an overpowering opposite effect. Whether such a phenomenon can be observed in other settings remains an interesting research question.

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