ESSAYS IN BEHAVIORAL ECONOMICS

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This dissertation consists of two distinct chapters that answer questions in behavioral economics about the relationship between labor supply and reference points. Each chapter is divided into two parts. The first part of the first chapter proposes the theoretical background to better understand labor supply decisions of workers with multiple reference points. The second part contains empirical results from a laboratory experiment. The second chapter analyzes a classical contract theory problem with agents who have non-standard, reference dependent, preferences. The first part of the second chapter analyzes the principal-agent model under full information, while the second part of the chapter introduces uncertainty into the model.

The first essay uses a real effort experiment to test the predictions of models with expectation-based and history-based reference points. For the expectation-based reference point, an agent cares about outcomes relative to her expectation, and she experiences a loss in utility if the actual outcome is below her expectation. For the history-based reference point, an agent evaluates her actual outcome compared to an outcome that she had in the past, and she experiences a loss in utility if the actual outcome is below the one from the past. In the experiment, I manipulate participants' past earnings exogenously to establish a history-based reference point and manipulate expectations about future earnings to establish an expectation-based reference point. Consistent with the model's predictions, I found evidence of both kinds of reference points. Subjects

work significantly more in the high expectation treatment; on average, they earn \$1.1 more (a marginal effect of 18.2%) in the high expectation treatment compared to the average earnings of \$6.03 in the low expectation treatment. Subjects in the high history treatment earn \$0.46 more (a marginal effect of 7.2%) compared to the average earnings of \$6.35 in the low history treatment. The sign of the effect is in line with the main model's prediction for effort level, but the size of the effect is not significantly different from zero due to the low power of the test.

The second essay analyzes a principal-agent model with an agent who has reference-dependent preferences with exogenously given reference point over either money or effort level. I find that the optimal effort level, designed by the principal, does not depend on the reference salary. I show that employers with projects where effort is crucial hire agents with high reference points or push up the reference points of agents whose initial reference point is low. Finally, I discuss the predictions of the model for matching between employers and workers based on workers' reference dependence. I show that employers with projects where effort is crucial hire agents with high reference points or push up the reference points of agents whose initial reference point is low. The last part of the essay presents a theoretical model, in which the principal cannot observe the effort level produced by the agent, and is thus unable to make the optimal wage contract depend upon it. I analyze the Lagrangian corresponding to the problem with uncertainty and I derive conditions for the optimal wage contract and optimal effort level.

BIOGRAPHICAL SKETCH

Janos Zsiros was born and raised in Cegled, Hungary. He obtained his Bachelor's degree in Quantitative Economic Analysis from Corvinus University of Budapest in 2008. Afterwards, he moved to the Netherlands where he obtained his Master's degree in Economics from Tilburg University in 2010. After completing his Ph.D. from Cornell University he plans to join Analysis Group in Boston.

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CHAPTER 1

EFFORT PROVISION WITH EXPECTATION- AND HISTORY-BASED REFERENCE POINTS

1.1 Introduction

Long established studies from psychology and behavioral economics have shown that people's preferences regarding outcomes are reference-dependent, and they exhibit loss aversion around certain reference points. When an individual evaluates an actual outcome, she evaluates the outcome in comparison to a reference point. The potential outcomes lie either in the gain or loss domain, depending on whether the outcome is better or worse than the reference point. Loss aversion captures the idea that an individual's valuation of an increase in the outcome is different when that valuation is below or above the reference point. For example, a worker who had a previous job with a wage of \$15 000 might use this wage level as a reference point for her salary and, thus, would evaluate two possible wage levels of her new job, \$16 000 or \$14 000, with respect to her reference point. On the other hand, this worker might also have certain expectations about her future wage at the new job, which might also serve as a reference point when she evaluates her actual salary. In this paper, I test whether past earnings (history-based reference point) and expectations (expectation-based reference point) can serve as reference points when workers decide how much effort to exert on a job.

The early literature in behavioral economics focuses mostly on status-quo (or lagged status-quo) types of reference points, where the reference point is determined by the endowment or the history of certain variables. For example, Kahneman et al. [1990] present evidence of the endowment effect, even in a market setting where there is a possibility of learning. Odean [1998] finds evidence of the disposition effect among investors, and Genesove and Mayer [2001] reveals that house sellers are averse to realizing (nominal) losses. A recent paper by Herz and Taubinsky [2015] finds evidence of a history-based reference points, which is based on past fairness of transactions in their experiment.

The seminal paper of Koszegi and Rabin [2006] introduces expectations as potential reference points. Since then, behavioral economists have studied expectations as potential reference points both in the laboratory and in the field, and they find support for this idea in both domains. For example, Gill and Prowse [2012a] find evidence for loss aversion around endogenous reference points in expectations in a real-effort tournament, while Ericson and Fuster [2014] provide an explanation of the endowment effect, which is compatible with reference points over expectations. However, Ericson and Fuster [2014] also argue that due to the rich psychology behind the endowment effect, a theory with multiple reference points may be required. Interestingly, Heffetz and List [2014] do not find evidence that expectations alone can explain the endowment effect in their experiment.

Investigating the effect of different types of reference points can help answer the open question of what determines references points and whether there are other types of reference points beyond expectations that influence behavior. The key challenges of testing any reference points in the field are that it is not clear what types of reference points are relevant for the individuals Barberis [2013] and, it is not possible to observe the reference points directly. To circumvent these problems, I designed a real-effort experiment, building on the experiment of Abeler et al. [2011], in which I am able to manipulate participants' past earnings and expectations exogenously. Thus, the effect of the two types of reference points can be studied and separated from each other. In particular, my research addresses the following questions: (a) does a history-based reference point influence labor supply in an environment where it has been shown that expectations serve as reference points and influence behavior, (b) given the existence of such an effect, is it in line with a potential model of history-based reference points, (c) is there an interaction between the effects of the two kinds of reference points and, finally, (d) is there any observable difference between the subjects who are more affected by expectation-based reference points and those who are more affected by history-based reference points?

In my experiment, subjects work on a task that requires them to exert real effort (e.g., counting the number of zeros in tables of zeros and ones that are generated randomly). The design of the experiment is linked closely to the paper of Abeler et al. [2011]. They designed a novel real-effort experiment in which they are able to vary subjects' expectations exogenously and show that these expectations serve as reference points that influence effort provision. In my experiment, I added a first stage to the design of Abeler et al. [2011]. At this stage, subjects count tables for 8 minutes for a given piece wage. Piece rates are either 50 cents in the high history treatment or 20 cents in the low history treatment. These treatments introduce an exogenous variation in how much subjects earn in the first stage, and these past earnings could potentially serve as a history-based reference point that influence the effort decision in the second stage. The task at the second stage is the same as the first stage, with two main differences. First, subjects can decide how much they want to work and when they want to stop counting tables. They have a maximum of 60 minutes available to count tables. Subjects in this stage do not receive their accumulated earnings with certainty. Their earnings in this stage are determined as in Abeler et al. [2011]. Before starting the second stage, subjects choose one of two envelopes that contains either an "Acquired earnings" card or a "f dollars" card. Subjects are aware of this procedure and the value of f before choosing the envelope. Thus, they know that they have a 50% chance of ending up with either of the envelopes. Subjects in the high expectation treatment receive \$7 ($f = 7$) if they pick the envelope with the "7 dollars" card. Subjects in the low expectation treatment receive \$3 ($f = 3$) if they pick the envelope with the "3 dollars" card. Subjects in both treatments who pick the 'Acquired earnings" card receive the acquired earnings at the end of the experiment.

Classical economic theory and models with only expectation-based reference points predict no effect of the low history and high history treatments on how much subjects work in the second stage.[1] To generate predictions for the history treatment, I discuss four models. In the main model, I extend the model of Abeler et al. [2011] by introducing a history-based reference point. Beyond expectation, I assume that subjects' past earnings also serve as a reference point, and that they are loss-averse around these reference points. A subject in the high history treatment earns 50 cents for each table that is correctly solved, thus, at the end of the first stage, she has on average a significantly higher earnings level. My main model predicts that the higher earnings from the first stage create incentives through loss-aversion to exercise a higher effort level in the second stage. Thus, the main model predicts that subjects in the high history treatment work longer than subjects in the low history treatment. The predic-

[1]Models with expectation-based reference points would predict an effect if the model incorporated the possibility that past wage rates influenced expectations, thus, indirectly, they could also influence behavior. However, in my experiment I manipulate expectations directly, thus the possibility of this indirect effect is minuscule.

tions about the effect of the expectation-based reference points, following from the assumption that subjects are loss-averse around the expectation reference points, are identical to the predictions of the model of Abeler et al. [2011]. Average effort level in the high expectation treatment is higher than in the low expectation treatment. The probability that the subject stops working when acquired earnings is at $3 is higher in the low expectation treatment than in the high expectation treatment. The probability that the subjects stops working when acquired earnings is at $7 is higher in the high expectation treatment than in the low expectation treatment.

The data support the latter two hypotheses of the main model about expectation and its effect on labor supply. Subjects work significantly more in the high expectation treatment compared to the low expectation treatment; on average, they earn $1.1 more in the high expectation treatment that translates to a marginal effect of 18.2%. This replicates the results of Abeler et al. [2011] and establishes that expectations serve as a reference point and significantly influence the effort provision of subjects. The other prediction about the effect of the expectation reference point is also confirmed in my data, as in the paper of Abeler et al. [2011]. The probability of stopping work when earnings are equal to $3 is higher in the low expectation treatment (the fixed amount of $3) than in the high expectation treatment. The probability of stopping work when earnings are equal to $7 is higher in the high expectation treatment (the fixed amount is $7) than in the low expectation treatment. Furthermore, the modal choice in both the low expectation and high expectation treatments is to stop working exactly when earnings equal the fixed payments of $3 or $7. There is evidence on the effect of a history-based reference point. Subjects in the high history treatment earn $0.46 (a marginal effect of 7.3%) more on average than subjects in the low history treatment. This means that subjects in the high history treatment with the higher earnings from the first stage, on average, earn more in the second stage than subjects in the low history treatment with lower first stage earnings. The sign of the effect is in line with the prediction of the model, however, it is not statistically significant due to small sample size and the lack of power of test.

This paper fits into the broader discussion that studies how reference points influence labor supply in the laboratory and in the field (e.g., Camerer et al. [1997], Goette et al. [2004], Farber [2008], Crawford and Meng [2011b], Abeler et al. [2011], Gneezy et al. [2015]).

The chapter is organized as follows. Section 1.2 describes the experimental design. Section 1.3 outlines the environment of the model and makes the main assumptions used in the models. Section 1.4 presents predictions from a standard model and section 1.5 predictions from a standard model with changing marginal utility. Sections 1.6 and1.7 present behavioral models of expectation and history-based reference points and make predictions for how these reference points influence behavior in the experiment. Section 1.8 summarizes all the predictions of the different models. In Section 1.9, I analyze the data from the experiment and discuss whether the hypotheses can be rejected or not. Finally, Section 1.10 concludes. The Appendix A contains derivations and provides further graphs and tables of the analysis that are not included in the main text.

1.2 Design

The experiment is designed to create an environment in which past earnings can be manipulated precisely and can be tested if they serve as a history-based reference point that influences behavior. This experiment is closely linked to the paper of Abeler et al. [2011]. The authors designed a novel real-effort experiment in which they are able to vary the subjects' expectations exogenously, and to show that these expectations serve as reference points and can influence effort provision. In this experiment, I introduce an exogenous variation on past experiences of the piece wage rate to the experimental design of Abeler et al. [2011]. As a result, there is an exogenous variation of past piece wage rates that can serve potentially as an additional (history-based) reference point for the subjects' decisions regarding effort provision. Having exogenous variation over both expectations and past experience, the effect of the two potential reference points can be studied and separated from each other.

As in the experiment of Abeler et al. [2011], the main output variable is the effort exercised by the subjects during the second stage of the experiment. Effort (denoted by e during the second stage) is measured by the number of tables in which, the subjects calculated the number of zeros correctly. These tables consist of 150 zeros and ones that are ordered randomly (See Figure 1.1). This is a tedious task, however, it does not require any specific prior knowledge. Furthermore, in this environment, performance is easily measurable and there is limited possibility for learning. The task is also clearly artificial without any intrinsic value to the experimenter; therefore, subjects have no incentive to use effort in the experiment as a way of reciprocating for the payments offered by the experimenter. This is an important property of the task, because piece wage changes in one of the treatments during the experiment. This change could create a concern that subjects reciprocate the changes in the piece rate through effort if they believed that effort in the experiment benefits the experimenter somehow.

The experiment starts with a practice round, and it has two main stages. There are questionnaires before both stages, and there is another questionnaire at the end of the experiment. Table 1.1 illustrates the experimental design, which is a 2x2 between-subject design.

Table 1.1: Summary of the Treatment Differences

History / Expectation	E_L	E_H
H_L	$\overline{w}$ = 20 cent, f = \$3	$\overline{w}$ = 20 cent, f = \$7
H_H	$\overline{w}$ = 50 cent, f = \$3	$\overline{w}$ = 50 cent, f = \$7

Prior to the first stage, subjects read the instructions for the first stage and they are told that there is a second stage but the subjects do not receive detailed information about it until a later phase in the experiment. Subjects are also asked to rate their tiredness level on the modified five point Borg scale Borg [1962, 1990] (1=Not tired; 2=A little tired; 3=Moderately tired; 4=A lot tired; and 5=Very tired) which is used in medical research Lu et al. [2010], Wolinsky et al. [1998] for measuring individuals' fatigue and physical tiredness. This measure serves as a baseline for the analysis of whether subjects' tiredness after the first stage differs significantly between the two treatments H_L and H_H. After subjects read the instructions, they have a 2-minute practice round during which they can count tables without monetary incentives. This stage helps subjects familiarize themselves with the task, its difficulty, the computer interface[2], and helps them to learn about their effort costs. Moreover, performance from this stage (i.e., the number of tables that are correctly solved per minute) is used as an indicator for individual productivity level for the analysis of the data from the second stage.

Half of the subjects are selected randomly to participate in treatment H_L and the other half are assigned to treatment H_H during the first stage. Subjects have **8 minutes** to count as many tables as possible for which they receive a piece rate wage $\overline{w}$ for each table that is solved correctly. If they enter an incorrect number, they have 2 more trials for the same table. If their answer is incorrect for the third time, then the piece rate $\overline{w}$ is deducted from their accumulated earnings. This procedure ensures that subjects don't guess during the experiment. The only difference between H_L and H_H treatments is the level of piece rate that subjects earn in the H_L treatment; subjects earn **\$0.2** for each correctly solved tables, and in H_H they earn **\$0.5**. This difference in piece wage rate results in different history-based reference points about piece wage rate for subjects during the second stage. The two treatments are calibrated so that there is an important difference economically between the piece rates and between the potential earning levels that subjects can earn in the two treatments.

After the first stage, there is a 3-minute break in which subjects remain at the computer where they do not have a task, which allows them to relax and regenerate themselves. Afterwards, subjects read the instructions for the second stage of the experiment, which closely follows the second stage of the exper-

[2]Figure 1.1 contains an image of the computer screen for the first stage which only differs from the practice round in that the earnings from the first stage are displayed. During the practice round subjects presented only with the information on how many tables they solved correctly and incorrectly.

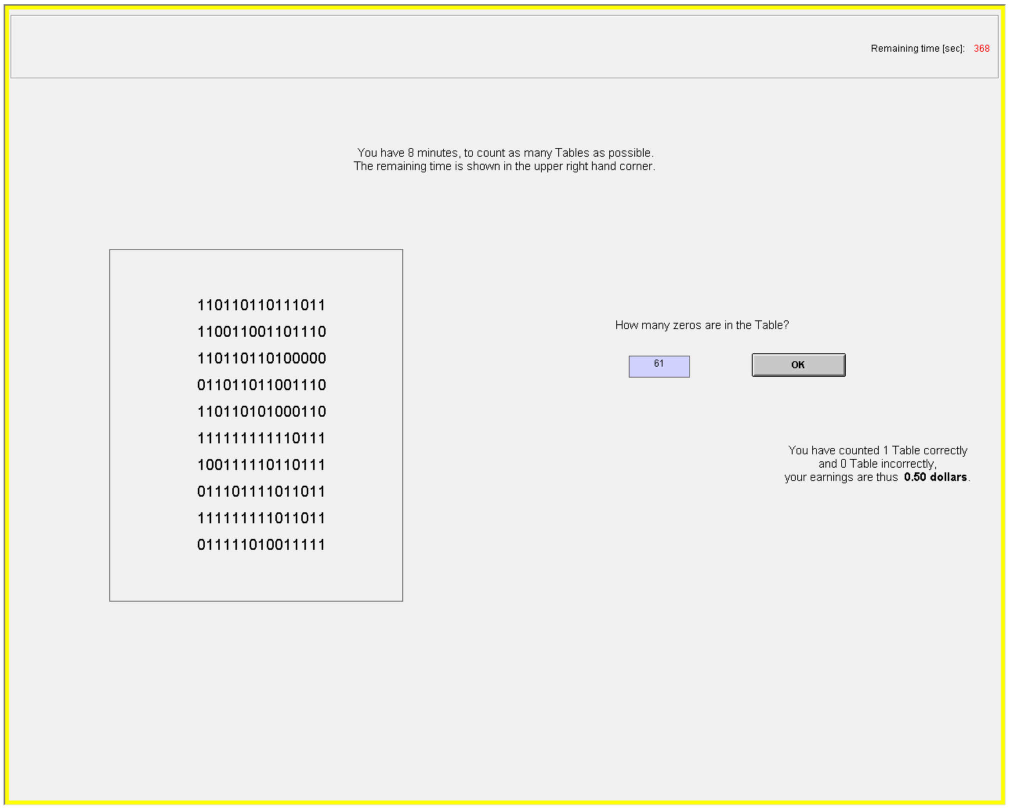

Figure 1.1: Screenshot of the First Stage Computer Screen

iment of Abeler et al. [2011]. Afterwards, they fill out a questionnaire about background information and are asked again about their tiredness level on the same five point Borg scale as before in the first stage Borg [1962, 1990]. The difference between this measure and the previous reflects how subjects' tiredness has changed as a result of the effort expended during the first stage.

Half of the subjects from both H_L and H_H treatments are selected randomly and assigned to treatment E_L and E_H. I denote the treatment combinations by (H_i, E_j), where $i, j \in \{L, H\}$.

Before beginning the second stage, subjects are presented with a computer screen that summarizes their performance and earnings from the first stage. The screen displays the number of tables that were correctly solved, the number of tables where the number of zeros were entered three times incorrectly, and "Your earnings from the first stage: $x\overline{w} - y\overline{w} = m_1$", where the number of tables that were correctly solved is substituted to x, the number of tables that were solved incorrectly is substituted for y, the first stage piece rate is substituted for $\overline{w}$ and their overall earnings from the first stage is substituted for m_1.

The task at the second stage is the same as that of the first stage but with two main differences. First, subjects decide how much they want to work and for how long, and they have a maximum of 60 minutes available at this stage. Whenever a subject wants to finish the experiment, she simply has to push a button on the screen and then the second stage of the experiment is finished for her; and she can continue and finish the experiment by filling out a short questionnaire. Afterwards, she is paid and she can leave the lab. Therefore, the earlier she finishes the second stage, the earlier she can leave. Second, subjects don't receive their accumulated earnings from this stage with certainty. Their earnings are determined by a method is similar to the one in the paper of Abeler et al. [2011]. Before starting the second stage, subjects choose an envelope out of two that contains a card with either "Acquired earnings" or a card with "f dollars". Subjects know this and the value of f before choosing the envelope, so they are aware that they have a 50% chance of choosing either envelope. After choosing, however, they can not open the envelope until the end of the second stage, of which they are also aware. Subjects' payment is determined at the end of the second stage after she opens the envelope.

The rational expectations of subjects regarding earnings at the moment of deciding whether to continue working or stop depends on the 50% probability that she will either receive her acquired earnings we or the 50% probability that – that she would receive the fixed f payment. Because uncertainty is not resolved until the end of the second stage, the subject's rational expectation can be varied exogenously by changing the amount of the fixed f payment. The two treatments, E_L and E_H only differ from each other in the fixed payment. Subjects at E_L receive $f = \$3$ and subjects at E_H receive $f = \$7$; when they chose the envelope, the fixed amounts of either "3 dollars" or "7 dollars", respectively, are printed on cards in the envelope, depending on the treatment.

The piece rate per correct table is **$0.2** for all the subjects during the second stage. This means that for H_L subjects, the piece rate is the same during the second stage as it is during the first stage, but for H_H subjects the **$0.2** piece rate in the second stage is lower than the **$0.5** piece rate that they obtain during the first stage. The main innovation of the paper is that it adds these treatments over history-based reference points on top of the treatments of Abeler et al. [2011], which influences the rational expectations about earnings. Subjects at treatment H_H with a previous piece rate of **$0.5** arrive to the second stage with the experience of having earned **$0.5** but they now earn a smaller **$0.2** s piece wage rate for the same task. Subjects in H_H earn more than subjects in H_L during the first stage as a result of the higher piece rate. If subjects have reference-dependence over earnings level of the first stage $\overline{we}$ then because of the different earnings in the first stage subjects in H_H on average have higher history-based reference points than subjects in H_L; this could influence their behavior during the second stage. On average, the difference between the first stage earnings (See Table 1.4 on page 35) of the two treatments is approximately \$2.93 (4.86 – 1.93 = 2.93), assuming that subjects exert effort during the **8** minutes of the first stage similarly to subjects in the first stage of Abeler et al. [2011]. On average, subjects needed 48 seconds to count the number of zeros correctly in a table at the first stage of their experiment.

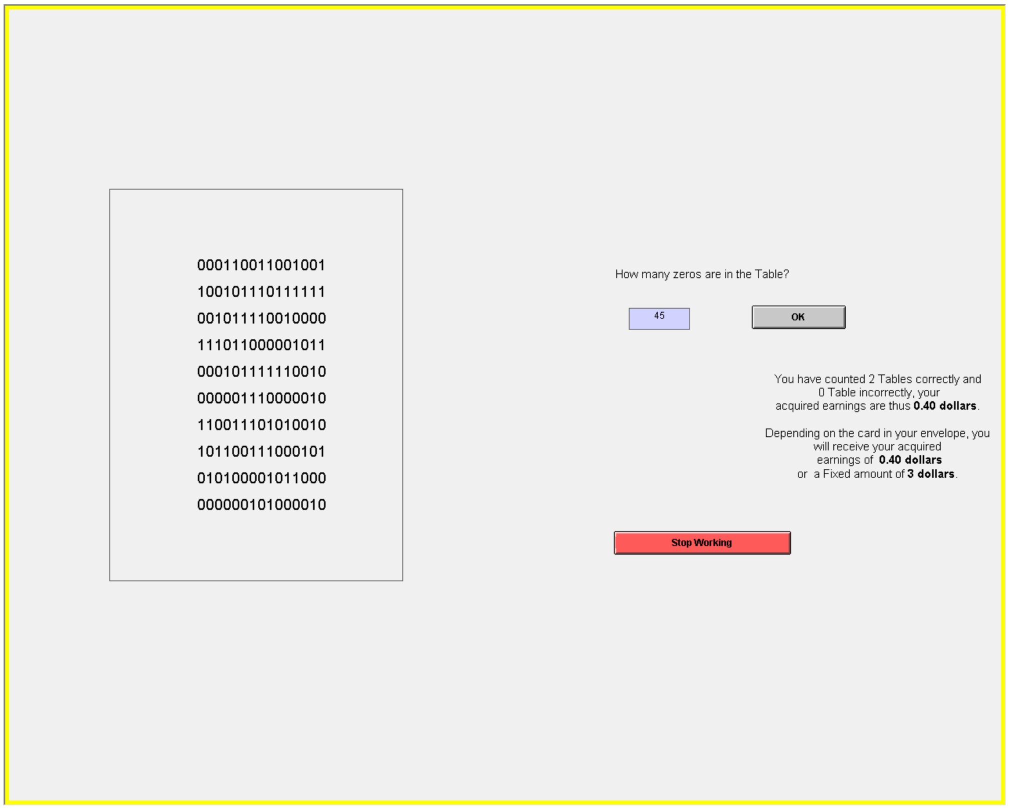

Figure 1.2: Screenshot of the Second Stage Computer Screen

After the second stage, subjects are given survey questionnaires. Similar to Abeler et al. [2011], subjects are asked to describe the reasons for their stopping decision. They are also presented with six choice situations. At each choice, they can either choose to receive $ 0 for sure or enter a lottery in which they have a 50% probability that they win $6 or that they receive Y, where Y varies choice by choice between -2 to -7 dollars. One of the six decisions is selected randomly and depending on the decision of the subject, either $ 0 or the result of the lottery is paid out. Abeler et al. [2011] use the number of lotteries that a subject rejects as a proxy for the individual's degree of loss aversion for their analysis. They cite previous studies (Fehr and Goette [2007], Gachter et al. [2010]) to show that similar measures predict loss-averse behavior in terms of labor supply or strength of the endowment effect. Additionally, subjects are asked about their motivations to exercise effort, whether their motivation changed compared to the first stage and, if so, whether it decreased or increased. Furthermore, they are also asked about the reason of change of motivation. They have to select the two most likely reasons out of six options: "(a) uncertainty of payment, (b) I felt tired, (c) piece wage rate seemed less motivating in the second stage, (d) the task was boring, (e) the piece wage rate seemed unfair, or (f) other: (please specify)".

In each treatment (H_i, E_j) there are 70 subjects, thus, altogether the experiment consist of $4 * 70 = 280$ subjects. No subject participated in more than one treatment. Subjects were students from Cornell University from various majors who had not taken any class in Behavioral Economics. Experiments were computerized using the software z-Tree of Fischbacher [2007]. Subjects receive a **8** dollars show up fee in addition to their earnings during the two stages. The experiment took about 90 minutes including the questionnaires and the instructions.

1.3 Setup for the Theoretical Analysis

This and the next sections propose models that capture how outcomes from the past can influence labor supply decisions. The goal is to derive predictions that can be tested in the experiment or on observational data. The basic setup of the model is closely linked to experiment and to the paper of Abeler et al. [2011]. The authors designed a novel real-effort experiment in which they are able to vary the subjects' expectations exogenously, and to show that these expectations serve as reference points and can influence effort provision. The experiment introduces an exogenous variation on past experiences of the piece wage rate to the experimental design of Abeler et al. [2011]. As a result, there is an exogenous variation of past piece wage rates that can serve potentially as an additional (history-based) reference point for the subjects' decisions regarding effort provision. Having exogenous variation over both expectations and past experience, the effect of the two potential reference points can be studied and separated from each other.

The world has two periods (stages), but the agent does not know anything about the second period from the the first period's perspective. She cannot maximize her lifetime utility from the first period perspective, thus she makes decisions in the first period independently from the second period. In each period the agent decides how much to work, she performs a task for which she receives financial compensation. The main output variable in the model is the effort exercised by the agent (subjects in the experiment) in the second period. Effort in the second period is denoted by e and it is measured in the experiment by the number of tables in which, the subject calculates the number of zeros correctly. Effort in the first period is denoted by $\overline{e}$. The agent receives $\overline{w}$ piece rate for each task that she solves correctly, thus, her earnings from the first period equals $\overline{we}$. The agent solves the same task at the second period but there is a difference in the compensation structure. At the second period the agent either receives a fixed payment f with probability $\frac{1}{2}$ or the accumulated earnings with probability $\frac{1}{2}$. Accumulated earnings depend on how many tasks she solves correctly in the second period and the piece rate in the second period. Therefore, accumulated earnings in the second period equals we, where $w > 0$ is the piece rate wage that she receives with probability $\frac{1}{2}$.

Assumption 1. *Consumption utility function of the agent is a standard separable utility function $U(m, e) = u(m) - c(e)$ in money and effort.*

I assume that the consumption utility function of the agent is a standard separable utility function $U(m, e) = u(m) - c(e)$ in money and effort, where m is money (in this setup $m = we$), $c(e)$ is the subject's cost of effort with $c'(.) > 0$, $c''(.) > 0$. This is the main assumption of the model, all the predictions of the model rely on this assumption.

Assumption 2. *The consumption utility is linear in money in the model and takes the following form $u(m) = \phi m$.*

The outcomes in the experiment are not very large, thus, I further simplify the model and assume the consumption utility to be linear in money $u(m) = \phi m$. For all models of the paper except one I assume $\phi = 1$.

Table 1.1 (on page 8) illustrates the actual parameters of the model that are used in the experiment. The models in this chapter generate predictions for this set of parameters. Namely, the predictions compare the effect of the different piece wages in the first period (H_L and H_H) and the effect of the different fixed amounts f in the second period (E_L and E_H). The predictions of the model focus on the variables in the second period.

1.4 Predictions: Standard Model

Using the notations and assumptions outlined in the previous section, the decision problem of a standard agent can be described by the following maximization problem

$$\max_e \frac{we+f}{2} - c(e),$$

where the choice variable is e the effort level in the second period. Furthermore, I assume that she maximizes her expected utility and choose her effort level optimally. In order to solve the maximization problem, I derive the first order condition corresponding to the problem

$$\frac{w}{2} - c'(e) = 0.$$

From the first order condition I can derive the first hypothesis that illustrates the optimal effort level for the standard agent.

Hypothesis 1. *The standard agent's optimal effort level is independent of the fixed f payment, and also independent of the $\overline{w}$ piece wage rate.*

The optimal effort level for the standard agent only depends on the piece wage rate in the second period and her effort cost function. Since the optimal effort level does not depend on the fixed amount or the piece wage rate in the first period, the agent exercises the same effort level in the low history, high history, low expectation and high expectation treatments. This prediction can be tested on the data from the experiment.

Furthermore, it is simple to modify this setting and assume a general concave $u(m)$ utility function over money, in which case an income effect from the first period would change the above prediction. In this model, the agent's problem in the second period is to maximize his utility depending on the effort level of the second period. With a nonlinear utility over money the first period's earnings would enter the second period's utility maximization problem influencing the optimal effort level. The higher piece rate in the first period results in a higher earnings at the end of the first period. This would have an income effect on the the optimal effort level in the second period. The income effect implies a lower optimal effort level when the piece rate is higher in the first period (as in the high history treatment). This would predict a lower optimal effort level for the agent in the high history (H_H) treatment compared to the low history (H_L) treatment.

1.5 Predictions: Standard Model with Changing Marginal Utility of Money

This section extends the standard model with changing marginal utility of money. I assume that the experience of having different piece wage rate influences the agent's marginal utility of money. The marginal utility of money goes down after the agent experienced a drop in piece wage rate, while if the piece wage rate increases then her marginal utility of money goes up. An agent in the high history treatment experiences a drop in the piece wage rate. This influences her optimal effort choice through the changing marginal utility of money. The agent's utility function of money takes the following form

$$u(m) = \begin{cases} \phi(w, w^r)we - c(e), & \text{if } m = we \\ f - c(e) & \text{if } m = f \end{cases},$$

where w is the current, second period piece wage rate, w^r is the piece wage rate that the agent uses for comparison, in this framework the agent uses the piece wage rate from the first period$w^r = \overline{w}$, $\phi(w, w^r)$ is the term that changes the marginal utility of money; $\phi(w, w^r) < 1$ if $w < w^r$, $\phi(w, w^r) = 1$ if $w = w^r$, and

$\phi(w, w^r) > 1$ if $w > w^r$. The last term captures the change in the marginal utility of money when the agent faces a change in piece wage rate.

The agent chooses the optimal effort level by maximizing her expected utility in the second period, which takes the following form

$$\max_e \frac{\phi(w, w^r)we - c(e)}{2} + \frac{f - c(e)}{2}.$$

This maximization problem has a solution, and the first order condition for the solution can be written as

$$\frac{1}{2}\phi(w, w^r)w - c(e) = 0.$$

There are two cases depending on which history treatment the agent encounters. An agent in the low history treatment (H_L) has the same piece wage rate in both periods, thus $w = w^r = \overline{w}$ which yields the same first order condition $\frac{w}{2} - c'(e) = 0$, and thus same optimal effort level as the standard agent has. An agent in the high history treatment experiences a drop in the piece wage rate since $w < w^r = \overline{w}$, which yields the $\frac{1}{2}\phi(w, w^r)w - c(e) = 0$ first order condition, where $\phi(w, w^r) < 1$. Comparing this first order condition with the one for the standard agent, it follows that the optimal effort level e is lower for an agent in the low history treatment.

Hypothesis 2. *The optimal effort level for a standard agent with changing marginal utility of money is independent of the fixed f payment, but it does depend on the $\overline{w}$ piece wage rate from the first period. The optimal effort level is lower for an agent in the high history (H_H) treatment compared to the agent in the low history (H_L) treatment.*

1.6 Predictions: History-based Reference Dependence Over Past Earnings

This section developes a model to incorporate a history-based reference point based on the model of Abeler et al. [2011] . The model takes the Koszegi and Rabin [2006] approach to incorporate expectations as a reference points by assuming that the agent has reference-dependence gain-loss utility over the subjects' rational expectations. Beyond expectations, this model also assumes that the agent has reference points over past earnings $\overline{we}$, where $\overline{w}$ is the past piece rate and $\overline{e}$ is the past effort level.

Assumption 3. *The gain-loss utility function is separable in money and effort dimensions and tied directly to the consumption utility as in Koszegi and Rabin [2006].*

Furthermore, I make the following assumption.

Assumption 4. *There is a common linear gain-loss utility function $\mu(x)$ which is used to evaluate outcomes c to a reference bundle r for both reference points across both dimensions.*

Lastly, following Koszegi and Rabin [2006] I assume the following:

Assumption 5. *The gain-loss function is piece-wise linear $\mu(x) = \eta x$ for $x \geq 0$ and $\mu(x) = \eta\lambda x$ for $x < 0$, where $\eta > 0$, $\lambda > 1$ and x is the difference in utility of an outcome with respect to the reference bundle.*

The loss-aversion (i.e., losses loom larger than equal-sized gains) is expressed by the parameter $\lambda > 1$.

The total utility of the person is the sum of her consumption utility, the gain-loss utility over her expectation about possible earnings, and a second gain-loss utility term over the past earnings $\overline{we}$ as a history-based reference point.

Following Abeler et al. [2011], I assume that the first gain-loss utility term depends on the subjects' rational expectations about possible earnings. These expectations hold before the uncertainty is resolved, because subjects can not open the envelope until the end of the second stage when they have already decided on effort provision. Therefore, the piece rate earning w and the fixed payment f of the second stage determine the reference point over expectations.

The second gain-loss utility term depends both on subjects' potential earnings we and fixed payment f and her past piece rate $\overline{w}$ and past effort level $\overline{e}$. It captures the gain-loss feeling due to lower earnings than the past earnings level. Subjects facing a lower piece rate in the first stage have lower first stage earnings, because the effort level is similar during the first stage. I assume, for simplicity, that the agent's history-based reference point is her past earnings level $\overline{we}$), but this does not depend on the stochastic feature of the payment scheme.[3] Therefore, with 50% probability the agent receives her actual earnings we, which might feel like a gain or loss compared to the certain reference point of her past earnings level. And with 50% probability, she receives the fixed f payment. I do not discuss separately the cases depending on whether the fixed payment f is below or above her reference point of past earnings level because that term only contains parameters and predetermined variables; the term drops out during differentiation and does not affect the interior solution for the optimal effort level.

[3]Without this simplifying assumption the two terms would have 1/4 constant instead of the 1/2 constant, and there would be a third term, however, overall it would not change the predictions qualitatively.

I analyze the model's first order conditions to derive comparative static results which help to generate predictions for the behavior of agents across the different treatments.

The setting of the model is similar to the model of Abeler et al. [2011] except that there is an additional, history-based, reference point: past earnings $\overline{we}$, where $\overline{w}$ is the past piece rate and $\overline{e}$ is the past effort. As before, I assume that the piece rate is lower at the second stage than at the first stage $w < \overline{w}$, therefore there are four different cases to analyze.

In the first case (a) I assume that the subject intends to stop at an accumulated earnings level which is below the fixed payment $we < f$ and the current earnings level is smaller than her reference earnings level $we < \overline{we}$ then her expected utility is given by

$$U = \frac{we + f}{2} + \frac{1}{2}\left[\frac{1}{2}\eta(we - we) + \frac{1}{2}\eta\lambda(we - f)\right] + \frac{1}{2}\left[\frac{1}{2}\eta(f - we) + \frac{1}{2}\eta(f - f)\right]$$
$$+\frac{1}{2}\eta\lambda(we - \overline{we}) + \frac{1}{2}(\eta\mathbb{1}_{f\geq\overline{we}} + \eta\lambda\mathbb{1}_{f<\overline{we}})(f - \overline{we}) - c(e)$$

that can be simplified to the following form of the utility function

$$U = \frac{we + f}{2} + \underbrace{\frac{1}{4}(\eta\lambda(we - f)) + \frac{1}{4}(\eta(f - we))}_{\text{expectation ref. dependence}} \tag{1.6.1}$$
$$+\underbrace{\frac{1}{2}\eta\lambda(we - \overline{we}) + \frac{1}{2}(\eta\mathbb{1}_{f\geq\overline{we}} + \eta\lambda\mathbb{1}_{f<\overline{we}})(f - \overline{we})}_{\text{history-based ref. dependence}} - c(e),$$

where the expectation ref. dependence term is the standard gain-loss utility of Koszegi and Rabin [2006] and the history-based ref. dependence term expresses the gain-loss feeling, because earnings are lower than the past earnings. I assume, for simplicity, that the agent's status-quo reference point is her potential earning level $\overline{we}$) but does not depend on the stochastic feature of the payment scheme.[4] Therefore, with 50% probability the agent receives her actual earnings we which feels like a loss compared to the certain reference point of her past earnings level. And with 50% probability she receives the fixed f payment. I do not separately discuss the cases depending on whether the fixed payment f is below or above her reference point of past earnings level because that term only contains parameters and predetermined variables, it drops out during differentiation and does not affect the interior solution for optimal effort level.

Therefore, the first order condition is the following

$$\frac{\partial U}{\partial e} = \frac{w}{2} + \underbrace{\frac{1}{4}\eta\lambda w - \frac{1}{4}\eta w}_{\kappa_a} + \underbrace{\frac{1}{2}\eta\lambda w}_{\Omega_a} - c'(e) = 0, \tag{1.6.2}$$

where $\Omega_a > 0$ term is the change of the marginal utility due to the history-based reference dependence and loss-aversion. Compared to an agent without history-based reference point the agent's incentives to exercise effort is increased because of the additive positive $\Omega_a > 0$ term.

Secondly, in the next case (b) I study the situation when the subject intends to stop at an accumulated earnings level which is below the fixed payment $we < f$ and the current earnings level is greater or equal than her reference earnings level $we \geq \overline{we}$ then her expected utility is given by

$$U = \frac{we + f}{2} + \underbrace{\frac{1}{4}(\eta\lambda(we - f)) + \frac{1}{4}(\eta(f - we))}_{\text{expectation ref. dependence}} \tag{1.6.3}$$

$$+ \underbrace{\frac{1}{2}\eta(we - \overline{we}) + \frac{1}{2}(\eta\mathbb{1}_{f \geq \overline{we}} + \eta\lambda\mathbb{1}_{f < \overline{we}})(f - \overline{we})}_{\text{history-based ref. dependence}} - c(e).$$

[4]Without this simplifying assumption the two terms would have 1/4 constant instead of the 1/2 and there would be a third term, however overall it would not change the predictions qualitatively.

The term is almost identical to the expression in case (a) except fourth term where there is no λ parameter since the current earning level is above the reference point, thus the term is just $\frac{1}{2}\eta(we - \overline{we})$.

The first order condition is also almost identical as before with the change in the third term where there is no λ, thus the first order condition is

$$\frac{\partial U}{\partial e} = \frac{w}{2} + \underbrace{\frac{1}{4}\eta\lambda w - \frac{1}{4}\eta w}_{\kappa_a} + \underbrace{\frac{1}{2}\eta w}_{\Omega_b} - c'(e) = 0, \tag{1.6.4}$$

where $\Omega_b > 0$ term is the change of the marginal utility due to history-based reference dependence and loss-aversion. Compared to an agent without history-based reference point the agent's incentives to exercise effort is increased because of the additive positive $\Omega_b > 0$ term, however it is smaller overall than in case (a) where the $\lambda > 1$ loss-aversion parameter further pushes the incentives upwards.

Section A.1 (on page 88 of the Appendix) deals with the last two cases; when the the agent intends to stop at an accumulated earnings level above the fixed payment $we \geq f$. In those cases the history-based reference points have the same effect as in case (a) and case (b) depending whether the reference earnings are above or below the accumulated earnings. The main difference comes from the loss-aversion over the expectation reference points similarly to the previous section.

In all four cases the expectation-based reference dependence part of the utility function is identical to the model of Abeler et al. [2011]. This implies the next two hypothesis about the effect of the fixed amount f (low versus high expectation treatments) on the optimal effort level in the second period.

Hypothesis 3. *The average effort expended by subjects in the E_H treatment is higher* *than the average effort expended by subjects in the E_L treatment.*

Hypothesis 4. *The probability that subjects stop work at $we = f_L$ is higher in the E_L treatment than in the E_H treatment, and the probability that subjects stop work at $we = F_H$ is higher in E_H than in E_L.*

These two hypotheses are identical to Hypothesis 1 and Hypothesis 2 of the paper of Abeler et al. [2011]. Their logic follows through directly, because the gain-loss utility of the expectation terms in this model is the same as in their model. Comparing κ_a to κ_b and κ_c, it follows that the marginal returns to effort are higher when the accumulated earnings are below f than when they are above f. Therefore, gain-loss utility over the expectations reference point creates an additional incentive to exert effort when below the fixed payment amount. Thus, when increasing the amount of the fixed payment, average effort increases since the marginal return to effort remains higher up to a higher effort level. The gain-loss utility over expectations creates incentives for the agent to exercise as much effort that her acquired earnings are around the fixed payment level, because above f there is a drop in the incentives to exercise effort.

Furthermore, because of the loss-aversion $\lambda > 1$ around the history-based reference point, the incentives for exercising effort is greater when the subject's accumulated earning is below her past earnings than when her accumulated earning is above her past earnings (which functions as a second reference point).

Hypothesis 5. *The average effort level of subjects during the second stage is higher in the H_H (high history) treatment than in the H_L (low history) treatment.*

This prediction captures the intuition that the incentive for exercising effort is greater when the subject's accumulated earnings are below her reference point over past earnings than when her accumulated earnings are above her reference point. This is the case, because there is a kink in preferences due to the loss aversion $\lambda > 1$ around past earnings. Subjects in H_H treatment have on average higher first stage earnings than subjects in H_L treatment.

1.7 Predictions: History-based Reference Dependence Over Past Piece Rate

This section develops another model of history-based reference points by extending the model of Abeler et al. [2011] to incorporate a history-based reference point over the past piece rate.

As in the previous section, I follow the models of Abeler et al. [2011] and Koszegi and Rabin [2006] to incorporate reference-dependence gain-loss utility over the subjects rational expectations as reference point. I extend their model by assuming that subjects also have reference points over past wage rates denoted by $\overline{w}$ which changes the marginal returns of effort.

I make the same assumptions about the general form of the gain loss utility function as in the previous section 1.6: gain-loss utility function is separable in money and effort dimensions, it is tied directly to the consumption utility, there is a common linear gain-loss utility function, and the gain-loss function is piece-wise linear.

The overall utility of an agent is the sum of her consumption utility, the gain-loss utility over her expectation about possible earnings, and a second gain-loss utility term over the past piece rate $\overline{w}$ as a history-based reference point. Following Abeler et al. [2011], I assume that the first gain-loss utility term depends on subjects' rational expectations about possible earnings. These expectations hold before the uncertainty is resolved since subjects cannot open the envelope until the end of the second stage when they have already decided on effort provision.

The second gain-loss utility term depends both on subjects' potential earnings we and fixed payment f and her past piece rate $\overline{w}$. It captures subjects' potential loss feeling related to the decreased piece rate since $\overline{w} = 30 > 20 = w$ in cents. When a subject faces a lower piece rate, the feeling that she could have reached higher earnings $\overline{w}e$ with the past piece rate results in additional feeling of loss. Furthermore, I assume the loss feeling comes from the lower piece rate over the history-based reference piece rate and subjects do not take into account in their history-based reference point that even if they had the higher $\overline{w}$ piece rate they would have a 50% probability that they would receive the fixed f payment. Therefore, I assume that the agent's history-based reference point is around the certain potential earning level $\overline{w}e$ given the past piece rate – the amount she would have earned under the first stage's piece rate.[5] Since consumption utility is separable across money and effort dimensions, effort does not enter the gain-loss utility.

Following Abeler et al. [2011], I analyze the model's first order conditions in order to derive comparative static results which help to generate predictions for behavioral between treatments.

There are three cases that have to be considered for characterizing the optimal effort choice of loss-averse agents.

[5]Adding the uncertainty to the agent's history-based reference point does not change the predictions of the model qualitatively, although the effects of the decreased piece rate become smaller.

Firstly, in the case (a) I study the situation when the subject intends to stop at an accumulated earnings level which is below the fixed payment $we < f$ and the current piece rate is smaller than her reference piece rate $w < \overline{w}$ (therefore $we < \overline{w}e$ and the subject s accumulated earnings under the reference piece rate is below the fixed payment $\overline{w}e < f$ then her expected utility is given by

$$U = \frac{we+f}{2} + \frac{1}{2}\left[\frac{1}{2}\eta(we-we) + \frac{1}{2}\eta\lambda(we-f)\right] + \frac{1}{2}\left[\frac{1}{2}\eta(f-we) + \frac{1}{2}\eta(f-f)\right]$$
$$+\frac{1}{2}\eta\lambda(we-\overline{w}e) + \frac{1}{2}\eta\lambda(f-\overline{w}e) - c(e).$$

This simplifies to

$$U = \frac{we+f}{2} + \underbrace{\frac{1}{4}(\eta\lambda(we-f)) + \frac{1}{4}(\eta(f-we))}_{\text{expecation ref. dependence}} + \underbrace{\frac{1}{2}\eta\lambda(we-\overline{w}e) + \frac{1}{2}\eta(f-\overline{w}e)}_{\text{history-based ref. dependence}} - c(e),$$

where the expectation ref. dependence term is the standard gain-loss utility of Koszegi and Rabin [2006] over expectations as reference points, while the history-based ref. dependence term expresses the gain-loss feeling of subjects due to the decreased piece rate. I assume that the agent's history-based reference point is her potential earning under the past piece rate $\overline{w}e$).[6] Therefore, with 50% probability the agent receives her actual earnings we which feels like a loss compared to the certain reference point of her potential earning under the past piece wage rate. And with 50% probability she receives the fixed f payment which is an actual gain compared to her potential earning level $\overline{w}e$ under the past piece rate.

The first order condition is

$$\frac{\partial U}{\partial e} = \frac{w}{2} + \underbrace{\frac{1}{4}\eta\lambda w - \frac{1}{4}\eta w}_{\kappa_a} + \underbrace{\frac{1}{2}\eta\lambda(w-\overline{w}) - \frac{1}{2}\eta\overline{w}}_{\Theta_a} - c'(e) = 0, \tag{1.7.1}$$

[6] Without this simplifying assumption the two terms would have 1/4 constant instead of the 1/2 and there would be a third term, however overall it would not change the predictions qualitatively.

where Θ_a term is the change of the marginal utility due to the history-based loss-aversion. Since the current piece rate is smaller than the agent's reference piece rate she feels an additional loss which pushes her incentives downward to exercise effort $\Theta_a < 0$ since it is a sum of two negative terms because of $w < \overline{w}$.

Secondly, in the next case (b) I study the situation when the subject intends to stop at an accumulated earnings level which is below the fixed payment $we < f$ and the current piece rate is smaller than her reference piece rate $w < \overline{w}$ (therefore $we < \overline{w}e$ and the subject s accumulated earnings under the reference piece rate is above the fixed payment $\overline{w}e \geq f$ then her expected utility is given by

$$U = \frac{we + f}{2} + \underbrace{\frac{1}{4}(\eta\lambda(we - f)) + \frac{1}{4}(\eta(f - we))}_{\text{expectation ref. dependence}} + \underbrace{\frac{1}{2}\eta\lambda(we - \overline{w}e) + \frac{1}{2}\eta\lambda(f - \overline{w}e)}_{\text{history-based ref. dependence}} - c(e).$$

The first order condition is

$$\frac{\partial U}{\partial e} = \frac{w}{2} + \underbrace{\frac{1}{4}\eta\lambda w - \frac{1}{4}\eta w}_{\kappa_b} + \underbrace{\frac{1}{2}\eta\lambda(w - \overline{w}) - \frac{1}{2}\eta\lambda\overline{w}}_{\Theta_b} - c'(e) = 0, \qquad (1.7.2)$$

where Θ_b term is the change of the marginal utility due to history-based loss-aversion. Since the current piece rate is smaller than the agent's reference piece rate she feels an additional loss which pushes her incentives downward to exercise effort $\Theta_b < 0$ since it is a sum of two negative terms because of $w < \overline{w}$, where the interpretation of the two gain-loss terms is similar to case (a).

Thirdly, in the next case (c) I study the situation when the subject intends to stop at an accumulated earnings level which is above the fixed payment $we \geq f$ and the current piece rate is smaller than her reference piece rate $w < \overline{w}$, then it follows that $f \leq we < \overline{w}e$ the subject's accumulated earnings under the reference piece rate is above current acquired earning which is above the fixed payment and her expected utility is given by

$$U = \frac{we+f}{2} + \underbrace{\frac{1}{4}(\eta(we-f)) + \frac{1}{4}(\eta\lambda(f-we))}_{\text{expectation ref. dependence}} + \underbrace{\frac{1}{2}\eta\lambda(we-\overline{w}e) + \frac{1}{2}\eta\lambda(f-\overline{w}e)}_{\text{history-based ref. dependence}} - c(e),$$

where the interpretation of the two gain-loss terms is similar to case (a).

The first order condition is

$$\frac{\partial U}{\partial e} = \frac{w}{2} + \underbrace{\frac{1}{4}\eta w - \frac{1}{4}\eta\lambda w}_{\kappa_c} + \underbrace{\frac{1}{2}\eta\lambda(w-\overline{w}) - \frac{1}{2}\eta\lambda\overline{w}}_{\Theta_c} - c'(e) = 0, \tag{1.7.3}$$

where Θ_c term is the change of the marginal utility due to history-based loss-aversion. Since the current piece rate is smaller than the agent's reference piece rate she feels an additional loss which pushes her incentives downward to exercise effort $\Theta_c < 0$ since it is a sum of two negative terms because of $w < \overline{w}$.

Hypothesis 6. *Hypothesis Average effort in the E_H treatment is higher than in the E_L treatment.*

Hypothesis 7. *The probability of stopping at $we = f_L$ is higher in the E_L treatment than in the E_H treatment, the probability of stopping at $we = F_H$ is higher in E_H than in E_L.*

The first two hypotheses are the same as Hypothesis 1 and Hypothesis 2 of Abeler et al. [2011] and their logic carries through directly since the gain-loss utility of the expectation terms in this model is the same as in their model. Comparing κ_a to κ_b and κ_c, it follows that the marginal returns to effort are higher when the accumulated earnings are below f than when they are above f. Therefore, gain-loss utility over the expectations reference point creates an additional incentive to exert effort when below the fixed payment amount. Thus, when increasing the amount of the fixed payment, average effort increases since the marginal return to effort remains higher up to a higher effort level. The gain-loss utility over the expectations as reference point creates incentives for the agent to exercise as much effort that her acquired earnings are around the fixed payment level, since above f there is a drop in the incentives to exercise effort. Abeler et al. [2011] also points out that the stronger the loss-aversion of subjects the larger fraction of subjects will stop at f.

Hypothesis 8. *The average effort in the H_L treatment is higher than in the H_H treatment.*

History-based reference dependence decreases the marginal return of effort in all three cases, $\Theta_a < 0$, $\Theta_b < 0$ and $\Theta_c < 0$ are all negative in the first-order conditions. The negative effect of history-based loss aversion for subjects who experienced a drop in piece rate (H_H) is always larger in absolute value than the effect for subjects whose current piece wage rate equals their past piece rate (subjects in the S_L treatment). This follows from comparing an agent' first order conditions from the H_H treatment and an agent from H_L, the Θs for the former agent is always larger in absolute value than for an agent in treatment H_L this can be seen if for getting the Θs for the subject at H_L , the $\overline{w} = w$ is substituted in.

1.8 Summary of the Models' Predictions

This section summarizes the main predictions of the different models presented in the previous sections. I propose various models to show that standard models do not make predictions that are in line with the results from the experiment. Furthermore, I present two feasible ways to incorporate the history-based reference point, but the data from the experiment shows that only one of the model can describe actual behavior of subjects.

Table 1.2 contains the summary of the predictions for the effects of the high history and high expectation treatments, respectively. Each row shows the predictions of the various models on the effect of the high history treatment on the average effort in the second stage (Hist. on Effort), the effect of the high expectation treatment on the average effort in the second stage (Exp. on Effort), and the effect of the high expectation treatment on the probability of stopping to work at $7.

Table 1.2: Models' Predictions

Model \Treatment	Hist. on Effort	Exp. on Effort	Exp. on Prob.
Standard	$\emptyset$	$\emptyset$	$\emptyset$
Changing Marginal Util.	$-$	$\emptyset$	$\emptyset$
Ref. Dep. Past Earnings	$+$	$+$	$+$
Ref. Dep. Past Wage	$-$	$+$	$+$

The standard model (in the first row) predicts that neither the high history nor the high expectation treatment has any effect on average effort level in the second stage. Furthermore, it predicts that the high expectation treatment has no effect on the probability of stopping.

The standard model with changing marginal utility (second row) has the same predictions for the effect of the high expectation treatment on average effort and on the probability of stopping as the standard model. However, this model's main prediction is average effort is lower in the high history treatment due to the changing marginal utility.

Both behavioral models with reference dependence make the same predictions about the effect of the high expectation treatment. First, average effort is higher for subjects in the high expectation treatment, this means that when the fixed amount is higher subjects work more. Second, the probability of stopping at $7 is higher in the high expectation treatment compared to the low expectation treatment, and the probability of stopping at $3 is higher in the low expectation treatment. The two models differ in the predictions they make about the effect of the high history treatment. The behavioral model with reference dependence over past earnings predicts, uniquely among these four models, that the average effort is higher for subjects in the high history treatment. On the other hand, the behavioral model with reference dependence over past wage predicts a negative effect of the high history treatment. Comparing these predictions with the actual effects of the history and expectation treatments on the data helps to select which model describes best subjects' behavior in the lab.

1.9 Results

Subjects were assigned randomly to low (H_L) and high history (H_H) treatments after the practice round. The randomization was successful; there is no significant difference between the demographic variables across the two treatments (Table 1.3) according to the non-parametric Mann-Whitney test[7]. Subjects solved correctly 9.73 tables in the low and 9.82 in the high history treatments during the first stage (Table 1.4). The differences are not statistically different from each other; the higher piece rate did not have an effect on the first stage

[7]A general reference for non-parametric tests (including the Mann-Whitney test) is the book by Conover [1999].

behavior of subjects. However, as a result of the higher piece rate ($0.5) of sub-

Table 1.3: Descriptive Statistics of Demographic Variables for the Low History and High History Treatments

History		Age	Female	Work
Low	Mean	20.31	0.59	0.59
	Std.dev.	2.11	0.49	0.49
High	Mean	20.59	0.74	0.64
	Std.dev.	1.65	0.44	0.48
Total	Mean	20.45	0.66	0.61
	Std.dev.	1.89	0.47	0.49

Notes: This table contains descriptive statistics (mean and standard deviation) by the history treatment. The first column (Age) contains these statistics for the age variable in years, the second (Female) for a dummy variable that is 1 if the subject is a female, and the third (Work) for a dummy variable that is 1 if the subject currently works for pay.

jects in the high history treatment, their average earnings are higher than the earnings of subjects in the low history treatment with a lower ($0.2) piece rate. Subjects' average earnings is $3.40 in the first stage. Subjects in the high history treatment (H_H) have average earnings of $4.86, while subjects in the low history treatment (H_L) have average earnings of $1.93. The difference in the first stage earnings is $2.93[8] and statistically significant according to the non-parametric

[8] Taking the difference between the high and low history treatment from the firs row of Table 1.4: $4.86 – $1.93 = $2.93.

Mann-Whitney test.

A standard model would either predict no effect for the second stage labor supply of subjects, or it would predict that subject in the high history treatment work less in the second stage because of the income effect. However, the model outlined in section 1.6 predicts that subjects in the high history treatment work more due to loss aversion and due to the higher history-based reference point. The other prediction of the model is that subjects in the high expectation (E_H) treatment work more in the second stage than subjects in the low expectation (E_L) treatment due to a higher expectation reference point. In this section, I test these predictions of the model from Section 1.6 on the effects of the history- and expectation-based reference points.

Table 1.4: Descriptive Statistics of First Stage Behavior for the Low History and High History Treatments

History		Earnings	Tables Solved	Tables Incorrectly Solved
Low	Mean	1.93	9.73	0.09
	Std.dev.	0.55	2.69	0.32
High	Mean	4.86	9.82	0.09
	Std.dev.	1.32	2.55	0.34
Total	Mean	3.40	9.78	0.09
	Std.dev.	1.78	2.61	0.33

Notes: This table contains the means and standard deviations of earnings ($), the number of correctly solved tables and the number of incorrectly solved tables in the first stage by the history treatment.

Figure 1.3 displays the distribution of acquired earnings[9] during the second

[9]By earnings I refer to acquired earnings that subjects accumulate during the second stage

stage for the low expectation treatment (E_L, top panel) and the high expectation treatment (E_H, bottom panel). The two histograms are significantly different from each other (Kolmogorov-Smirnov test with a p-value of 0.000), which indicates that subjects with \$7 in the envelope has a different distribution of acquired earnings than subjects with only \$3 in the envelope. Figure A.1 in the appendix displays the cumulative distribution of acquired earnings for the low and high expectation treatments. This graph suggests that earnings in the high expectation treatment stochastically dominates earnings in the low expectation treatment.

1.9.1 Result 1.

The first result supports Hypothesis 1.

Result 1. *Subjects in the high expectation (E_H) treatment (envelope with the* \$7*) work significantly more than subjects in the low expectation (E_L) treatment (envelope with the* \$3*). This result is identical to result 1 of Abeler et al. [2011].*

Subjects in the low expectation treatment stop working after accumulating \$6.03 on average, and subjects in the high expectation treatment stop on average at \$7.13 (See the last row of Table 1.5). The treatment difference of \$1.1 is positive and statistically significant (non-parametric Mann-Whitney U-test with a p-value of 0.016). The marginal effect compared to the low expectation treatment is 18.2%. To further examine the difference, I control for productivity, gender, temperature, and time of day controls in an OLS regression (See in Table 1.6). Column 1 of Table 1.6 contains the regression result on a simple linear

by solving tables.

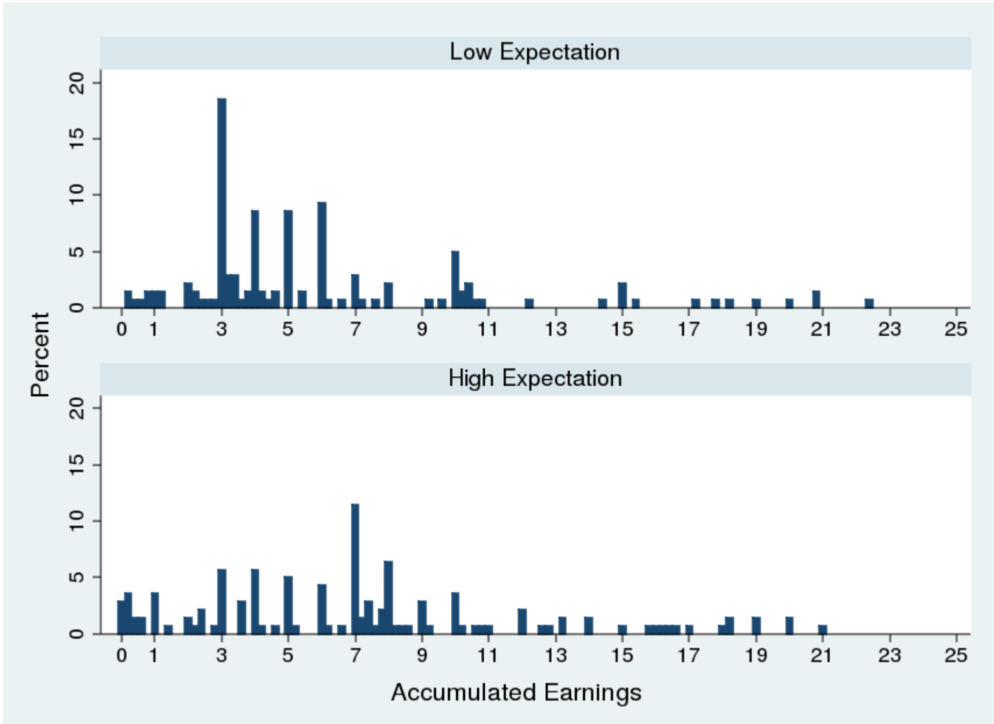

Figure 1.3: Histogram of Second Stage Accumulated Acquired Earnings (in $) at Which a Subject Stopped for Low Expectation and High Expectation Treatments

OLS model with acquired earnings as a left-hand side variable and a dummy for the high expectation treatment as a right hand side variable. The parameter estimate of the treatment dummy is 1.1, which is significant at 10% and in line with the difference in the averages between the treatments. Subjects in the high expectation treatment, on average, earn $1.1 more than subjects in the low expectation treatment. Column 2 contains the regression results of a model with controls. The parameter estimate of the treatment dummy 1.06, and it is similar to the one without controls and is also significant at 10%. The proxy variable for productivity is the time (in seconds multiplied by -1) that subjects needed to solve correctly a table during the practice round. Solving tables correctly during the practice round was not incentivized monetarily[10], thus, there were subjects

[10]During the practice round, subjects familiarize themselves with the task and they practice

Table 1.5: Summary of Second Stage Acquired Earnings for the Treatments

		History		
Expectation		Low	High	Total
Low	Mean	5.9	6.17	6.03
	Std.dev.	4.62	4.68	4.64
	N	70	70	140
High	Mean	6.81	7.45	7.13
	Std.dev.	5.29	4.74	5.01
	N	70	70	140
Total	Mean	6.35	6.81	6.58
	Std.dev.	4.97	4.74	4.85
	N	140	140	280

Notes: This table contains the mean, standard deviation and sample size of earnings (in $) for the history and expectation treatments.

who did not solve any table correctly. Therefore, these subjects do not have a valid productivity. Altogether, 24 subjects out of the 280 have no valid productivity; for them, I use the average productivity as a proxy for productivity. A subject, on average, needed 49.52 seconds to correctly solve a table during the practice round. The only significant control variable is productivity (with an estimate of 0.04). A subject with 1 second "higher" productivity (solved a table one second faster during the practice round) earns 4 cents more at the second stage. The parameter estimate of the female dummy is positive but not signifi-

it without any financial incentives.

cant statistically.

The standard errors for all models in Table 1.6 are estimated using the heteroscedasticity-consistent standard error estimator of White [1980].

Table 1.6: Treatment Difference in Effort (High Expectation Treatment Compared to Low Expectation Treatment

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	b/se	b/se	b/se	b/se	b/se	b/se	b/se	b/se
High Expectation Treatment	1.10*	1.06*	1.17	1.16	1.36**	1.35**	3.50*	3.47*
	(0.58)	(0.58)	(0.86)	(0.83)	(0.60)	(0.59)	(1.93)	(1.95)
Productivity		0.04***	0.05**	0.03		0.05***		0.07
		(0.02)	(0.02)	(0.02)		(0.02)		(0.05)
Female		0.14	-0.20	0.24		-0.32		0.37
		(0.65)	(0.93)	(0.98)		(0.69)		(2.17)
Controls for temperature	No	Yes	Yes	Yes	No	Yes	No	Yes
Controls for time of day	No	Yes	Yes	Yes	No	Yes	No	Yes
Constant	6.03***	8.09***	7.34***	8.45***	6.02***	8.58***	24.19***	26.91***
	(0.39)	(1.38)	(2.11)	(1.86)	(0.40)	(1.43)	(1.31)	(4.57)
Observations	280	280	140	140	256	256	280	280
R^2	0.013	0.048	0.065	0.042	0.020	0.068	0.012	0.022

Notes: Detailed notes are on page 105 of section A.4.1 of the Appendix.

Standard errors are in parentheses and estimated using the heteroscedasticity-consistent standard error estimator of White [1980].

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

Column 3 contains the same model with controls for the subset of subjects who were in the low history (H_L) treatment with a piece rate of 20 cents in the first stage. The parameter of the expectation treatment dummy is 1.17, similar to the estimates for the full sample, however, it is statistically insignificant. Column 4 contains the estimates for the subset of subjects in the high history treatment with an estimate of 1.16 on the high expectation treatment dummy that is not statistically significant.[11]

1.9.2 Robustness checks on Result 1.

Columns 5 – 6 of Table 1.6 contain the same models as columns 1 – 2, but the models are estimated on the full sample without the 24 subjects who did not have a valid productivity because they did not solve any table correctly during the practice round. The parameter estimates on the high expectation treatment dummy is 1.36 without controls and 1.35 with controls. The parameters are significant at the 5% level in both models. Subjects in the high expectation treatment earn $1.36 more than subjects in the low expectation treatment. This is a 22.6% increase in average earnings compared to the $6.02 average earnings of subjects in the low expectation treatment. Result 1 is robust to dropping subjects without valid productivity and, as a result, the effect of the expectation treatment becomes larger.[12]

Another way to measure effort is using the time spent in the second stage of the experiment. Therefore, I use this variable as an alternative measure of effort as in Abeler et al. [2011]. Subjects in the low expectation treatment work for 24.19 minutes on average, while subjects in the high expectation treatment

[11]Table A.1 at page 92 of Appendix contains the estimation results of the models with and without controls for the full sample, the high history, and low history subsamples. The results on the subsamples are similar without the controls.

[12]Table A.4 at page 95 of Appendix contains the estimation results of the models with and without controls for the full sample, the high history, and low history subsamples after dropping the 24 subjects without valid productivity. The results on the subsamples are also robust to dropping these subjects.

work for 27.69 minutes. The difference of 3.5 minutes between the two treatments is statistically significant (non-parametric Mann-Whitney U-test with a p-value of 0.023). Subjects in the high expectation treatment work on average for 3.5 minutes longer than subjects in the low expectation treatment, a marginal effect of 14.5%. Column 7 of Table 1.6 contains the OLS regression results of linear models with the high expectation treatment dummy as dependent variable. Column 8 contains the OLS regression results with additional controls. The parameter estimate on the high expectation dummy is 3.47 when controls for subject's gender, the time of the day and the temperature of the day are added. The OLS estimates on the treatment dummy are significantly different from zero at the 10% significance level. Table A.3 (on page 94 of the Appendix) contains the regression results of Tobit models which takes into account censoring; the time spent in the second stage is censored from below at 0 and from above at 60, because subjects could work for up to an hour. The effect of the high expectation treatment is similar, and also significantly different from zero at the 10% significance level.[13] The results on the effects of the expectation reference point on the time spent at the second stage are robust to dropping the subjects without valid productivity. The parameters of both the OLS and Tobit models (See Table *A*.5 – *A*.6 at the Appendix) of the high expectation treatment dummy are significant at 10%, and have similar magnitude as the parameter estimates obtained from the full sample.

[13]The effect of the high expectation treatment is similar for the subset of subjects in the low history and high history treatments (See tables *A*.2 – *A*.3 at pages 93 – 94 of the Appendix). The parameter estimates are, however, statistically insignificant with or without controls due to the smaller sample size and as a result the higher standard errors.

1.9.3 Result 2.

Result 2. *The probability of stopping when earnings are equal to* \$3 *is higher in the low expectation treatment (envelope with the fixed amount of* \$3*) than in the high expectation treatment. The probability of stopping when earnings are equal to* \$7 *is higher in the high expectation treatment (envelope with the fixed amount is* \$7*) than in the low expectation treatment. The modal choice in both the low expectation and high expectation treatments is to stop exactly when earnings equal the fixed payments of* \$3 *or* \$7*. Similar to result 1, this result also replicates the findings of* Abeler et al. *[*2011*].*

Figure 1.3 (See page 37) shows the distribution of acquired earnings during the second stage for the low expectation and high expectation treatments. First, stopping decisions are distributed between \$0 and \$23; some subjects stop immediately, and others work for the full one hour. Second, acquired earnings are clustered (18.6% of subjects) around \$3 in the low expectation treatment. In the low expectation treatment the fixed amount is \$3, thus with 50% probability they earn \$3. Only 2.9% of the subjects stop at \$7 in the same treatment. On the other hand, there is clustering (11.43% of subjects) around \$7 in the high expectation treatment in which the fixed amount is \$7. Only a very small number (5.7%) of subjects stop at exactly \$3. Furthermore, the modal choice in both treatments is to stop exactly when accumulated acquired earnings equal the fixed payment of \$3 in the low expectation treatment and \$7 in the high expectation treatment.

To further examine stopping behavior I estimate a multinomial logit model with three outcomes: "stop at \$3", "stop at \$7", and "stop elsewhere", as in Abeler et al. [2011]. Table 1.7 contains the estimates of the multinomial logit re-

Table 1.7: Tendency to Stop at the Fixed Payment (with High Expectation Treatment and High History Treatment Variables)

	(1)		(2)	
	3	7	3	7
	b/se	b/se	b/se	b/se
High Expectation Treatment	-1.24***	1.33**	-1.26***	1.37**
	(0.43)	(0.58)	(0.43)	(0.59)
High History Treatment	0.76*	0.75	0.78*	0.92*
	(0.39)	(0.49)	(0.40)	(0.53)
Productivity			0.00	-0.02*
			(0.01)	(0.01)
Female			-0.09	0.52
			(0.41)	(0.60)
Controls for temperature	No	No	Yes	Yes
Controls for time of day	No	No	Yes	Yes
Constant	-1.86***	-3.73***	-1.40	-5.80***
	(0.32)	(0.60)	(0.90)	(1.32)
Observations	280		280	
Pseudo R^2	0.069		0.097	

Notes: Detailed notes are on page 106 of section A.4.2 of the Appendix.

Standard errors are in parentheses.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

gressions with and without controls. The first column of table 1.7 contains the parameter estimates of the multinomial logit model with "stop at $3" as the dependent variable, while the second column contains the parameter estimates of the model with "stop at $7" as the dependent variable. Columns 3 and 4 contain the estimates of the models with additional controls. The first row contains the parameter estimates on the high expectation treatment dummy and shows that subjects in the high expectation treatment are less likely to stop when acquired earnings are exactly $3 and more likely to stop at $7, compared to subjects in the low expectation treatment.

1.9.4 Robustness checks on Result 2.

Result 2 is robust to dropping the 24 subjects without valid productivity from the analysis. First, acquired earnings are clustered (18.2% of subjects) around $3, which is also the modal choice, in the low expectation treatment. On the other hand, only 3% of subjects stop at $7 in the same treatment. In the high expectation treatment, there is clustering (10.5% of subjects) around $7, which is also the modal choice, in the high expectation treatment. Only 4.8% of subjects stop at exactly $3.

Table A.13 (page 104 of the Appendix) shows the results of the multinomial logit regressions on the same sample. The results are in line with Result 2; subjects in the high expectation treatment are significantly less likely to stop at $3 and significantly more likely to stop at $7 with and without additional control variables compared to subjects in the low expectation treatment.

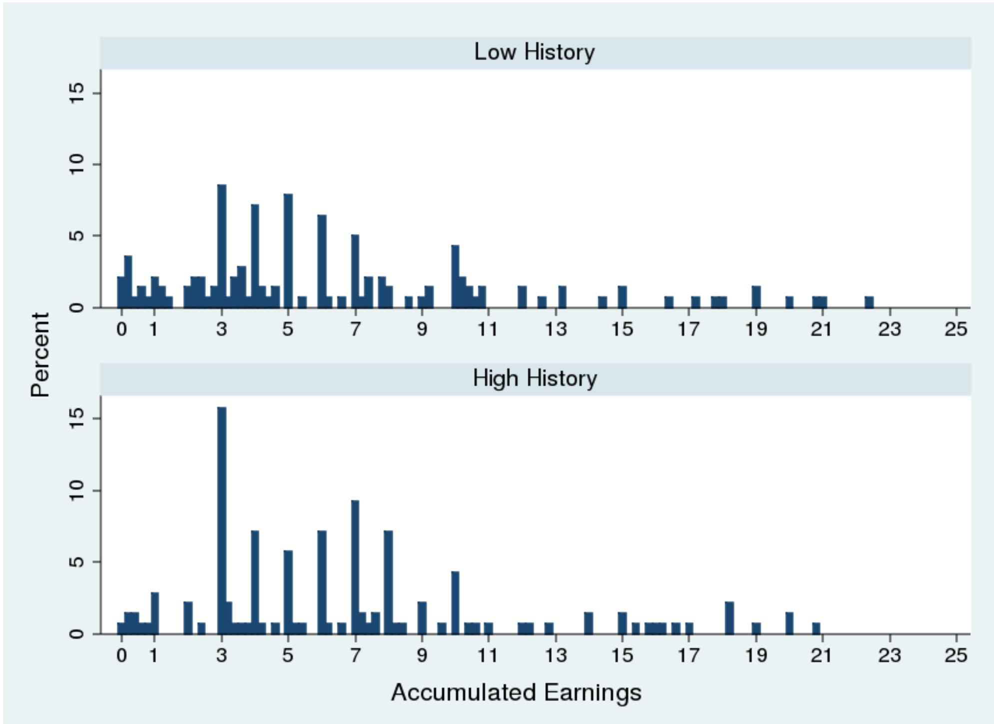

Figure 1.4: Histogram of Second Stage Accumulated Acquired Earnings (in \$) at Which a Subject Stopped for Low History and High History Treatments

1.9.5 Result 3.

Result 3. *There is evidence supporting Hypothesis 3 based on the* \$0.46 *difference (7.3%) between the low history and the high history treatments. However, this difference is not statistically significant due to the low power of the test.*

Figure 1.4 displays the distribution of acquired earnings in the second stage for the subjects at the low history treatment (distribution at the top) and for the ones at the high history treatment (distribution at the bottom). The two distributions are not statistically significantly different from each other (according to the Kolmogorov-Smirnof nonparametric test). On the other hand, there seems to be more mass at exactly \$3 and \$7.[14] In both treatments there are subjects who work very little (and earn around \$0) at the second stage and some who work much more and whose acquired earnings are around \$21-\$23.

Table 1.5 (See page 38) contains the mean and standard deviation of earnings (in dollars) at the second stage for the different history and expectation treatments. This table shows that on average subjects in the high history treatment earn \$0.46 more than subjects in the low history treatment. However, this difference is statistically not significant according to the nonparametric Mann-Whitney U-test. The effect of the high-history treatment seems larger based on the \$0.64 difference between the high history and low history treatments among the subjects in the high expectation treatment. The difference of \$0.27 between the history treatments is smaller among subjects in the low expectation treatment. These differences are not significantly different from zero according to the nonparametric Mann-Whitney U-test.

Interestingly, high history treatment seems to matter for the effect on the high expectation treatment. The largest effect (\$1.28) of the expectation treatment is among subjects in the high history treatment (See Table 1.5 on page 38).

To examine further the effects of the history treatment, I run OLS regressions to include additional controls that could explain subjects' effort provision at the second stage. Column 1 of Table 1.8 contains the regression results on a simple linear OLS model with acquired earnings as a left-hand side variable and a dummy for the high history treatment as a right-hand side variable. The parameter estimate for the treatment dummy is 0.46, which is in line with the

[14]These two numbers are important at the second stage of the experiment, because \$3 is the fixed amount in the low expectation treatment and \$7 is the fixed amount at the high expectation treatment.

Table 1.8: Treatment Difference in Effort (High History Treatment Compared to Low History Treatment

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	b/se	b/se	b/se	b/se	b/se	b/se	b/se	b/se
High History Treatment	0.46	0.19	0.17	0.21	0.45	0.20	1.66	1.33
	(0.58)	(0.60)	(0.81)	(0.94)	(0.60)	(0.63)	(1.94)	(2.02)
Productivity		0.04***	0.03	0.06**		0.04***		0.07
		(0.02)	(0.02)	(0.03)		(0.02)		(0.05)
Female		0.18	0.03	0.16		-0.26		0.38
		(0.65)	(0.87)	(1.00)		(0.70)		(2.20)
Controls for temperature	No	Yes	Yes	Yes	No	Yes	No	Yes
Controls for time of day	No	Yes	Yes	Yes	No	Yes	No	Yes
Constant	6.35***	8.58***	7.48***	9.86***	6.45***	9.16***	25.11***	28.10***
	(0.42)	(1.43)	(2.02)	(2.08)	(0.45)	(1.50)	(1.41)	(4.62)
Observations	280	280	140	140	256	256	280	280
R^2	0.002	0.036	0.034	0.054	0.002	0.048	0.003	0.012

Notes: Detailed notes are on page 106 of section A.4.3 of the Appendix.

Standard errors are in parentheses and estimated using the heteroscedasticity-consistent standard error estimator of White [1980].

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

difference in the averages between the treatments, but not statistically significant. Subjects in the high history treatment, on average, earn $0.46 more than subjects in the low history treatment, which is a 7.3% increase in acquired earnings. Column 2 contains the regression results of a model with controls. The parameter estimate on the treatment dummy shrinks to 0.19, and it is also not statistically significant. The parameter estimate of productivity[15] is 0.04 and

[15]The productivity variable is the time (in seconds multiplied by -1) that subjects needed to

significantly different from zero at 1% similar to the model with the expectation treatment dummy. Section 1.9.6 analyzes the robustness of these results by dropping the 24 subjects from the sample who have no valid productivity. The standard errors for all models in Table 1.8 are estimated using the heteroscedasticity-consistent standard error estimator of White [1980].

To better understand the effects o the history treatment, I include the high history treatment dummy in the multinomial logit model (Table 1.7 (See page 43)). The table contains the estimates of the multinomial logit regressions with both the expectation and history treatment dummies and additional controls. The first column of table 1.7 contains the parameter estimates of the multinomial logit model with "stop at $3" as the dependent variable, while the second column contains the parameter estimates of the model with "stop at $7" as the dependent variable. Columns 3 and 4 contain the estimates of the model with additional controls. The second row contains the parameter estimates on the high history treatment dummy. The estimates show that the expectation based reference point has a similar effect as in the paper of Abeler et al. [2011]; being in the high expectation treatment significantly decreases the probability of stopping at exactly $3, and significantly increases the probability of stopping at exactly $7. On the other hand, being at the high history treatment (and receiving high piece rate at the first stage) has a positive and significant effect on the probability of stopping at $3. Furthermore, being at the high history treatment has a positive and significant effect on stopping at $7.

correctly solve a table during the practice round. Solving tables correctly during the practice round was not monetarily incentivized. Altogether, 24 subjects out of the 280 have no valid productivity in the practice round, for them, I use the average productivity as a proxy for productivity. A subject, on average, needed 49.52 seconds to correctly solve a table during the practice round.

1.9.6 Robustness checks on Result 3.

Columns 5 – 6 of Table 1.8 contain the same models as column 1 – 2, but the models are estimated on the full sample without the 24 subjects who did not have a valid productivity. First, the parameter estimates on the high history treatment dummy are almost the same as the estimates for the full sample with a 1 cent difference. Second, similar to the estimates in columns 1 – 2, the parameter estimates of the high history treatment are insignificant in both models. Therefore, I conclude that Result 3 is robust to dropping subjects without valid productivity.[16]

Columns 7 – 8 of Table 1.8 contain the OLS regression results on models with time spent in the second stage of the experiment as a dependent variable. Column 7 of Table 1.8 contains regression results of linear models with the high history treatment dummy as the only dependent variable. Column 8 contains the regression results with additional controls. The parameter estimate on the high history treatment dummy is 1.66 without controls and 1.33 with controls for subject's gender, the time of day, and the temperature of the day. Subjects in the high history treatment work 1.66 minutes longer than subjects in the low history treatment as predicted by the model. However, the OLS estimates on the treatment dummy are not significantly different from zero.

Table A.9 (on page 100 of the Appendix) contains the regression results of Tobit models which take into account censoring; the time spent in the second stage is censored from below at 0 and from above at 60, because subjects can work for up to an hour. The effect of the high history treatment is similar, and also not

[16]Table A.10 at page 101 of Appendix contain the estimation results of the models with and without controls for the full sample, the high expectation, and the low expectation subsamples after dropping the 24 subjects without valid productivity.

statistically significant.[17] The results on the effects (positive but insignificant) of the history reference point on the time spent at the second stage are robust to dropping the subjects without valid productivity. Both the OLS and Tobit models' parameters (See Table A.11 – A.12 of the Appendix) of the high history treatment dummy are insignificant with similar magnitudes as the parameter estimates obtained from the full sample.

A potential explanation for the weak results on the history treatment may come directly from the behavioral model. For some subjects, the history based reference point could have been irrelevant if they were planning to work for more than \$5-\$6 worth in the second stage. Past earnings as reference point does not affect their behavior in the second stage because they would be on the gain domain under both the low and high history treatment. This could explain why the size of the effect of the high history treatment is not large enough to be statistically significant.

Comparing Results 1-3 with the predictions of the different models (Table 1.2 (on page 32), there is only one model whose predictions are in line with subjects' behavior. The standard model and the standard model with changing marginal utility are not compatible with Result 1 and Result 2, because both models predict that the expectation treatment has no effect on average effort and on the probability of stopping. On the other hand, both behavioral models are in line with Result 1 and Result 2; both models make the same predictions about the effect of the high expectation treatment compatible with the data. The difference between the two behavioral models is in their predictions for the high

[17]The effect of the high history treatment is similar for the subset of subjects in the low and high expectation treatments (See tables A.8 – A.9 at pages 99 – 100 of the Appendix). The parameter estimates are, statistically insignificant with or without controls due to the small sample size and as a result the higher standard errors.

history treatment. Only the behavioral model with reference dependence over past earnings predicts a positive effect of the high history treatment on average effort which is compatible with Result 3 from the experiment.

1.10 Conclusion

The literature from psychology and behavioral economics has shown that people's preferences regarding outcomes are reference-dependent and exhibit loss aversion around certain reference points. Many recent papers, for example Abeler et al. [2011] and Gill and Prowse [2012a], focus on expectations as reference points and show that they serve as reference points that influence behavior. However, it is not clear that expectations alone can explain behavior in every domain, for example Ericson and Fuster [2014] argue that due to the rich psychology behind the endowment effect, a theory with multiple reference points may be required. Furthermore Heffetz and List [2014] find no evidence that expectations alone can explain the endowment effect in their experiment.

Investigating different types of reference points can help answer the open question of what determines references points and whether there are other types of reference points beyond expectations that influence behavior. This paper uses a real effort experiment to test the predictions of a model with multiple reference points. I find evidence of both kinds of reference points. I replicate the findings of Abeler et al. [2011] on expectations. I show that, in my experiment, expectations serve as reference points and they influence the subjects' labor supply. Subjects work significantly more in the high expectation treatment; on average, they earn $1.1 more (a marginal effect of 18.2%) in the high expectation treatment compared to the average earnings of \$6.03 in the low expectation treatment. On the other hand, I find evidence of another type of reference point: the history-based reference point. Subjects in the high history treatment earn \$0.46 more (a marginal effect of 7.2%) compared to the average earnings of \$6.35 in the low history treatment. I find that the positive effect of the high history treatment is consistent across different subsamples and robust to having different dependent variables in the regressions or dropping subjects without valid productivity levels. However, I find that the size of the estimate of the high history treatment is not significantly different from zero. The main issue is that the experiment is underpowered for this effect size. To have 80% power with 5% significance level with the same relative effect size as I found in my experiment, a much larger sample size is required (with approximately 700 – 900 subjects). One way to address this problem would be to run the experiment online, for example on Amazon's Mechanical turk, where obtaining the required sample size would be both cheaper and faster. Another way to circumvent the problem of low power would be to redesign the lab experiment in a way that could result in a larger expected effect size. One possible way to achieve this would be by changing the structure of the first stage and increasing the difference between the payments of the high and low history treatments. A fixed prize payment would be a possible solution; the subject receives a fixed prize in the first stage if she solves a sufficient number of tables, where the number of tables is a target that everyone can achieve. With this structure, the difference in the payments in the first stage between the high and low history treatments could be fixed and manipulated precisely by the experimenter. The difference in the first stage payments between the treatments is \$2.93 in the experiment. By increasing this difference in payments, the effect of the history treatment could increase. Furthermore, more people could be affected by the history treatment, for example, if the prizes were $4 and $9 in the first stage, then there would be more people on the loss domain relative to the history-based reference point. This would result in a greater average effect size and greater statistical power.

Further research on multiple reference points either through online or lab experiments could reveal intriguing findings on what determines reference points and how they affect behavior.

CHAPTER 2

THE PRINCIPAL-AGENT MODEL WITH LOSS-AVERSE AGENTS

2.1 Introduction

Several recent papers in the behavioral economics literature analyzed classical contract theory problems and produced novel results about firm and consumer behavior. These papers relax some of the standard assumptions of fully rational expected utility maximizing agents, which yields new insights to better understand certain phenomena. Several papers study firms' profit maximization problem, for example, DellaVigna and Malmendier [2004] study the optimal contract design for firms that interact with consumers who have time-inconsistent preferences. Likewise, Heidhues and Koszegi [2014] study a monopoly pricing problem with loss-averse consumers. Meanwhile, other papers tackle the principal-agent model with non-standard behavioral agents. O'Donoghue and Rabin [1999] analyze a principal-agent problem with time-inconsistent agents, where the principal's objective is to create incentives for the agent to complete a task in a timely manner. Finally, de la Rosa [2011] analyzes a principal-agent model with an overconfident agent who is overconfident about her ability and importance in the project.

This paper analyzes a principal-agent model with an agent who has reference-dependent preferences with exogenously given reference point over either money or effort level. I assume that the agent is loss-averse – she suffers more severely from a loss than she enjoys an equal amount of gain. The potential loss (or gain) in utility can be associated with a wage realization that is smaller (higher) than the reference salary when the agent has reference-dependence over wealth. However, when the agent has reference-dependence over effort, the potential loss (or gain) in utility is a consequence of being incentivized by the optimal wage contract to invest more (less) effort in the project than the agent's reference effort. I study the interaction of such an agent with a rational profit maximizing principal. I assume throughout the paper a piecewise linear "gain-loss" utility function, which is often used in the literature Heidhues and Koszegi [2014], except for section 2.4.1 and section 2.4.2, where I employ a general "gain-loss" function following Koszegi and Rabin [2006].

The first part of the paper analyzes the principal-agent problem where the principal can observe and contract on the effort level of the agent. The problem of the principal can be written as a maximization problem with one constraint; the individual rationality constraint that ensures that the agent's utility upon accepting the contract is as high as if she rejects and takes the outside option. The optimal contract leaves the agent indifferent between accepting the contract and her outside option. This yields a simple wage contract. With an agent who has reference-dependent preference over money, I find that the optimal effort level, designed by the principal, does not depend on the reference salary given that the reference salary is above a threshold or below a lower threshold. Specifically, the optimal effort level is greater when the agent's reference salary is large (above the threshold level) than when the reference salary is low (below the lower threshold level). Moreover, I show that under some weak conditions the principal might be better off with an agent with more pronounced reference dependence, because the marginal cost to incentivize the agent to exert a higher effort level is lower. Similarly, when the agent has reference dependence over effort, the optimal effort level does not depend on the reference effort given that the reference effort is above a threshold or below a lower threshold.

Specifically, the optimal effort level is greater when the agent's reference effort is large (above the threshold level) than when the reference effort is low (below the lower threshold level). I find that the marginal cost to incentivize the agent to exert a higher effort level is lower for the principal when contracting with an agent whose reference effort level is sufficiently high than with an agent who has a low enough reference effort. Finally, I discuss the predictions of the model for matching between employers and workers based on workers' reference dependence. I show that employers with projects where effort is crucial hire agents with high reference points or push up the reference points of agents whose initial reference point is low.

The last part of the paper deals with a setting, in which the principal cannot observe the effort level produced by the agent, and is thus unable to make the optimal wage contract depend upon it. The principal observes output that stochastically depends on the effort level undertaken by the agent. I assume that effort produces a first-order stochastic dominant shift on output level, which is a standard assumption in the contract theory literature Stole [2001]. In this case, the principal's maximization problem has an additional constraint compared to the full information case which changes the optimal wage contract. The incentive compatibility constraint guarantees that the effort level designed by the principal is optimal for the agent given the wage contract, *i.e.* it maximizes her expected utility with the given wage contract. I follow the standard first-order approach Stole [2001] by replacing the incentive compatibility condition with the corresponding first order condition. Then, I analyze the corresponding Lagrangian by deriving conditions for the optimal wage contract and optimal effort level. With reference-dependent preferences over money, similar to the full-information model I show that the optimal contract does not directly depend on the reference-wage level but depends on whether the wage at a given output is above or below the reference-wage level. If the reference-wage level is such that the gain-loss utility part of the utility has positive expectation, the agent experiences a gain in expectation. In this case, I show that the optimal wage contract for incentivizing the agent for a given effort level increases as the agent's utility becomes more reference-dependent. In particular, compared to an agent without reference dependence it is more costly for the principal to create incentives to undertake a particular effort level for an agent with reference dependence on money. In the principal-agent problem where the principal employs an agent with reference-dependent preferences over effort level, I show that the optimal wage contract can be characterized by the same implicit equation (Borch-rule Stole [2001]) as in a problem with an agent without reference-dependent preferences. Reference dependence influences the wage contract only indirectly through the individual rationality and incentive compatibility first-order conditions and the optimal effort level. The effect of reference dependence on the optimal effort level is ambiguous. With a few additional assumptions I am able to determine the effect of reference dependence with the curvature of the agent's marginal disutility function. If the marginal disutility function is linear, then the optimal effort level does not change. If it is convex, then the optimal effort level increases. Finally, if it is concave, then the optimal effort level increases as the reference dependence level of the agent increases.

The chapter is organized as follows. Section 2.2 further discusses the aforementioned literature. Section 2.3 presents the model under full-information where the principal can observe and contract on the effort level undertaken by the agent. In Section 2.4, I consider the asymmetric information case where the principal does not observe effort level, but the output level which stochastically depends on the effort level of the agent. Finally, Section 2.5 concludes. Appendix B contains proofs for the results in this chapter.

2.2 Related Literature

The idea of reference-dependent preferences and loss-aversion were introduced to the economics literature by the groundbreaking work of Kahneman and Tversky [1979]. Based on experiments on hypothetical choice problems they proposed a new framework, prospect-theory, to model decision-making under risk. Their model assumes that people evaluate risky lotteries based on the potential changes in their wealth compared to a reference wealth level. They hypothesize that the value function for changes of wealth is concave above the reference point and convex below the reference point. This assumption captures loss-aversion and is based on suggestive evidence that losses loom larger than gains when people evaluate changes in wealth. Beyond this early evidence on loss-aversion, recent papers studied and found evidence of loss-aversion on field-data and in laboratory experiments. Crawford and Meng [2011a] study the labor supply decision of cab drivers and estimate a reference-dependent model of labor supply. The structural estimation results in a significant loss-aversion parameter indicating that loss-aversion plays a key role in the labor-supply decisions of cab drivers. Gill and Prowse [2012b] study experimentally whether agents are disappointment averse in a computerized real effort task. They find significant evidence that agents are loss averse around their expectation based reference point.

Distinct from this, several papers in the contract theory literature studied and explored the consequences of distinct behavioral assumptions about the agents in the model. For example, DellaVigna and Malmendier [2004] study the consequences of time-inconsistency on firm's optimal contract design. They assume standard expected profit maximizer firms which sell to consumers with time-inconsistent preferences who are not fully aware of their time-inconsistency. They find that firms will price investment goods (with immediate cost and delayed benefit for the consumers) below marginal cost and price leisure goods (with immediate benefit and delayed cost for the consumers) above marginal cost. Heidhues and Koszegi [2014] study a monopoly's pricing problem when selling products to loss-averse consumers. They make the assumption that firms are aware of the consumers' preferences, an assumption of which I posit. They show that the optimal strategy for the firm is to offer a variable sale price and a fixed regular price if it is costly to observe the realized price on the market, and choose a sticky regular price and hold no sales otherwise. O'Donoghue and Rabin [1999] analyze a principal-agent problem, where the principal's objective is to incentivize an agent to complete a task in a timely manner. The agent has present-biased preferences and naive expectation about her future behavior, both of which create motivation for procrastination. If the agent has private information about the cost of completing the task, then the principal cannot disentangle whether the agent is rationally delaying the completion of task or procrastinating. Therefore, the first-best efficiency cannot be achieved for time-inconsistent agents. The authors show that the second-best optimal contract for procrastinators involves an increasing punishment for delay as time passes. Englmaier and Wambach [2010] assume that a standard profit-maximizing principal hires an inequity-averse agent and study the optimal contract design of the principal. They show that hiring an inequity-averse agent changes the structure of the optimal contract implying a strong tendency toward a linear sharing rule. Lastly, Hart and Moore [2008] argue that a contract provides a reference point for a trading relationship through setting the entitlements. The model assumes that a party's ex post performance depends on whether she gets what she is entitled to relative to the outcomes permitted by the contract. The analysis provides a basis for long-term contracts in the absence of contractible investments and shows why a simple employment contract can be optimal.

2.3 Full-Information Case (Contractible Effort)

This section analyzes a contracting problem where the agent has reference-dependent preferences either over money or over effort level undertaken in the job.[1] I assume that there is one agent and one principal in the market, where the principal's goal is to maximize profit. The assumption that a standard profit maximizing principal and a behavioral agent interact on the market follows the behavioral contract theory literature, for example Englmaier and Wambach [2010] assume that a profit-maximizing principal hires an inequity-averse agent.

Throughout the paper, I assume that the principal knows everything about the agent's preferences and reference points, thus my paper does not address the possibility of adverse selection. The principal has a production technology $f(a)$ with the standard concavity assumptions ($f'(.) > 0$ and $f''(.) < 0$) that satisfies the Inada conditions, where a is the effort level undertaken by the agent at work. The principal offers a take-it-or-leave-it contract $w(a)$ to the agent that depends

[1] Denote an agent with reference-dependent preferences as reference-dependent agent and an agent with no reference-dependence in her preferences as standard agent.

on the effort level, since effort a is contractible. The agent either accepts or rejects the contract, if she accepts, then she chooses effort level a on the job. Next, production takes place. The agent receives $w(a)$ and the principal receives $x - w(a)$.

2.3.1 Reference Dependence on Money

At this subsection, I assume that the agent has reference-dependent preference over money with an exogenous reference point $\overline{w}$. The agent has an exogenous reference salary, which is her status quo salary that she carries from her previous employment. The principal offers a contract $w(a)$ to the agent that she can accept or reject. If she accepts, then she chooses an effort level and production takes place. If she rejects the contract, then she receives unemployment insurance, which yields $\overline{u}$ utility.

Her preferences are represented by the following utility function

$$U = u(w) - \gamma(a) + \mu(u(w) - u(\overline{w})), \tag{2.3.1}$$

where w is the actual wage she earns and a is the effort level she undertakes on the job, $u(w)$ is the "consumption utility" she directly associates with the consumption she can achieve with her salary (under the assumption that she spends here entire sal ary), $\gamma(a)$ is the disutility of her effort and $\mu(.)$ expresses the "gain-loss utility" she experiences as a result of consuming more or less than her reference wage level $\overline{w}$.

Throughout the paper, I assume either a concave direct utility function ($u'(.) > 0$, $u''(.) < 0$) or a linear one $u(w) = w$. I also assume that the agent has no initial wealth and that the disutility function of effort is convex ($\gamma'(.) > 0$, $\gamma''(.) > 0$) with the first derivative going to zero as a approaches zero. I rely on the paper of Koszegi and Rabin [2006] to define a general $\mu(x)$ gain-loss function. I assume that the gain-loss function is continuous, twice-differentiable everywhere except zero and strictly increasing for $y > x > 0$. Furthermore, I also assume that if $y > x > 0$, then $\mu(y) + \mu(-y) < \mu(x) + \mu(-x)$, $\mu''(x) \leq 0$ for $x > 0$, $\mu''(x) \geq 0$ for $x < 0$, and $\lim_{x \to 0+} \frac{\mu'(-x)}{\mu'(x)} = \lambda > 1$. These assumptions capture the loss-aversion of the agent – her gain-loss utility is steeper on the loss domain than on the gain domain – and the decreasing rate of sensitivity to gains and losses as they become larger.

Throughout this section, I use a more specific gain-loss function from Koszegi and Rabin [2006], where the assumptions $\mu''(x) \leq 0$ for $x > 0$, $\mu''(x) \geq 0$ for $x < 0$ of the general gain-loss function are replaced with $\mu''(x) = 0 \; \forall x \neq 0$. This assumes that there is no diminishing sensitivity in gain-loss utility and results a special, piecewise linear gain-loss function

$$\mu(y) = \begin{cases} \nu y, & \text{if } y \geq 0 \\ \eta \nu y, & \text{if } y < 0 \end{cases},$$

with two parameters ($\nu > 0$, $\eta > 1$).[2] This specific "gain-loss" utility function is widely used in applied papers Heidhues and Koszegi [2014] because it captures the idea of loss aversion with one parameter $\eta > 1$ and because of its tractability. To further simplify the analysis, I assume that the agent has a simple linear direct utility function over wealth $u(w) = w$. The crucial assumption I use to solve the principal's problem in (2.3.2) is the linearity of the gain-loss function, be-

[2]This specific gain-loss function can be written more compactly with an indicator function, which yields the form

$$\mu(y) = [(\eta - 1)\mathbb{1}\{y < 0\} + 1]\, \nu y,$$

a fact I utilize for the proofs.

cause it enables me to express the optimal wage function from the participation constraints in a closed form.

The maximization problem of the principal can be written as

$$\max_{w(.),a} f(a) - w(a)$$
$$w(a) - \gamma(a) + \mu(w(a) - \overline{w}) \geq \overline{u}, \tag{2.3.2}$$

where $\overline{u}$ is utility level corresponding to the agent's outside option which she gets if she rejects the contract. The assumptions on the production and utility functions ensures an interior optimum. The principal chooses both the contract and the effort level, since she can design an optimal wage contract that ensures that the utility maximizing choice for the agent is the principal's desired effort level. For the profit maximizing contract the agent's participation constraint holds with equality since the direct utility $u(w(a))$ depends positively on wage and μ, γ are increasing functions. Otherwise, the principal would either increase a or decrease w, earning higher profit, that would decrease the left hand side of the constraint until when it reaches $\overline{u}$. Thus, the the optimal contract is

$$(w(a)) - \gamma(a) + \mu(w(a) - \overline{w}) = \overline{u}. \tag{2.3.3}$$

Theorem 1. *An optimal wage contract of the principal is*

$$w(a) = \begin{cases} \frac{\overline{u}+\gamma(a)+\nu\overline{w}}{1+\nu}, & \text{if } \overline{w} < \overline{u} + \gamma(a_0^*) \\ \frac{\overline{u}+\gamma(a)+\eta\nu\overline{w}}{1+\eta\nu}, & \text{if } \overline{w} > \overline{u} + \gamma(a_1^*) \end{cases},$$

where a_0^* is the optimal effort level determined by

$$\frac{f'(a_0^*)}{\gamma'(a_0^*)} = \frac{1}{1+\nu},$$

whenever the reference wage is such that $\overline{w} < \overline{u} + \gamma(a_0^*)$. a_1^* is the optimal effort level determined by the

$$\frac{f'(a_1^*)}{\gamma'(a_1^*)} = \frac{1}{1+\eta\nu},$$

whenever the reference wage is such that $\overline{w} > \overline{u} + \gamma(a_1^*)$. If the reference wage lies in the interval $[\overline{u}+\gamma(a_0^*), \overline{u}+\gamma(a_1^*)]$ then the principal offers a fix wage $w = \overline{w}$ if the agent works at least as much as $a^* = \gamma^{-1}(\overline{w} - \overline{u})$ effort, otherwise she pays zero salary. It is profitable for the principal to employ an agent with reference wage $\overline{w}$ only if $f(\gamma^{-1}(\overline{w}-\overline{u}))-\overline{w} \geq 0$.

The concavity of the production function and the convexity of the disutility function imply that $a_0^* < a_1^*$, which also guarantees that $[\overline{u} + \gamma(a_0^*), \overline{u} + \gamma(a_1^*)]$ is a nonempty interval. This establishes that a principal optimally incentivizes an agent with a high reference-wage level to work at a higher effort level than an agent with a low reference-wage level. An agent with high reference-wage level (beyond a critical value $\overline{u} + \gamma(a_1^*)$) experiences a loss because at the optimal contract she earns less than her reference salary level. However, this agent experiences higher marginal utility for a slightly higher salary as a result of increased effort because she is on the loss domain and is loss averse, $\eta > 1$. The principal knows this, and incorporates it into the optimal contract, which takes the form $w(a) = \frac{\overline{u}+\gamma(a)+\eta\nu\overline{w}}{1+\eta\nu}$. The larger denominator in the optimal contract shows that the principal can increase the agent's effort at a lower marginal cost as a result of the agent's loss aversion and high reference-salary. The principal equates marginal revenue, which is equal to $f'(a_1^*)$, with marginal cost at the profit maximizing effort level, since the marginal cost is lower than that for an agent whose reference-salary is low, the principal thus chooses a higher optimal effort level.

This theorem also establishes that the optimal effort level designed by the principal does not depend directly on the reference-salary if the reference-wage level is high enough or low enough. If the reference wage lies in the interval $[\overline{u}+\gamma(a_0^*), \overline{u}+\gamma(a_1^*)]$, then the effort level designed by the principal, $a^* = \gamma^{-1}(\overline{w}-\overline{u})$, monotonically increases with the agent's reference-wage level if it is profitable at all for the principal to employ such an agent. To guarantee the profitability of the hire, the condition $f(\gamma^{-1}(\overline{w} - \overline{u})) - \overline{w} \geq 0$ must hold , which guarantees that the principal earns a non-negative profit by hiring the agent. If the principal employs such an agent, then she offers a fixed wage $\overline{u} + \gamma(a^*)$ if she puts at least a^* effort into the job and zero otherwise. In the appendix, I show that any other contract can be dominated by this contract in the sense that no other contract can increase the principal's profit while ensuring that the agent's participation constraint binds.

Finally, comparative static results can be directly derived from Theorem 1 about the effect of changes in the production function (f) or changes in the disutility of effort function (γ). First, I assume that there is another production function that is a positive linear transformation of the original $g(a) = \alpha f(a) + \beta$ and $\alpha > 1$, thus productivity is higher than initially. The increase in productivity does not influence however the optimal wage contract of the agent because the principal only pays her enough to participate which does not depend on the production function. On the other hand, the optimal effort level is greater when the principal hires and agent (with production function g) who is more productive. This statement is true because the marginal product increased (it is $\alpha f'(a)$ instead of $f'(a)$), but the marginal cost is the same, thus the optimal effort level is higher. This shows that the principal always prefers to hire the most productive agents. Second, I assume that there is another agent whose disutility of effort function is a positive linear transformation of the original disutility function $\zeta(a) = \delta\gamma(a) + \omega$ and this person faces a greater disutility of effort $\delta > 1$. From the theorem it follows directly that the optimal wage contract is different for this agent, she gets monetary compensation for the higher disutility. However, she does not receive the dollar equivalent of the increased disutility, but receives less because this compensation also increases her reference dependent utility.[3] The principal faces the same marginal product because the production function is the same as before, but she faces a higher marginal cost of implementing a higher effort level. The higher marginal cost arises because the principal has to compensate the agent for the higher disutility of effort. These implies a lower optimal effort level and lower production. This also shows that the principal prefers to hire agents with the lowest disutility of effort, because it is the cheapest to incentivize them to work.

Theorem 2. *If v increases locally, meaning that the optimal salary $w(a^*)$ stays above or below the reference salary $\overline{w}$, then the optimal effort level a^* increases. The interval $[\overline{u} + \gamma(a_0^*), \overline{u} + \gamma(a_1^*)]$ shrinks since both $a_0^* \to \infty$ and $a_1^* \to \infty$ as $v \to \infty$.*

Higher reference-dependence level v corresponds to lower marginal cost of effort, $\gamma'(a)/(1 + v)$, for the principal, therefore optimally she induces a higher effort level for the agent by the optimal contract. This higher effort level is independent on the reference wage in the limit as the agent becomes infinitely reference dependent, because the optimal effort level goes to infinity on both the gain and loss domains. The agent is always indifferent between the contract and her outside option, and as in the literature I assume that in case of indifference she accepts the contract and reaches $\overline{u}$ utility level.

This theorem shows that employing an agent with a higher reference dependence increases the optimal effort level, but also increases the reference-dependent component of the optimal wage contract. Therefore, it is not obvious whether the principal's profit level increases or decreases. If the first ef-

[3]Whether she gets only a little bit less or a lot less that depends on whether she is on the gain or loss domain compared to her reference wage. If on the gain domain then she receives more compensation relative to when she is on the loss domain.

fect dominates the second, then the principal has incentives to pick individuals selectively according to their reference-dependence from a population of heterogeneous agent who have identical reference salary but different reference-dependence parameter.

Theorem 3. *The principal is better off by employing an agent with higher level of reference dependence $\nu_2 > \nu_1$ if*

$$f(a_2^*) - f(a_1^*) > w(a_2^*, \nu_2) - w(a_1^*, \nu_1), \tag{2.3.4}$$

given that $w(a_1^*, \nu_1)$ and $w(a_2^*, \nu_2)$ are both above the reference wage.

The theorem establishes that a principal is only better off by choosing an agent with higher level of reference dependence if the production function is sufficiently steep. This is captured by the left hand side of the inequality, which captures the increase in production as a result of the higher optimal effort level that the agent produces with because of her higher reference dependence. The principal hires her when the increase in production (profit) is higher than the wage cost of hiring her.

The principal hires an agent with higher reference dependence, if the increase in production, as a result of the higher effort of the agent with ν_2, dominates the increase in salary. Theorem (3) captures this by inequality (2.3.4), which after substituting in the optimal wage contracts and rearranging it results in

$$(1+\nu_1)(1+\nu_2)(f(a_2^*)-f(a_1^*)) > (\nu_1-\nu_2)\overline{u}+(\nu_2-\nu_1)\overline{w}+(1+\nu_1)\gamma(a_2^*)-(1+\nu_2)\gamma(a_1^*). \tag{2.3.5}$$

A condition that guarantees that inequality (2.3.5) holds is that the wage paid to the agent with higher reference-dependence ν_2 is equal to the wage paid to the other agent who has lower reference-dependence level ν_1. This case occurs, when the right-hand side of inequality (2.3.5) is zero, that is $(\nu_1 - \nu_2)\overline{u} + (\nu_2 - \nu_1)\overline{w} + (1 + \nu_1)\gamma(a_2^*) - (1 + \nu_2)\gamma(a_1^*) = 0$, which can be rewritten as $(\nu_2 - \nu_1)(\overline{w} - \overline{u}) = (1 + \nu_2)\gamma(a_1^*) - (1 + \nu_1)\gamma(a_2^*)$. In the special case when the relative increase in the utility cost of higher effort is smaller than the increase in reference dependence level $\frac{\gamma(a_2^*)}{\gamma(a_1^*)} < \frac{1+\nu_2}{1+\nu_1}$ guarantees that the right-hand side of the equation (2.3.5) is positive $(1 + \nu_2)\gamma(a_1^*) - (1 + \nu_1)\gamma(a_2^*) > 0$. There exists a combination of parameters $\overline{w}$ and $\overline{u}$ that guarantees that inequality (2.3.5) holds and thus the condition of Theorem (3) can be satisfied.

The increase in the wage component that depends on the reference-point, $\nu w/(1 + \nu)$, which is due to the stronger reference dependence, is dominated by the decrease in the wage component that depends on the agent's outside option, $\overline{u}/(1 + \nu)$. Moreover, the potential increase in the wage due to the higher disutility of the increased effort level is smaller than the effect of the higher reference dependence, which makes it cheaper for the principal to compensate for a given disutility of effort.

Under these particular conditions, it is profitable for the principal to employ an agent with higher reference dependence, therefore she does. On the margin, it is cheaper for the principal to incentivize the agent to provide higher effort level, which yields higher output level and higher final product from which the agent gets an increased wage that is smaller than the increase in the final product. The agent accepts this because the higher ν increases the agent's utility level if her salary is above her reference wage and this makes her accept a smaller wage with higher effort level under these special conditions.

Theorem 4. *The optimal effort level does not depend directly on the reference wage. It* *depends upon whether the wage paid at the optimum is above or below the reference-wage level whenever the reference-wage level lies outside of the* $[\overline{u} + \gamma(a_0^*), \overline{u} + \gamma(a_1^*)]$ *interval. The optimal effort level is higher when the reference wage is greater than* $\overline{u} + \gamma(a_1^*)]$ *than when when the reference wage is lower than* $\overline{u} + \gamma(a_0^*)$. *The optimal effort level is lowest when the principal employs an agent without reference dependent preferences,* $U = u(w) - \gamma(a)$.

Theorem (4) illustrates that optimal effort level does not depend quantitatively on the reference wage, it only depends on whether this reference wage will put her on the gain or loss domain. When she is in the loss domain (high reference wage) then it is cheaper to incentivize her to work more, thus, the optimal effort level is greater than when she is in the gain domain (low reference wage). It also outlines that reference dependence induces the agent to be more sensitive to changes in money. This makes it easier to incentivize her to work harder, thus optimal effort level is higher for her than for an agent with standard preferences.

The theorem shows that more production takes place with reference-dependent agents whose reference level is either above or below the actual salary than with agents with standard preferences over money and effort. Furthermore, the principal designs the highest optimal effort level when the agent's reservation wage is sufficiently high, greater than $\overline{u} + \gamma(a_1^*)$.

Distortion of the Reference Wage by the Principal

This subsection analyzes when the higher production level at Theorem (4) results in higher profit for the principal. If the higher profit can be achieved and the principal has the ability to influence the principal's reference salary, then a rational principal distorts the agent's reservation salary upwards.

Throughout this subsection, I assume that the principal has the ability to distort the potential agent's reservation salary before the contracting stage.

Assume that the initial reservation wage of the agent is $\overline{w}$, which is below what she would earn under the contract offered (denoted by $w_1(a)$) by the principal and optimal effort a^* induced by her reference point. Therefore, from Theorem (2) the optimal contract follows, $w_1(a^*) = \frac{\overline{u}+\gamma(a^*)+\nu\overline{w}}{1+\nu} > \overline{w} \Leftrightarrow \overline{u} + \gamma(a^*) > \overline{w}$. Assume that the principal can push the agent's reference wage level upwards to $\underline{w} > w_2(a^{**})$ for a fixed cost χ. For an agent with this higher reference-wage level, the principal optimally offers (See Theorem (2)) $w_2(a) = \frac{\overline{u}+\gamma(a)+\eta\nu\overline{w}}{1+\eta\nu}$ and incentivizes the agent to choose the optimal effort level $a^{**} > a^*$. This occurs when $\frac{\overline{u}+\gamma(a^{**})+\eta\nu\overline{w}}{1+\eta\nu} < \underline{w} \Leftrightarrow \overline{u} + \gamma(a^{**}) < \underline{w}$.

Theorem 5. *There exist parameter values where it is profitable for the principal to modify upwards the agent's reference salary level. The principal finds it optimal to influence the agent's reference level upwards to $\underline{w}$ from $\overline{w}$ whenever*

$$f(a^{**}) - \frac{\overline{u} + \gamma(a^{**}) + \eta\nu\underline{w}}{1 + \eta\nu} - \chi > f(a^*) - \frac{\overline{u} + \gamma(a^*) + \nu\overline{w}}{1 + \nu}, \tag{2.3.6}$$

which is equivalent to

$$(1 + \eta\nu)(1 + \eta)(f(a^{**}) - f(a^*)) > (1 + \nu)\gamma(a^{**}) - (1 + \eta\nu)\gamma(a^*) + \eta\nu(1 + \nu)\underline{w} - \nu(1 + \eta\nu)\overline{w}+$$

$$+\nu(1 - \eta)\overline{u} + \chi.$$

The basic idea behind this result is straightforward. Whenever the agent has a higher reference salary, the principal can incentivize the agent for higher effort at a lower wage cost, therefore under the optimal contract the agent works harder, which yields higher production. Thus, the profit-maximizing principal pushes the reference salary up as long as it is cheap enough to do so.

Furthermore, Theorem (5) also shed lights on when a profit-maximizing principal has incentives to push down the agent's reference salary. If the principal can influence the agent's reference salary at no cost $\chi = 0$ and inequality (2.3.6) does not hold, then the principal influences the agent's reference salary level downwards. If it is costly for the principal to influence the agent's reference salary, then the principal pushes down it whenever condition $f(a^{**}) - \frac{\overline{u}+\gamma(a^{**})+\eta\nu\underline{w}}{1+\eta\nu} < f(a^{*}) - \frac{\overline{u}+\gamma(a^{*})+\nu\overline{w}}{1+\nu} - \chi$ holds. The principal pays a higher reference-wage component to an agent with high reference wage salary, therefore if the higher production level does not compensate the principal for the higher wage cost, then she pushes the agent's reference salary downwards. This results a lower revenue as a result of lower production and also lower wage cost for the principal but overall a higher profit level.

A special case for this condition is when it is free to adjust the reference point, *e.g.*, $\chi = 0$; the cost increase is smaller than the increase in the slope of the gain-loss utility part $\frac{\gamma(a^{**})}{\gamma(a^{*})} < \frac{1+\eta\nu}{1+\nu}$; and the increase in the wage component of the higher reference-point is smaller than the decrease in the wage component of the reservation utility $\eta\nu(1+\nu)\underline{w} - \nu(1+\eta\nu)\overline{w} < \nu(\eta-1)\overline{u}$. When the production function is steep enough and the cost function is sufficiently flat, the principal finds it profitable to shift the reference point even in the presence of positive adjustment costs $\chi > 0$.

2.3.2 Reference Dependence on Effort Level

This section analyzes the contracting problem between a principal and an agent with reference-dependent preferences over effort level. There is an agent who has an exogenous reference point $\overline{a}$ over effort level. Her utility function is

$$U = u(w) - \gamma(a) + \mu(\gamma(\overline{a}) - \gamma(a)). \tag{2.3.7}$$

I use the same assumptions about the functional forms as in the previous section, in particular I assume a linear utility function $u(w) = w$, a concave production function $f(a)$ and a piecewise linear gain-loss function μ. The main difference is that the agent has reference-dependent preferences over effort which are represented by the utility function in equation (2.3.7). Based on Koszegi and Rabin [2006] the agent's loss-aversion is defined in terms of utility of effort, which yields that the gain-loss function is defined on utility levels instead of effort levels. The principal knows the reference-point of the agent when offering a contract. If the agent accepts the contract, she chooses her effort level and production takes place. The maximization problem of the principal is

$$\begin{aligned} &\max_{w(.),a} f(a) - w(a) \\ &w(a) - \gamma(a) + \mu(\gamma(\overline{a}) - \gamma(a)) \geq \overline{u}. \end{aligned} \tag{2.3.8}$$

Theorem 6. *The optimal contract takes the following form*

$$w(a) = \gamma(a) - \mu(\gamma(\overline{a}) - \gamma(a)) + \overline{u}. \tag{2.3.9}$$

Moreover, the slope of the wage function is lower when the reference effort is above the actual effort level than when the reference effort is below the effort level

$$w'(a) = \begin{cases} (1+\nu)\gamma'(a), & \textit{if } a < \overline{a} \\ (1+\eta\nu)\gamma'(a), & \textit{if } a > \overline{a}. \end{cases}$$

Theorem (6) illustrates that if the agent has high reference effort that is above the actual effort she undertakes in the job, then she gets penalized in the wage, *i.e.*, she earns less than an agent without reference dependence. Nonetheless, when the reference effort is low and below the actual effort level of the agent, then she gets compensated for the loss feeling from undertaking the higher effort level. If the agent's actual effort level is lower than her reference point and her outside option is low enough, then she can receive negative payment. For this negative payment she is compensated by the utility gain due to the low effort level relative to her reference point. The slope of the wage function shows that when the reference point decreases, the marginal cost of incentivizing a higher effort level becomes more expensive for the principal.

Theorem 7. *The optimal effort level does not depend on the reference effort level directly. It depends on whether the reference point for effort is above or below the optimal effort level. The optimal effort level is higher when the reference effort level is high enough, that is, it is above the threshold level determined by the optimal effort level compared to a situation when the agent has a lower reference effort level (below the threshold). The optimal effort level is the greatest when the principal hires an agent whose preference is not reference-dependent and has utility function $U = u(w) - \gamma(a)$. Moreover, the optimal effort level is decreasing in ν; that is, the principal designs a lower optimal effort level when she faces an agent with a higher reference-dependence level.*

If the agent has a low reference-effort, then working hard (above the reference point) incurs an additional disutility for the agent that comes from the gain-loss utility since her reference utility level is higher than her actual utility from effort.[4] This makes it more costly for the principal to incentivize the agent

[4]At this case, her utility of effort is negative and its absolute value is in effort, therefore an effort level which is higher than the reference effort level, pushes her to the loss domain.

for an infinitesimally higher effort level. The marginal cost of incentivizing an agent with low reference effort to exert slightly higher effort level is $(1+\nu\eta)\gamma'(a)$, which is greater than $(1+\nu)\gamma'(a)$ the marginal cost for an agent with a high reference effort level because of $\eta > 1$ capturing loss-aversion. Since the principal equates marginal revenue with the marginal cost of effort, it follows that the optimal effort level is lower for agents with low reference effort level than for agents with sufficiently high reference effort level.

Distortion of the Reference Effort Level by the Principal

Finally, assume that an agent has an initial low reference point $\overline{a} < a^*$ over effort level relative to the potential equilibrium effort levels. The principal can push this effort level up to $\underline{a} > a^*$ for a fix cost of χ.

Theorem 8. *There exist parameter values for which it is profitable for the principal to modify upwards the agent's reference effort level to $\underline{a} > a^*$ from $\overline{a} < a^{**}$. It is profitable whenever*

$$f(a^*) - \gamma(a^*) + \nu(\gamma(\underline{a}) - \gamma(a^*)) - \chi > f(a^{**}) - \gamma(a^{**}) + \eta\nu(\gamma(\overline{a}) - \gamma(a^{**})).$$

The intuition for Theorem (8) is that the marginal cost for the principal to incentivize an agent for slightly higher effort level is lower if the agent's current salary is below her reference salary and her preferences are reference-dependent over wealth. However, this marginal cost for the principal is lower when the agent's effort level is lower than her reference effort and she has reference-dependent preferences over effort.

The theorem (8) establishes that for some parameters of the model the principal has an incentive to push the agent's reference effort level upwards even if there is a fix cost attached to it. In the previous section, I derived a similar result for an agent who has reference-dependent preferences over money. The two results have a similar underlying intuition, although in one case the agent operates in her loss domain while in the other case she is in the gain domain.

2.3.3 Predictions for Different Jobs/Employers

Employers with projects where effort is crucial (*i.e.*, the marginal product of effort f' is high) have incentives to influence the reference points of agents. The model predicts that these principals push agent's reference point upwards. Similarly, the employers find it optimal to to push the reference point upwards for agents whose marginal disutility of effort is low. However, principals with projects where the marginal product of effort f' is low have incentives to not influence agents' reference points if they are low, and push them downwards if they are high. This suggests a particular matching on the market between employers and workers. On the one hand, employers with projects where effort is crucial hire agents with high reference points, which yields high production and high profit. On the other hand, employers with projects where higher effort has a small effect on production hire workers with lower reference points and pay lower salary to them.

2.4 Asymmetric Information (Non-Contractible Effort)

This section analyzes the principal-agent problem with a reference-dependent agent when the principal does not observe the agent's effort level, thus she cannot contract on it. The principal observes the verifiable output level $x \in X$, which is a random variable with conditional density $f(x, a)$ and cumulative distribution function $F(x, a)$ depending on the effort level $a \in A$ of the agent. Assume that the support of x does not depend on the effort level a, which implies that the first-best is not achievable Stole [2001]. The principal has full knowledge of the agent's preferences and reference levels and she takes these into account when designing the optimal contract and effort level. Because the principal offers a contract $w(x)$ at the initial period with full commitment, she cannot change $w(x)$ after the agent has accepted it. The agent either accepts and earns $w(x)$ or rejects and earns $\bar{u}$ according to her outside option. Once the agent accepts the contract, she chooses her optimal effort level a then production takes place. I assume that $F_a(x, a) < 0$, *i.e.*, effort produces a first-order stochastic dominant shift on output level. Moreover, I assume that $F(x, a)$ satisfies the monotone likelihood ratio property (MLRP), *i.e.*, its density satisfies $\frac{d}{dx} \frac{f_a(x,a)}{f(x,a)} \geq 0$. The agent gets paid $w(x)$ and the principal keeps the remainder $x - w(x)$. Assume that the principal evaluates her profit according to $V(x - w(x))$, which is a concave function $V'(.) > 0,\ V''(.) < 0$. The agent has reference-dependent preferences either about money or about effort level that are represented by a utility function $U = u(w) - \gamma(a) + \mu(.)$, where $u(w)$ is a concave consumption utility, $\gamma(a)$ a convex function that expresses the disutility of effort level a, and $\mu(.)$ the gain-loss function over either wage or effort level with the standard assumptions from Koszegi and Rabin [2006] as in Section (2.3).

2.4.1 Reference Dependence on Money

Assume that the agent has reference dependence over money, which is tied to her consumption utility,

$$U = u(w) - \gamma(a) + \mu(u(w(x)) - \overline{w}).$$

I use the general gain-loss function $\mu(.)$ defined in the previous section following Koszegi and Rabin [2006]. One of the crucial assumption is that $\mu''(y) > 0$ for $y < 0$ and $\mu''(y) < 0$ for $y > 0$, which implies that the gain-loss utility is convex over losses and concave over gains.

Assume that the agent has an exogenous non-random reference point for wage over $\overline{w}$. If the state of the world is such that her payment is greater than her reference salary $w(x) > \overline{w}$, then she experiences a gain, but otherwise she experiences a loss. The principal is aware of this when designing the optimal contract, therefore she has the following maximization problem:

$$\max_{w(.),a} E\left[V(x - w(x))|a\right]$$

$$E\left[u(w(x)) + \mu(u(w(x)) - u(\overline{w}))|a\right] - \gamma(a) \geq \overline{u}, \quad \text{(IR)}$$

$$a \in \arg\max_{a' \in A} E\left[u(w(x)) + \mu(u(w(x)) - u(\overline{w}))|a'\right] - \gamma(a'), \quad \text{(IC)}.$$

The individual rationality constraint (IR) expresses that the principal offers a contract that yields at least as much utility as the agent's outside option, $\overline{u}$, in expectation. If the contract did not satisfy this inequality – namely, in expectation the agent would not achieve $\overline{u}$ utility level – then the agent would not accept the contract since she would be better off by rejecting it and earning $\overline{u}$ utility with her outside option. The incentive compatibility constraint (IC) states the idea that the principal takes into account the agent's expected utility maximization.

The principal cannot observe and verify the effort level, a, chosen by the agent, therefore she designs a contract to incentivize the agent to choose the effort level a^* which maximizes the principal's objective function while satisfying (IR) and (IC).

I assume that the first-order approach is valid (see more about this in Laffont and Martimort [2001] and Stole [2001]), therefore I can replace the incentive compatibility constraint, with the corresponding first order condition which I get by differentiating the agent's objective function with respect to a

$$\int_{\underline{x}}^{\overline{x}} \left[u(w(x)) + \mu(u(w(x)) - w(\overline{w}))\right] f_a(x,a)dx - \gamma'(a) = 0. \quad \text{(ICFOC)}$$

The corresponding Lagrangian for the maximization problem then can be written as

$$\mathscr{L} =$$

$$= \int_{\underline{x}}^{\overline{x}} V(x-w(x))f(x,a)dx + \lambda\left[\int_{\underline{x}}^{\overline{x}} \left[u(w(x)) + \mu(u(w(x)) - u(\overline{w}))\right] f(x,a)dx - \gamma(a) - \overline{u}\right] +$$

$$+\beta\left[\int_{\underline{x}}^{\overline{x}} \left[u(w(x)) + \mu(u(w(x)) - w(\overline{w}))\right] f_a(x,a)dx - \gamma'(a)\right],$$

where $\lambda \geq 0, \beta$ are Lagrange multipliers for the(IR) and (ICFOC) constraints.

Theorem 9. *Assuming that the first-order approach is valid, the optimal contract can be characterized by the following equation*

$$\frac{V'(x-w(x))}{u'(w(x))} = \left[1 + \mu'(u(w(x)) - u(\overline{w}))\right]\left[\lambda + \beta\frac{f_a(x,a)}{f(x,a)}\right] \quad \forall x, \tag{2.4.1}$$

which holds for all $x \in X$. This condition simplifies to the standard Borch-rule Stole [2001] when the agent has the standard $U = u(w) - \gamma(a)$ utility function (i.e., $\mu(.) = 0$)

$$\frac{V'(x-w(x))}{u'(w(x))} = \left[\lambda + \beta\frac{f_a(x,a)}{f(x,a)}\right] \quad \forall x.$$

This theorem derives conditions for the optimal wage contract. After introducing uncertainty into the model, the optimal contract cannot be expressed directly. The above expression describe that for each state of the world the condition has to hold. Equation (2.4.1) describes the optimal wage scheme once the optimal a^* effort level is determined by taking first order conditions of $\mathscr{L}$ with respect to a.

Theorem (9) can be used for "naive" comparative static analysis that compares a contracting problem with an agent with reference-dependent preferences with an agent with preferences that can be represented by $U = u(w) - \gamma(a)$ utility function. If the "tightness" of the constraints can be ensured not to change significantly, *i.e.*, the Lagrange multipliers λ, β do not change much between the two problems, or alternatively the change of the multipliers is dominated by $\mu'(u(w(x)) - w(\overline{w}) > 0$, then it follows directly from Theorem (9) that the reference-dependent agent's wage contract dominates the standard agent's contract for all x. I assume that $\mu(y)$ is strictly increasing for all $y \neq 0$, thus $\mu'(y) > 0$ for all $y \neq 0$. Comparing the optimality conditions for the wage contract for the agent who has reference-dependent preferences and for agent who has standard preferences, the right hand side of equation (2.4.1) is strictly greater for the former. Therefore, the left hand side $\frac{V'(x-w(x))}{u'(w(x))}$ has to be greater for the problem with an agent who has reference-dependent preferences. The left-hand side increases only if the numerator increases and/or the denominator decreases, therefore $V'(x - w(x))$ must increase and $u'(w(x))$ must decrease, which is the case if $w(x)$ increases, since V and u are concave functions; therefore, if $w(x)$ increases then $x - w(x)$ decreases, $V'(x - w(x))$ increases and $u'(w(x))$ decreases.

This "naive" comparative static analysis avoids the issue that the Lagrange multipliers might change significantly between the two problem; therefore for a complete comparative static analysis that possibility must be considered.[5]

Assume the same piecewise linear gain-loss function as in Section (2.3) for the the rest of the subsection, which can be written compactly with an indicator function

$$\mu(y) = [(\eta - 1)\mathbb{1}\{y < 0\} + 1]\, \nu y,$$

where $\nu > 0$, $\eta > 1$ are parameters. With this specific gain-loss function the Lagrangian takes the following form

$$\mathscr{L} = \int_{\underline{x}}^{\overline{x}} V(x - w(x)) f(x,a) dx$$

$$+\lambda\Bigg[\int_{\underline{x}}^{\overline{x}} [u(w(x)) + ((\eta - 1)\mathbb{1}\{u(w(x)) - u(\overline{w}) < 0\} + 1)\, \nu(u(w(x)) - u(\overline{w}))]$$

$$\cdot f(x,a)dx - \gamma(a) - \overline{u}\Bigg]$$

$$+\beta\Bigg[\int_{\underline{x}}^{\overline{x}} [u(w(x)) + ((\eta - 1)\mathbb{1}\{u(w(x)) - u(\overline{w}) < 0\} + 1)\, \nu(u(w(x)) - u(\overline{w}))]$$

$$\cdot f_a(x,a)dx - \gamma'(a)\Bigg].$$

The next theorem analyzes the Lagrangian and establishes a comparative static result for the restricted problem where the effort level is not chosen.

Theorem 10. *Assume that $\overline{w}$ is such that*

$$\int_{\underline{x}}^{\overline{x}} ((\eta - 1)\mathbb{1}\{u(w(x)) - u(\overline{w}) < 0\} + 1)\, (u(w(x)) - u(\overline{w})) f(x,a) dx > 0$$

[5]For the full analysis it has to be shown that $\mathscr{L}$ is supermodular in $(a, w(.), \lambda, \beta, \nu,)$. However, the supermodularity of $\mathscr{L}$ does not follow without additional conditions. The problem is that it has to be guaranteed that $\mathscr{L}$ has increasing differences in $(w(.), a)$, which does not follow from the usual assumptions on the primitives of the model I use.

and $\int_{\underline{x}}^{\overline{x}} \left((\eta - 1)\mathbb{1}\{u(w(x)) - u(\overline{w}) < 0\} + 1\right)(u(w(x)) - u(\overline{w})) f_a(x, a)dx > 0$ *holds. Consider the restricted optimization problem that derives the optimal wage contract for implementing a given effort level a with an agent. Then the optimal wage contract,* $w(x)$*, is non-decreasing in* ν*. The optimal wage for implementing effort level a is higher for a problem with reference-dependent agent than with an agent with standard preferences that can be represented by the utility function* $U = u(w) - \gamma(a)$ *for all* $x \in X$*. If we denote the optimal contract for a problem with a reference-dependent agent by* $w^R(x)$ *and the optimal contract for a problem with the standard agent by* $w^S(x)$*, then*

$$w^R(x) \geq w^S(x) \; \forall x \in X.$$

Theorem 10 generalizes the results on the optimal incentive contracts from the full information case. The crucial difference is that this result with uncertainty is only proved for the constrained optimization problem. In this case, the principal maximizes her profit for a given effort level, which is not necessarily the optimal effort level. The result shows that if the agent is on the gain domain, then it is more costly to incentivize her to produce a given output level as she becomes more reference dependent. It also follows from this theorem, that the optimal wage for this type of agent (who is on the gain domain) is greater than for an agent with standard preferences, therefore it is more costly for the principal to hire such an agent.

The assumption $\int_{\underline{x}}^{\overline{x}} \left((\eta - 1)\mathbb{1}\{u(w(x)) - u(\overline{w}) < 0\} + 1\right)(u(w(x)) - u(\overline{w})) f(x, a)dx > 0$ guarantees that for all $\nu > 0$ the gain-loss part of utility is positive. This means that the reference wage level is sufficiently low, thus the utility gain experienced in the states of the world where $w(x) > \overline{w}$ in expectation outweighs the losses experienced when the state of the world is such that $w(x) < \overline{w}$. When this conditions holds, the theorem shows that it is more expensive to incentivize a reference-dependent agent to undertake effort level a compared to a standard agent. However, it is ambiguous whether the optimal effort level is higher or lower for a reference-dependent agent since these conditions do not ensure the supermodularity of $\mathscr{L}$ for the full model where a effort level is a choice variable.

2.4.2 Reference Dependence on Effort Level

I make the same assumptions as in subsection 2.4.1 except that in this subsection the agent has reference-dependent preferences over an exogenous $\overline{a}$ effort level

$$U = u(w) - \gamma(a) + \mu(\gamma(\overline{a}) - \gamma(a)).$$

If she undertakes more effort than her reference effort level $a > \overline{a}$, she experiences a utility loss, and her disutility level in absolute value is higher than the disutility from her reference effort level, otherwise she experiences a gain. The principal is aware of this when designing the optimal contract, therefore she faces the following maximization problem:

$$\max_{w(.),a} E\left[V(x - w(x))|a\right]$$

$$E\left[u(w(x))|a\right] - \gamma(a) + \mu(\gamma(\overline{a}) - \gamma(a)) \geq \overline{u}, \quad \text{(IR)}$$

$$a \in \arg\max_{a' \in A} E\left[u(w(x))|a'\right] - \gamma(a') + \mu(\gamma(\overline{a}) - \gamma(a')), \quad \text{(IC)}.$$

I assume that the first order approach is valid; therefore, I can replace the incentive compatibility constraint with the corresponding first order condition, which I get after differentiating the agent's objective function with respect to a

$$\int_{\underline{x}}^{\overline{x}} \left[u(w(x))\right] f_a(x,a)dx - \gamma'(a)\left[1 + \mu'(\gamma(\overline{a}) - \gamma(a))\right] = 0, \quad \text{(ICFOC)}$$

which guarantees that it is optimal for the agent to choose a^*, which the principal implements with the optimal contract. This is a constrained maximization problem with two constraints (IR) and (ICFOC), therefore I can write the Lagrangian for this problem as

$$\mathscr{L} = \int_{\underline{x}}^{\overline{x}} V(x-w(x))f(x,a)dx + \lambda\left[\int_{\underline{x}}^{\overline{x}} [u(w(x))]\, f(x,a)dx - \gamma(a) + \mu(\gamma(\overline{a}) - \gamma(a)) - \overline{u}\right] +$$
$$+\beta\left[\int_{\underline{x}}^{\overline{x}} [u(w(x))]\, f_a(x,a)dx - \gamma'(a)\left[1 + \mu'(\gamma(\overline{a}) - \gamma(a))\right]\right],$$

where $\lambda \geq 0, \beta$ are Lagrange multipliers for (IR) and (ICFOC) constraints.

Theorem 11. *Assuming that the first order approach is valid the optimal contract can be characterized by the following equation*

$$\frac{V'(x - w(x))}{u'(w(x))} = \lambda + \beta\frac{f_a(x,a)}{f(x,a)}.$$

Reference dependence on effort level does not directly influence the optimal wage contract for incentivizing the agent for a given effort level a, it has the same optimality condition as in a problem with a standard agent. But the reference dependence enters indirectly to the optimal wage contract through the Lagrange multipliers and the optimal effort level designed by the principal.

This result shows that the optimal wage contract does not directly depend on the agent's reference dependence when the agent is reference-dependent over effort and not over wealth. Whenever the tightness of the constraint does not change (*i.e.*, λ and β remain the same), then the optimal contract to implement a given effort level, a, is the same for an agent with reference dependence over effort than for an agent without reference-dependence. This is not the case when considering contracts that implement the optimal effort level. The optimal effort level is different for the problem with a reference-dependent agent because the principal takes into account the agent's reference dependence over effort level when determining the optimal effort level, a^*. The optimal effort level, a^*, enters the wage contract at $\frac{f_a(x,a^*)}{f(x,a^*)}$ term, which, in general, differs from the optimal effort level designed for a standard agent with utility function $U = u(w) - \gamma(a)$. Therefore, the optimal effort level is different when the principal interacts with a reference-dependent agent.

Theorem 12. *Assuming that the first order approach is valid the optimal effort level can be characterized by the following equation*

$$\int_{\underline{x}}^{\overline{x}} V(x - w(x)) f_a(x,a)dx + \beta\Bigg[\int_{\underline{x}}^{\overline{x}} [u(w(x))]\, f_{aa}(x,a)dx - \gamma''(a)\,[1 + \mu'(\gamma(\overline{a}) - \gamma(a))]$$
$$+(\gamma'(a))^2\mu''(\overline{a}) - \gamma(a))\Bigg] = 0$$

This theorem derives the first order condition for the optimal effort level under uncertainty for the principal's problem. The first term of the expression could be interpreted as marginal utility for the principal, which equals marginal expected profit with respect to the effort level. The second term could be interpreted as the marginal cost of having a higher effort level, which equals the additional expected compensation that the agent has to receive in expectation in order to increase her effort level. This conditions is fairly complicated compared to the full information case, however comparative static results can be derived by introducing further assumptions.

This condition for the optimal effort level further simplifies assuming a linear gain-loss function

$$\mu(y) = [(\eta - 1)\mathbb{1}\{y < 0\} + 1]\,\nu y,$$

where $\nu > 0$, $\eta > 1$ are parameters. After substituting $\mu'(\gamma(\overline{a}) - \gamma(a)) = [(\eta - 1)\mathbb{1}\{\gamma(\overline{a}) - \gamma(a) < 0\} + 1]\,\nu$ and $\mu''(\gamma(\overline{a}) - \gamma(a)) = 0$, the following expression for the optimal effort level results

$$\int_{\underline{x}}^{\overline{x}} V(x - w(x)) f_a(x,a)dx$$

$$+\beta\left[\int_{\underline{x}}^{\overline{x}}[u(w(x))]\,f_{aa}(x,a)dx-\gamma''(a)\left[1+\left[(\eta-1)\mathbb{1}\{\gamma(\overline{a})-\gamma(a)<0\}+1\right]\nu\right]\right]=0,$$

where $[(\eta-1)\mathbb{1}\{\gamma(\overline{a})-\gamma(a)<0\}+1]\,\nu > 0$ is a positive constant increasing in ν. It is either $\eta\nu$ or ν depending upon whether the agent undertakes more or less effort than her reservation level. Whether the optimal effort level increases or decreases depends on $f_a(x,a), f_{aa}(x,a), \gamma''(a)$. For example, if I assume a specific density function $f(x,a) = af_H(x) + (1-a)f_L(x))$ where $f_H(x)$ first-order stochastically dominates $f_L(x)$ then the condition for the optimal effort level further simplifies to

$$\int_{\underline{x}}^{\overline{x}} V(x-w(x))(f_H(x)-f_L(x))dx+\beta\left[-\gamma''(a)\left[1+\left[(\eta-1)\mathbb{1}\{\gamma(\overline{a})-\gamma(a)<0\}+1\right]\nu\right]\right]=0.$$

If the two integrals in the condition do not depend significantly on the optimal effort level through the wage contract, then the effect of increasing ν by the curvature of the marginal disutility function can be determined. For example, if it is linear $\gamma'''(a) = 0$ then the optimal effort level does not change dramatically as reference dependence increases. If the marginal disutility function is convex $\gamma'''(a) > 0$, then the optimal effort level decreases. If it is concave $\gamma'''(a) < 0$, then the optimal effort level increases as reference dependence ν goes up.

2.5 Conclusion

In the standard principal-agent model, an agent with standard separable utility function in effort and money interacts with a utility maximizing principal. In this paper, I analyze the principal-agent model with a loss-averse agent who has reference-dependent utility function either over money or effort level. Loss aversion indicates that the agent experiences losses more severely than gains when her behavior differs from the reference level.

Under full-information where the principal can observe and contract on effort, the optimal contract makes the agent indifferent between accepting the contract and her outside option, which yields a simple wage contract. With reference-dependent agents over money, the optimal effort level designed by the principal increases as the reference dependence of agents increases but does not depend directly on the agent's reference-wage level. The principal might be better off with an agent with more pronounced reference dependence because under some weak conditions it is cheaper for the principal to incentivize a given effort level. If the agent has reference-dependence over effort level, then the optimal effort level does not depend on the reference effort level directly but depends upon whether the reference effort level is above or below the optimal effort level. Moreover, it is cheaper to incentivize an agent for a higher effort level on the margin when she is currently below her reference point.

I discuss the predictions of the model for matching between employers and workers based on workers' reference dependence. Employers with projects where effort is crucial have incentives to influence the reference points of agents. The model predicts that these principals push agent's reference point upwards. Similarly, the employers would push the reference point upwards for agents whose marginal disutility of effort is low. However, principals with projects where the marginal product of effort is low have incentives to not influence agents' reference points if they are low, and push them downwards if the reference points are are high. A particular matching on the market between employers and workers is suggested. On the one hand, employers with projects where effort is crucial hire agents with high reference points, which yields high production and high profit. On the other hand, employers with projects where higher effort has a small effect on production hire workers with lower reference points and pay lower salary to them.

Under asymmetric information, I assume that the principal cannot observe the effort level. With an agent who has reference-dependent preferences over money, I find, that the salary paid to the agent in a given state of the world, determined by the optimal contract, does not directly depend on the reference wage level, but depends on whether the salary at that state of the world is above or below the reference wage level. If the reference wage level is such that the gain-loss utility part is positive in expectation, the agent experiences a gain. In this case I can show that the optimal wage contract for incentivizing the agent for a given effort level increases as the agent's utility becomes more reference-dependent. In particular, it costs more for the principal to urge an agent with reference dependence on money to undertake a particular effort level than an agent without reference dependence. For the problem where the principal employs an agent who has reference-dependent preferences over effort level, I show that the optimal wage contract is described by the same implicit equation (Borch-rule) as the standard optimal wage contract with an agent without reference-dependent preferences. Thus, reference dependence influences the wage contract indirectly through the individual rationality and incentive compatibility first-order conditions and through the optimal effort level. The effect of reference dependence on the optimal effort level is ambiguous. With some simplifying assumptions I pin down the effect of reference dependence using the curvature of the marginal disutility function of the agent.

Further research on the principal-agent model, both theoretical and experimental, could reveal intriguing findings on how different reference points are formed in this domain and how they affect behavior and contracts.

APPENDIX A

APPENDIX FOR CHAPTER 2: EFFORT PROVISION WITH EXPECTATION- AND HISTORY-BASED REFERENCE POINTS

A.1 Further Details on the History-based Reference Dependence Over Past Earnings Model

In the next case (c) I study the situation when the subject intends to stop at an accumulated earnings level which is above the fixed payment $we \geq< f$ and the current earnings level is smaller than her reference earnings level $we < \overline{we}$ then her expected utility is given by

$$U = \frac{we + f}{2} + \underbrace{\frac{1}{4}(\eta(we - f)) + \frac{1}{4}(\eta\lambda(f - we))}_{\text{expectation ref. dependence}} \tag{A.1.1}$$

$$+ \underbrace{\frac{1}{2}\eta\lambda(we - \overline{we}) + \frac{1}{2}(\eta\mathbb{1}_{f\geq\overline{we}} + \eta\lambda\mathbb{1}_{f<\overline{we}})(f - \overline{we})}_{\text{history-based ref. dependence}} - c(e),$$

The first order condition is

$$\frac{\partial U}{\partial e} = \frac{w}{2} + \underbrace{\frac{1}{4}\eta w - \frac{1}{4}\eta\lambda w}_{\kappa_c} + \underbrace{\frac{1}{2}\eta\lambda w}_{\Omega_c} - c'(e) = 0, \tag{A.1.2}$$

where $\Omega_c > 0$ term is the change of the marginal utility due to history-based reference dependence and loss-aversion. Compared to an agent without history-based reference point the agent's incentives to exercise effort is increased because of the additive positive $\Omega_c > 0$ term.

In the next case (d) I study the last possible case when the subject intends to stop at an accumulated earnings level which is above the fixed payment $we \geq f$

and the current earnings level is greater than equal to her reference earnings level $we \geq \overline{we}$ then her expected utility is given by

$$U = \frac{we + f}{2} + \underbrace{\frac{1}{4}(\eta(we - f)) + \frac{1}{4}(\eta\lambda(f - we))}_{\text{expectation ref. dependence}} \tag{A.1.3}$$

$$+ \underbrace{\frac{1}{2}\eta(we - \overline{we}) + \frac{1}{2}(\eta\mathbb{1}_{f \geq \overline{we}} + \eta\lambda\mathbb{1}_{f < \overline{we}})(f - \overline{we})}_{\text{history-based ref. dependence}} - c(e).$$

The first order condition is

$$\frac{\partial U}{\partial e} = \frac{w}{2} + \underbrace{\frac{1}{4}\eta w - \frac{1}{4}\eta\lambda w}_{\kappa_c} + \underbrace{\frac{1}{2}\eta w}_{\Omega_d} - c'(e) = 0, \tag{A.1.4}$$

where $\Omega_d > 0$ term is the change of the marginal utility due to the history-based reference dependence and due to her loss-aversion. Compared to an agent without history-based reference point the agent's incentives to exercise effort is increased because of the additive positive $\Omega_d > 0$ term, however, it is smaller overall than in case (c) where the $\lambda > 1$ loss-aversion parameter further pushes the incentives upwards.

A.2 Further Figures

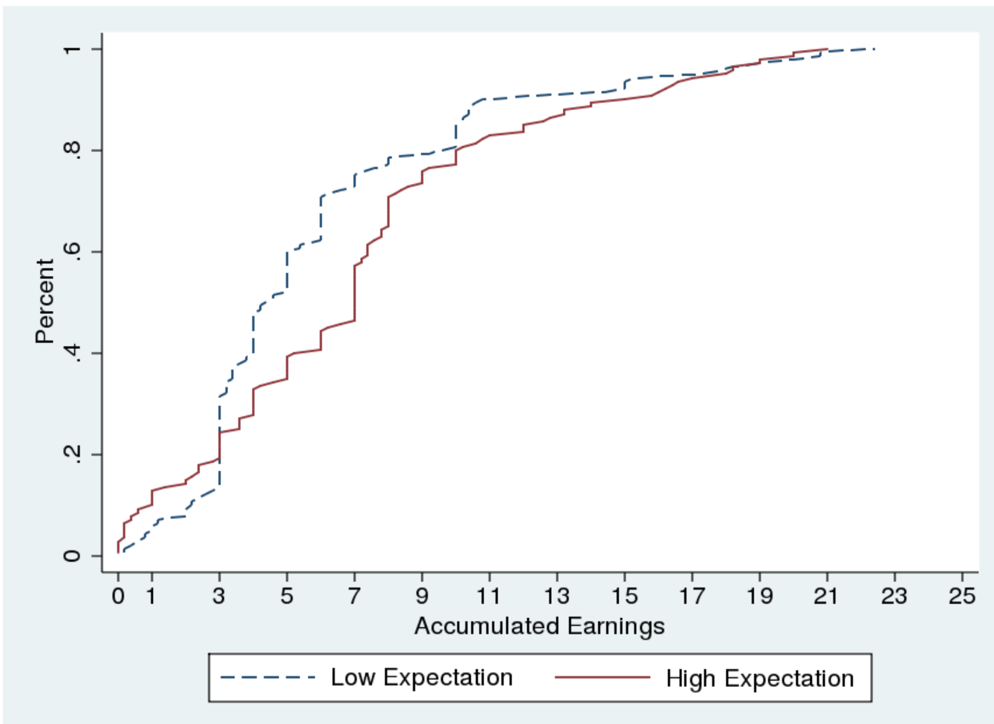

Figure A.1: Cumulative Distribution of of Second Stage Accumulated Acquired Earnings (in $) at Which a Subject Stopped for Low Expectation and High Expectation Treatments

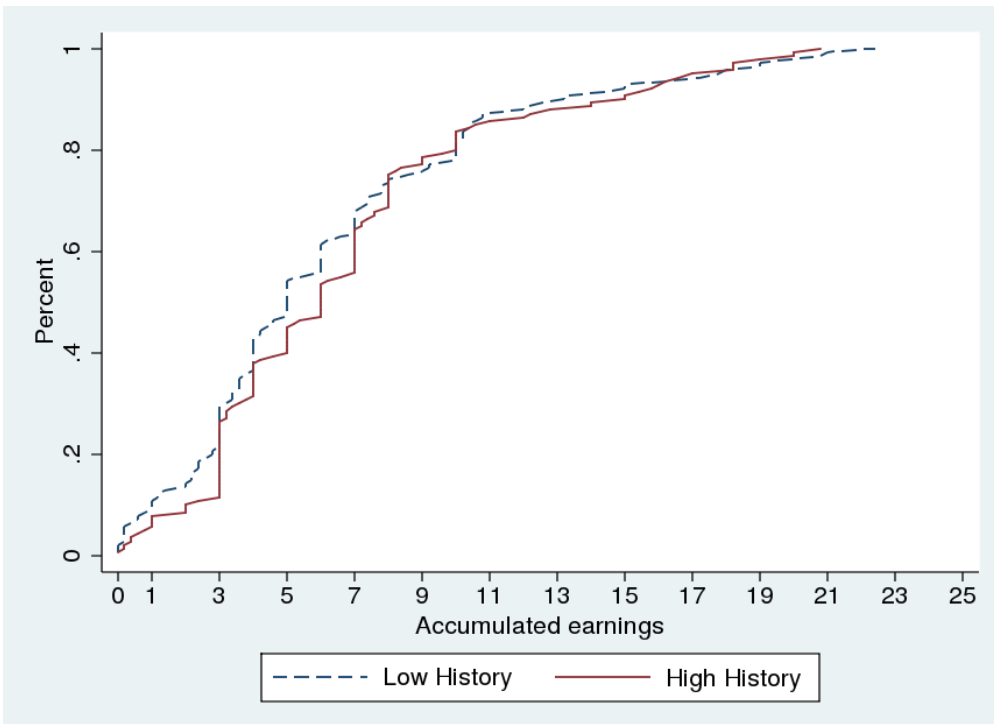

Figure A.2: Cumulative Distribution of Second Stage Accumulated Acquired Earnings (in $) at Which a Subject Stopped for Low History and High History Treatments

A.3 Further Regression Results

Table A.1: Treatment Difference in Effort (Acquired Earnings in \$) High Expectation Treatment Compared to Low Expectation Treatment

	(1)	(2)	(3) H_L	(4) H_L	(5) H_H	(6) H_H
	b/se	b/se	b/se	b/se	b/se	b/se
High Exp. treatment	1.10*	1.06*	0.91	1.17	1.29	1.16
	(0.58)	(0.58)	(0.84)	(0.86)	(0.80)	(0.83)
Productivity		0.04***		0.05**		0.03
		(0.02)		(0.02)		(0.02)
Female		0.14		-0.20		0.24
		(0.65)		(0.93)		(0.98)
Controls for temperature	No	Yes	No	Yes	No	Yes
Controls for time of day	No	Yes	No	Yes	No	Yes
Constant	6.03***	8.09***	5.90***	7.34***	6.17***	8.45***
	(0.39)	(1.38)	(0.55)	(2.11)	(0.56)	(1.86)
Observations	280	280	140	140	140	140
R^2	0.013	0.048	0.008	0.065	0.019	0.042

Notes: Detailed notes are on page 107 of section A.4.4 of the Appendix.

Standard errors are in parentheses and estimated using the heteroscedasticity-consistent standard error estimator of White [1980].

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

Table A.2: Treatment Difference in Effort (Time Spent Working in Minutes) High Expectation Treatment Compared to Low Expectation Treatment

	(1)	(2)	(3) H_L	(4) H_L	(5) H_H	(6) H_H
	b/se	b/se	b/se	b/se	b/se	b/se
High Expectation treatment	3.50*	3.47*	2.96	3.85	4.04	4.18
	(1.93)	(1.95)	(2.82)	(2.91)	(2.66)	(2.76)
Productivity		0.07		0.10		0.01
		(0.05)		(0.06)		(0.08)
Female		0.37		-1.06		-0.19
		(2.17)		(3.16)		(3.29)
Controls for temperature	No	Yes	No	Yes	No	Yes
Controls for time of day	No	Yes	No	Yes	No	Yes
Constant	24.19***	26.91***	23.63***	23.46***	24.75***	29.12***
	(1.31)	(4.57)	(1.89)	(6.75)	(1.82)	(6.60)
Observations	280	280	140	140	140	140
R^2	0.012	0.022	0.008	0.051	0.017	0.032

Notes: Detailed notes are on page 108 of section A.4.5 of the Appendix.

Standard errors are in parentheses and estimated using the heteroscedasticity-consistent standard error estimator of White [1980].

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

Table A.3: Treatment Difference in Effort (Tobit Regression for Time Spent Working in Minutes) High Expectation Treatment Compared to Low Expectation Treatment

	(1)	(2)	(3) H_L	(4) H_L	(5) H_H	(6) H_H
	model	model	model	model	model	model
	b/se	b/se	b/se	b/se	b/se	b/se
High Expectation treatment	3.68*	3.63*	2.99	3.91	4.36	4.45
	(2.09)	(2.09)	(3.06)	(3.04)	(2.85)	(2.86)
Productivity		0.09		0.11		0.03
		(0.06)		(0.08)		(0.09)
Female		0.18		-1.40		-0.24
		(2.24)		(3.16)		(3.34)
Controls for temperature	No	Yes	No	Yes	No	Yes
Controls for time of day	No	Yes	No	Yes	No	Yes
Constant	24.65***	28.56***	24.21***	25.18***	25.10***	30.64***
	(1.48)	(4.72)	(2.16)	(6.62)	(2.01)	(6.82)
Observations	280	280	140	140	140	140
Pseudo R^2	0.001	0.003	0.001	0.006	0.002	0.004

Notes: Detailed notes are on page 109 of section A.4.6 of the Appendix.

Standard errors are in parentheses.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

Table A.4: Treatment Difference in Effort (Acquired Earnings in $) High Expectation Treatment Compared to Low Expectation Treatment (Subjects Without Productivity Dropped)

	(1)	(2)	(3) H_L	(4) H_L	(5) H_H	(6) H_H
	b/se	b/se	b/se	b/se	b/se	b/se
High Expectation treatment	1.36**	1.35**	1.15	1.38	1.56*	1.48*
	(0.60)	(0.59)	(0.90)	(0.91)	(0.80)	(0.82)
Productivity		0.05***		0.05**		0.03
		(0.02)		(0.02)		(0.02)
Female		-0.32		-0.50		-0.38
		(0.69)		(1.02)		(1.01)
Controls for temperature	No	Yes	No	Yes	No	Yes
Controls for time of day	No	Yes	No	Yes	No	Yes
Constant	6.02***	8.58***	5.89***	8.31***	6.14***	8.53***
	(0.40)	(1.43)	(0.58)	(2.21)	(0.54)	(1.93)
Observations	256	256	127	127	129	129
R^2	0.020	0.068	0.013	0.081	0.029	0.063

Notes: Detailed notes are on page 110 of section A.4.7 of the Appendix.

Standard errors are in parentheses and estimated using the heteroscedasticity-consistent standard error estimator of White [1980].

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

Table A.5: Treatment Difference in Effort (Time Spent Working in Minutes) High Expectation Treatment Compared to Low Expectation Treatment (Subjects Without Productivity Dropped)

	(1)	(2)	(3) H_L	(4) H_L	(5) H_H	(6) H_H
	b/se	b/se	b/se	b/se	b/se	b/se
High Expectation treatment	3.91*	3.93*	2.84	3.48	4.93*	5.10*
	(2.01)	(2.01)	(3.00)	(3.04)	(2.68)	(2.77)
Productivity		0.07		0.10		0.01
		(0.05)		(0.06)		(0.08)
Female		-0.24		-1.35		-0.80
		(2.30)		(3.48)		(3.36)
Controls for temperature	No	Yes	No	Yes	No	Yes
Controls for time of day	No	Yes	No	Yes	No	Yes
Constant	23.87***	27.14***	23.69***	25.83***	24.05***	27.32***
	(1.34)	(4.73)	(1.99)	(7.05)	(1.81)	(6.78)
Observations	256	256	127	127	129	129
R^2	0.015	0.031	0.007	0.054	0.026	0.043

Notes: Detailed notes are on page 111 of section A.4.8 of the Appendix.

Standard errors are in parentheses and estimated using the heteroscedasticity-consistent standard error estimator of White [1980].

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

Table A.6: Treatment Difference in Effort (Tobit Regression for Time Spent Working in Minutes) High Expectation Treatment Compared to Low Expectation Treatment (Subjects Without Productivity Dropped)

	(1)	(2)	(3) H_L	(4) H_L	(5) H_H	(6) H_H
	model	model	model	model	model	model
	b/se	b/se	b/se	b/se	b/se	b/se
High Expectation Treatment	4.14*	4.16*	2.93	3.63	5.29*	5.41*
	(2.18)	(2.17)	(3.27)	(3.24)	(2.90)	(2.90)
Productivity		0.09		0.12		0.03
		(0.06)		(0.08)		(0.09)
Female		-0.53		-1.87		-0.86
		(2.37)		(3.45)		(3.44)
Controls for temperature	No	Yes	No	Yes	No	Yes
Controls for time of day	No	Yes	No	Yes	No	Yes
Constant	24.35***	28.91***	24.32***	27.89***	24.40***	28.73***
	(1.52)	(4.83)	(2.26)	(6.97)	(2.02)	(6.81)
Observations	256	256	127	127	129	129
Pseudo R^2	0.002	0.004	0.001	0.007	0.003	0.005

Notes: Detailed notes are on page 112 of section A.4.9 of the Appendix.

Standard errors are in parentheses.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

Table A.7: Treatment Difference in Effort (Acquired Earnings in $) High History Treatment Compared to Low History Treatment

	(1)	(2)	(3) E_L	(4) E_L	(5) E_H	(6) E_H
	b/se	b/se	b/se	b/se	b/se	b/se
High History Treatment	0.46	0.19	0.27	0.17	0.65	0.21
	(0.58)	(0.60)	(0.79)	(0.81)	(0.85)	(0.94)
Productivity		0.04***		0.03		0.06**
		(0.02)		(0.02)		(0.03)
Female		0.18		0.03		0.16
		(0.65)		(0.87)		(1.00)
Controls for temperature	No	Yes	No	Yes	No	Yes
Controls for time of day	No	Yes	No	Yes	No	Yes
Constant	6.35***	8.58***	5.90***	7.48***	6.81***	9.86***
	(0.42)	(1.43)	(0.55)	(2.02)	(0.63)	(2.08)
Observations	280	280	140	140	140	140
R^2	0.002	0.036	0.001	0.034	0.004	0.054

Notes: Detailed notes are on page 113 of section A.4.10 of the Appendix.

Standard errors are in parentheses and estimated using the heteroscedasticity-consistent standard error estimator of White [1980].

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

Table A.8: Treatment Difference in Effort (Time Spent Working in Minutes)
High History Treatment Compared to Low History Treatment

	(1)	(2)	(3) E_L	(4) E_L	(5) E_H	(6) E_H
	b/se	b/se	b/se	b/se	b/se	b/se
High History Treatment	1.66	1.33	1.12	1.26	2.20	1.05
	(1.94)	(2.02)	(2.63)	(2.71)	(2.85)	(3.07)
Productivity		0.07		-0.01		0.16**
		(0.05)		(0.06)		(0.08)
Female		0.38		-0.97		1.77
		(2.20)		(3.00)		(3.37)
Controls for temperature	No	Yes	No	Yes	No	Yes
Controls for time of day	No	Yes	No	Yes	No	Yes
Constant	25.11***	28.10***	23.63***	23.21***	26.59***	33.88***
	(1.41)	(4.62)	(1.89)	(6.87)	(2.10)	(6.38)
Observations	280	280	140	140	140	140
R^2	0.003	0.012	0.001	0.009	0.004	0.052

Notes: Detailed notes are on page 113 of section A.4.11 of the Appendix.

Standard errors are in parentheses and estimated using the heteroscedasticity-consistent standard error estimator of White [1980].

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

Table A.9: Treatment Difference in Effort (Tobit Regression for Time Spent Working in Minutes) High History Treatment Compared to Low History Treatment

	(1) model b/se	(2) model b/se	(3) E_L model b/se	(4) E_L model b/se	(5) E_H model b/se	(6) E_H model b/se
High History Treatment	1.62	1.24	0.95	1.08	2.33	1.14
	(2.10)	(2.15)	(2.80)	(2.83)	(3.11)	(3.21)
Productivity		0.08		0.00		0.17*
		(0.06)		(0.08)		(0.09)
Female		0.22		-1.11		1.62
		(2.27)		(3.04)		(3.42)
Controls for temperature	No	Yes	No	Yes	No	Yes
Controls for time of day	No	Yes	No	Yes	No	Yes
Constant	25.68***	29.90***	24.13***	24.72***	27.21***	35.89***
	(1.49)	(4.76)	(1.98)	(6.58)	(2.20)	(6.81)
Observations	280	280	140	140	140	140
Pseudo R^2	0.000	0.002	0.000	0.001	0.000	0.007

Notes: Detailed notes are on page 114 of section A.4.12 of the Appendix.

Standard errors are in parentheses.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

Table A.10: Treatment Difference in Effort (Acquired Earnings in $) High History Treatment Compared to Low History Treatment (Subjects Without Productivity Dropped)

	(1)	(2)	(3) E_L	(4) E_L	(5) E_H	(6) E_H
	b/se	b/se	b/se	b/se	b/se	b/se
High History Treatment	0.45	0.20	0.25	0.15	0.65	0.18
	(0.60)	(0.63)	(0.80)	(0.82)	(0.90)	(0.99)
Productivity		0.04***		0.03*		0.06**
		(0.02)		(0.02)		(0.03)
Female		-0.26		-0.45		-0.18
		(0.70)		(0.92)		(1.07)
Controls for temperature	No	Yes	No	Yes	No	Yes
Controls for time of day	No	Yes	No	Yes	No	Yes
Constant	6.45***	9.16***	5.89***	7.87***	7.05***	10.62***
	(0.45)	(1.50)	(0.58)	(2.07)	(0.69)	(2.22)
Observations	256	256	132	132	124	124
R^2	0.002	0.048	0.001	0.042	0.004	0.071

Notes: Detailed notes are on page 115 of section A.4.13 of the Appendix.

Standard errors are in parentheses and estimated using the heteroscedasticity-consistent standard error estimator of White [1980].

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

Table A.11: Treatment Difference in Effort (Time Spent Working in Minutes) High History Treatment Compared to Low History Treatment (Subjects Without Productivity Dropped)

	(1)	(2)	(3) E_L	(4) E_L	(5) E_H	(6) E_H
	b/se	b/se	b/se	b/se	b/se	b/se
High History Treatment	1.40	1.02	0.36	0.35	2.45	1.18
	(2.01)	(2.10)	(2.69)	(2.77)	(2.99)	(3.20)
Productivity		0.07		-0.01		0.15**
		(0.05)		(0.06)		(0.08)
Female		-0.14		-1.10		1.21
		(2.33)		(3.19)		(3.51)
Controls for temperature	No	Yes	No	Yes	No	Yes
Controls for time of day	No	Yes	No	Yes	No	Yes
Constant	25.05***	28.55***	23.69***	23.25***	26.53***	34.41***
	(1.49)	(4.83)	(1.99)	(7.03)	(2.25)	(6.72)
Observations	256	256	132	132	124	124
R^2	0.002	0.017	0.000	0.017	0.005	0.060

Notes: Detailed notes are on page 116 of section A.4.14 of the Appendix.

Standard errors are in parentheses and estimated using the heteroscedasticity-consistent standard error estimator of White [1980].

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

Table A.12: Treatment Difference in Effort (Tobit Regression for Time Spent Working in Minutes) High History Treatment Compared to Low History Treatment (Subjects Without Productivity Dropped)

	(1) model b/se	(2) model b/se	(3) E_L model b/se	(4) E_L model b/se	(5) E_H model b/se	(6) E_H model b/se
High History Treatment	1.35	0.91	0.18	0.15	2.58	1.24
	(2.20)	(2.24)	(2.89)	(2.91)	(3.29)	(3.36)
Productivity		0.08		0.01		0.17*
		(0.06)		(0.08)		(0.09)
Female		-0.39		-1.30		0.97
		(2.40)		(3.18)		(3.68)
Controls for temperature	No	Yes	No	Yes	No	Yes
Controls for time of day	No	Yes	No	Yes	No	Yes
Constant	25.68***	30.52***	24.22***	24.79***	27.24***	36.71***
	(1.56)	(4.92)	(2.04)	(6.61)	(2.35)	(7.19)
Observations	256	256	132	132	124	124
Pseudo R^2	0.000	0.002	0.000	0.002	0.001	0.008

Notes: Detailed notes are on page 117 of section A.4.15 of the Appendix.

Standard errors are in parentheses.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

Table A.13: Tendency to Stop at the Fixed Payment for Subjects with Valid Productivity (with High Expectation Treatment and High History Treatment Variables)

	(1)		(2)	
	3	7	3	7
	b/se	b/se	b/se	b/se
High Expectation Treatment	-1.40***	1.16*	-1.43***	1.22**
	(0.48)	(0.59)	(0.48)	(0.61)
High History Treatment	0.69*	0.99*	0.70*	1.28**
	(0.41)	(0.55)	(0.43)	(0.60)
Productivity			0.00	-0.02*
			(0.01)	(0.01)
Female			-0.05	0.15
			(0.45)	(0.64)
Controls for temperature	No	No	Yes	Yes
Controls for time of day	No	No	Yes	Yes
Constant	-1.84***	-3.83***	-1.63*	-6.24***
	(0.34)	(0.64)	(0.96)	(1.53)
Observations	256		256	
Pseudo R^2	0.073		0.104	

Notes: Detailed notes are on page 118 of section A.4.16 of the Appendix.

Standard errors are in parentheses.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

A.4 Notes for Regression Results

This section contains notes for the tables with regression results.

A.4.1 Notes for Table 1.6 on page 39

For columns 1 – 6 the dependent variable is the level of accumulated acquired earnings (in $) at which a subject stopped working in the second stage. For columns 7 – 8 the dependent variable is the time (in minutes) spent in the second stage of the experiment. Columns 1 – 8 report results from OLS regressions. The main explanatory variable is the high expectation treatment dummy. The proxy variable for productivity is the time (in seconds multiplied by -1) that subjects needed to correctly solve a table during the practice round. There were subjects who did not solve any table correctly and, thus, these subjects don't have a valid productivity. Altogether, 24 subjects have no valid productivity; for them, I use the average productivity as a proxy for productivity. Female dummy is 1 if the subject is female, and 0 if male. Temperature controls include a dummy variable that is 1 if the the average temperature of the day is less than 59 degrees Fahrenheit, and the other dummy variable is 1 if the the average temperature of the day is between 59 and 68 degrees Fahrenheit. Time of the day controls include a dummy variable that is 1 if the the starting time of the experiment is before 1pm, and the other dummy variable is 1 if the the starting time of the experiment is between 1pm and 3:12pm. Columns 1 – 2 and 7 – 8 contains the estimation results based on the full sample. Column 3 contains the estimation results based on the subsample of subjects in the low history treatment. Column 4 contains the estimation results based on the subsample of subjects in the high history treatment Columns 5 – 6 contains the estimation results based on the full sample but without the 24 subjects with no valid productivity.

A.4.2 Notes for Table 1.7 on page 43

The table reports results of multinomial logit regressions. The dependent variable indicates three outcomes: “stop at \$3”, “stop at \$7”, and “stop elsewhere” which is the reference category. The table contains estimates based on the full sample. The first column of the table contains the parameter estimates of model with the high expectation and high history treatment dummies only. Column 3 and 4 contain the estimates of the model with additional controls. The proxy variable for productivity is the time (in seconds multiplied by -1) that subjects needed to correctly solve a table during the practice round. There were subjects who did not solve any table correctly, thus, these subjects don’t have a valid productivity. Altogether, 24 subjects have no valid productivity; for them, I use the average productivity as a proxy for productivity.

A.4.3 Notes for Table 1.8 on page 47

For columns 1 – 6 the dependent variable is the level of accumulated acquired earnings (in \$) at which a subject stopped working in the second stage. For columns 7 – 8 the dependent variable is the time (in minutes) spent in the second stage of the experiment. Columns 1 – 8 report results from OLS regressions. The main explanatory variable is the high history treatment dummy. The proxy variable for productivity is the time (in seconds multiplied by -1) that subjects needed to correctly solve a table during the practice round. There were subjects who did not solve any table correctly and, thus, these subjects don't have a valid productivity. Altogether, 24 subjects have no valid productivity; for them, I use the average productivity as a proxy for productivity. Female dummy is 1 if the subject is female, and 0 if male. Temperature controls include a dummy variable that is 1 if the the average temperature of the day is less than 59 degrees Fahrenheit, and the other dummy variable is 1 if the the average temperature of the day is between 59 and 68 degrees Fahrenheit. Time of the day controls include a dummy variable that is 1 if the the starting time of the experiment is before 1pm, and the other dummy variable is 1 if the the starting time of the experiment is between 1pm and 3:12pm. Columns 1 – 2 and 7 – 8 contains the estimation results based on the full sample. Column 3 contains the estimation results based on the subsample of subjects in the low expectation treatment. Column 4 contains the estimation results based on the subsample of subjects in the high expectation treatment Columns 5 – 6 contains the estimation results based on the full sample but without the 24 subjects with no valid productivity.

A.4.4 Notes for Table A.1 on page 92

For columns 1 – 6 the dependent variable is the level of accumulated acquired earnings (in $) at which a subject stopped working in the second stage. Columns 1 – 6 report results from OLS regressions. The main explanatory variable is the high expectation treatment dummy. The proxy variable for productivity is the time (in seconds multiplied by -1) that subjects needed to correctly solve a table during the practice round. There were subjects who did not solve any table correctly, thus these subjects don't have a valid productivity. Altogether, 24 subjects have no valid productivity, for them, I use the average productivity as a proxy for productivity. Female dummy is 1 if the subject is female, and 0 if male. Temperature controls include a dummy variable that is 1 if the the average temperature of the day is less than 59 Fahrenheit, and the other dummy variable is 1 if the the average temperature of the day is between 59 and 68 Fahrenheit. Time of the day controls include a dummy variable that is 1 if the the starting time of the experiment is before 1pm, and the other dummy variable is 1 if the the starting time of the experiment is between 1pm and 3:12pm. Columns 1 – 2 contain the estimation results based on the full sample. Columns 3 – 4 contain the estimation results based on the subsample of subjects in the low history treatment. Columns 4 – 5 contain the estimation results based on the subsample of subjects in the high history treatment.

A.4.5 Notes for Table A.2 on page 93

For columns 1 – 6 the dependent variable is the time (in minutes) spent in the second stage of the experiment. Columns 1 – 6 report results from OLS regressions. The main explanatory variable is the high expectation treatment dummy. The proxy variable for productivity is the time (in seconds multiplied by -1) that subjects needed to correctly solve a table during the practice round. There were subjects who did not solve any table correctly, thus these subjects don't have a valid productivity. Altogether, 24 subjects have no valid productivity, for them, I use the average productivity as a proxy for productivity. Female dummy is 1 if the subject is female, and 0 if male. Temperature controls include a dummy variable that is 1 if the the average temperature of the day is less than 59 Fahrenheit, and the other dummy variable is 1 if the the average temperature of the day is between 59 and 68 Fahrenheit. Time of the day controls include a dummy variable that is 1 if the the starting time of the experiment is before 1pm, and the other dummy variable is 1 if the the starting time of the experiment is between 1pm and 3:12pm. Columns 1 – 2 contain the estimation results based on the full sample. Columns 3 – 4 contain the estimation results based on the subsample of subjects in the low history treatment. Columns 4 – 5 contain the estimation results based on the subsample of subjects in the high history treatment.

A.4.6 Notes for Table A.3 on page 94

For columns 1 – 6 the dependent variable is the time (in minutes) spent in the second stage of the experiment. Columns 1 – 6 report results from Tobit censored regressions (time spent at the second stage is censored from below at 0 and from above at 60). The main explanatory variable is the high expectation treatment dummy. The proxy variable for productivity is the time (in seconds multiplied by -1) that subjects needed to correctly solve a table during the practice round. There were subjects who did not solve any table correctly, thus these subjects don't have a valid productivity. Altogether, 24 subjects have no valid productivity, for them, I use the average productivity as a proxy for productivity. Female dummy is 1 if the subject is female, and 0 if male. Temperature controls include a dummy variable that is 1 if the the average temperature of the day is less than 59 Fahrenheit, and the other dummy variable is 1 if the the average temperature of the day is between 59 and 68 Fahrenheit. Time of the day controls include a dummy variable that is 1 if the the starting time of the experiment is before 1pm, and the other dummy variable is 1 if the the starting time of the experiment is between 1pm and 3:12pm. Columns 1 – 2 contain the estimation results based on the full sample. Columns 3 – 4 contain the estimation results based on the subsample of subjects in the low history treatment. Columns 4 – 5 contain the estimation results based on the subsample of subjects in the high history treatment.

A.4.7 Notes for Table A.4 on page 95

For columns 1 – 6 the dependent variable is the level of accumulated acquired earnings (in $) at which a subject stopped working in the second stage. Columns 1 – 6 report results from OLS regressions. The main explanatory variable is the high expectation treatment dummy. The proxy variable for productivity is the time (in seconds multiplied by -1) that subjects needed to correctly solve a table during the practice round. There were subjects who did not solve any table correctly, thus these subjects don't have a valid productivity. Altogether, 24 subjects have no valid productivity, for them, I use the average productivity as a proxy for productivity. Female dummy is 1 if the subject is female, and 0 if male. Temperature controls include a dummy variable that is 1 if the the average temperature of the day is less than 59 Fahrenheit, and the other dummy variable is 1 if the the average temperature of the day is between 59 and 68 Fahrenheit. Time of the day controls include a dummy variable that is 1 if the the starting time of the experiment is before 1pm, and the other dummy variable is 1 if the the starting time of the experiment is between 1pm and 3:12pm. Columns 1 – 2 contain the estimation results based on the full sample without the 24 subjects who have no valid productivity. Columns 3 – 4 contain the estimation results based on the subsample of subjects in the low history treatment without subjects in the low history treatment who have no valid productivity. Columns 4 – 5 contain the estimation results based on the subsample of subjects in the high history treatment without subjects in the high history treatment who have no valid productivity.

A.4.8 Notes for Table A.5 on page 96

For columns 1 – 6 the dependent variable is the time (in minutes) spent in the second stage of the experiment. Columns 1 – 6 report results from OLS regressions. The main explanatory variable is the high expectation treatment dummy. The proxy variable for productivity is the time (in seconds multiplied by -1) that subjects needed to correctly solve a table during the practice round. There were subjects who did not solve any table correctly, thus these subjects don't have a valid productivity. Altogether, 24 subjects have no valid productivity, for them, I use the average productivity as a proxy for productivity. Female dummy is 1 if the subject is female, and 0 if male. Temperature controls include a dummy variable that is 1 if the the average temperature of the day is less than 59 Fahrenheit, and the other dummy variable is 1 if the the average temperature of the day is between 59 and 68 Fahrenheit. Time of the day controls include a dummy variable that is 1 if the the starting time of the experiment is before 1pm, and the other dummy variable is 1 if the the starting time of the experiment is between 1pm and 3:12pm. Columns 1 – 2 contain the estimation results based on the full sample without the 24 subjects who have no valid productivity. Columns 3 – 4 contain the estimation results based on the subsample of subjects in the low history treatment without subjects in the low history treatment who have no valid productivity. Columns 4 – 5 contain the estimation results based on the subsample of subjects in the high history treatment without subjects in the high history treatment who have no valid productivity.

A.4.9 Notes for Table A.6 on page 97

For columns 1 – 6 the dependent variable is the time (in minutes) spent in the second stage of the experiment. Columns 1 – 6 report results from Tobit censored regressions (time spent at the second stage is censored from below at 0 and from above at 60). The main explanatory variable is the high expectation treatment dummy. The proxy variable for productivity is the time (in seconds multiplied by -1) that subjects needed to correctly solve a table during the practice round. There were subjects who did not solve any table correctly, thus these subjects don't have a valid productivity. Altogether, 24 subjects have no valid productivity, for them, I use the average productivity as a proxy for productivity. Female dummy is 1 if the subject is female, and 0 if male. Temperature controls include a dummy variable that is 1 if the the average temperature of the day is less than 59 Fahrenheit, and the other dummy variable is 1 if the the average temperature of the day is between 59 and 68 Fahrenheit. Time of the day controls include a dummy variable that is 1 if the the starting time of the experiment is before 1pm, and the other dummy variable is 1 if the the starting time of the experiment is between 1pm and 3:12pm. Columns 1 – 2 contain the estimation results based on the full sample without the 24 subjects who have no valid productivity. Columns 3 – 4 contain the estimation results based on the subsample of subjects in the low history treatment without subjects in the low history treatment who have no valid productivity. Columns 4 – 5 contain the estimation results based on the subsample of subjects in the high history treatment without subjects in the high history treatment who have no valid productivity.

A.4.10 Notes for Table A.7 on page 98

For columns 1 – 6 the dependent variable is the level of accumulated acquired earnings (in $) at which a subject stopped working in the second stage. Columns 1 – 6 report results from OLS regressions. The main explanatory variable is the high history treatment dummy. The proxy variable for productivity is the time (in seconds multiplied by -1) that subjects needed to correctly solve a table during the practice round. There were subjects who did not solve any table correctly, thus these subjects don't have a valid productivity. Altogether, 24 subjects have no valid productivity, for them, I use the average productivity as a proxy for productivity. Female dummy is 1 if the subject is female, and 0 if male. Temperature controls include a dummy variable that is 1 if the the average temperature of the day is less than 59 Fahrenheit, and the other dummy variable is 1 if the the average temperature of the day is between 59 and 68 Fahrenheit. Time of the day controls include a dummy variable that is 1 if the the starting time of the experiment is before 1pm, and the other dummy variable is 1 if the the starting time of the experiment is between 1pm and 3:12pm. Columns 1 – 2 contain the estimation results based on the full sample. Columns 3 – 4 contain the estimation results based on the subsample of subjects in the low expectation treatment. Columns 4 – 5 contain the estimation results based on the subsample of subjects in the high expectation treatment.

A.4.11 Notes for Table A.8 on page 99

For columns 1 – 6 the dependent variable is the time (in minutes) spent in the second stage of the experiment. Columns 1 – 6 report results from OLS regressions. The main explanatory variable is the high history treatment dummy. The proxy variable for productivity is the time (in seconds multiplied by -1) that subjects needed to correctly solve a table during the practice round. There were subjects who did not solve any table correctly, thus these subjects don't have a valid productivity. Altogether, 24 subjects have no valid productivity, for them, I use the average productivity as a proxy for productivity. Female dummy is 1 if the subject is female, and 0 if male. Temperature controls include a dummy variable that is 1 if the the average temperature of the day is less than 59 Fahrenheit, and the other dummy variable is 1 if the the average temperature of the day is between 59 and 68 Fahrenheit. Time of the day controls include a dummy variable that is 1 if the the starting time of the experiment is before 1pm, and the other dummy variable is 1 if the the starting time of the experiment is between 1pm and 3:12pm. Columns 1 – 2 contain the estimation results based on the full sample. Columns 3 – 4 contain the estimation results based on the subsample of subjects in the low expectation treatment. Columns 4 – 5 contain the estimation results based on the subsample of subjects in the high expectation treatment.

A.4.12 Notes for Table A.9 on page 100

For columns 1 – 6 the dependent variable is the time (in minutes) spent in the second stage of the experiment. Columns 1 – 6 report results from Tobit censored regressions (time spent at the second stage is censored from below at 0 and from above at 60). The main explanatory variable is the high history treatment dummy. The proxy variable for productivity is the time (in seconds multiplied by -1) that subjects needed to correctly solve a table during the practice round. There were subjects who did not solve any table correctly, thus these subjects don't have a valid productivity. Altogether, 24 subjects have no valid productivity, for them, I use the average productivity as a proxy for productivity. Female dummy is 1 if the subject is female, and 0 if male. Temperature controls include a dummy variable that is 1 if the the average temperature of the day is less than 59 Fahrenheit, and the other dummy variable is 1 if the the average temperature of the day is between 59 and 68 Fahrenheit. Time of the day controls include a dummy variable that is 1 if the the starting time of the experiment is before 1pm, and the other dummy variable is 1 if the the starting time of the experiment is between 1pm and 3:12pm. Columns 1 – 2 contain the estimation results based on the full sample. Columns 3 – 4 contain the estimation results based on the subsample of subjects in the low expectation treatment. Columns 4 – 5 contain the estimation results based on the subsample of subjects in the high expectation treatment.

A.4.13 Notes for Table A.10 on page 101

For columns 1 – 6 the dependent variable is the level of accumulated acquired earnings (in $) at which a subject stopped working in the second stage. Columns 1 – 6 report results from OLS regressions. The main explanatory variable is the high history treatment dummy. The proxy variable for productivity is the time (in seconds multiplied by -1) that subjects needed to correctly solve a table during the practice round. There were subjects who did not solve any table correctly, thus these subjects don't have a valid productivity. Altogether, 24 subjects have no valid productivity, for them, I use the average productivity as a proxy for productivity. Female dummy is 1 if the subject is female, and 0 if male. Temperature controls include a dummy variable that is 1 if the the average temperature of the day is less than 59 Fahrenheit, and the other dummy variable is 1 if the the average temperature of the day is between 59 and 68 Fahrenheit. Time of the day controls include a dummy variable that is 1 if the the starting time of the experiment is before 1pm, and the other dummy variable is 1 if the the starting time of the experiment is between 1pm and 3:12pm. Columns 1 – 2 contain the estimation results based on the full sample without the 24 subjects who have no valid productivity. Columns 3 – 4 contain the estimation results based on the subsample of subjects in the low expectation treatment without subjects in the low expectation treatment who have no valid productivity. Columns 4 – 5 contain the estimation results based on the subsample of subjects in the high expectation treatment without subjects in the high expectation treatment who have no valid productivity.

A.4.14 Notes for Table A.11 on page 102

For columns 1 – 6 the dependent variable is the time (in minutes) spent in the second stage of the experiment. Columns 1 – 6 report results from OLS regressions. The main explanatory variable is the high history treatment dummy. The proxy variable for productivity is the time (in seconds multiplied by -1) that subjects needed to correctly solve a table during the practice round. There were subjects who did not solve any table correctly, thus these subjects don't have a valid productivity. Altogether, 24 subjects have no valid productivity, for them, I use the average productivity as a proxy for productivity. Female dummy is 1 if the subject is female, and 0 if male. Temperature controls include a dummy variable that is 1 if the the average temperature of the day is less than 59 Fahrenheit, and the other dummy variable is 1 if the the average temperature of the day is between 59 and 68 Fahrenheit. Time of the day controls include a dummy variable that is 1 if the the starting time of the experiment is before 1pm, and the other dummy variable is 1 if the the starting time of the experiment is between 1pm and 3:12pm. Columns 1 – 2 contain the estimation results based on the full sample without the 24 subjects who have no valid productivity. Columns 3 – 4 contain the estimation results based on the subsample of subjects in the low expectation treatment without subjects in the low expectation treatment who have no valid productivity. Columns 4 – 5 contain the estimation results based on the subsample of subjects in the high expectation treatment without subjects in the high expectation treatment who have no valid productivity.

A.4.15 Notes for Table A.12 on page 103

For columns 1 – 6 the dependent variable is the time (in minutes) spent in the second stage of the experiment. Columns 1 – 6 report results from Tobit censored regressions (time spent at the second stage is censored from below at 0 and from above at 60). The main explanatory variable is the high history treatment dummy. The proxy variable for productivity is the time (in seconds multiplied by -1) that subjects needed to correctly solve a table during the practice round. There were subjects who did not solve any table correctly, thus these subjects don't have a valid productivity. Altogether, 24 subjects have no valid productivity, for them, I use the average productivity as a proxy for productivity. Female dummy is 1 if the subject is female, and 0 if male. Temperature controls include a dummy variable that is 1 if the the average temperature of the day is less than 59 Fahrenheit, and the other dummy variable is 1 if the the average temperature of the day is between 59 and 68 Fahrenheit. Time of the day controls include a dummy variable that is 1 if the the starting time of the experiment is before 1pm, and the other dummy variable is 1 if the the starting time of the experiment is between 1pm and 3:12pm. Columns 1 – 2 contain the estimation results based on the full sample without the 24 subjects who have no valid productivity. Columns 3 – 4 contain the estimation results based on the subsample of subjects in the low expectation treatment without subjects in the low expectation treatment who have no valid productivity. Columns 4 – 5 contain the estimation results based on the subsample of subjects in the high expectation treatment without subjects in the high expectation treatment who have no valid productivity.

A.4.16 Notes for Table A.13 on page 104

The table reports results of multinomial logit regressions. The dependent variable indicates three outcomes: "stop at $3", "stop at $7", and "stop elsewhere" which is the reference category. The first column of table contains the parameter estimates of the multinomial logit model with the high expectation and high history treatment dummies only. Column 3 and 4 contain the estimates of the model with additional controls. The proxy variable for productivity is the time (in seconds multiplied by -1) that subjects needed to correctly solve a table during the practice round. There were subjects who did not solve any table correctly, thus these subjects don't have a valid productivity. Altogether, 24 subjects have no valid productivity. The table contains estimates based on the sample without these 24 subjects.

APPENDIX B

APPENDIX FOR CHAPTER 3: THE PRINCIPAL-AGENT MODEL WITH LOSS-AVERSE AGENTS

B.1 Derivations and Proofs

This section contans the proofs of the theorems of the chapter.

B.1.1 Proof of Theorem 1

Proof. If the initial wage offer at the optimal wage is above the reference wage $w(a_0^*) > \overline{w}$, then the constraint becomes $w(a) - \gamma(a) + \nu(w(a) - \overline{w}) = \overline{u}$, from which the optimal wage contract can be expressed

$$w(a) = \frac{\overline{u} + \gamma(a) + \nu\overline{w}}{1 + \nu}.$$

This is greater than the reference wage whenever $\overline{u} + \gamma(a^*) > \overline{w}$. Plugging the wage into the objective of the principal I get the following unconstrained optimization problem:

$$\max_a f(a) - \frac{\overline{u} + \gamma(a) + \nu\overline{w}}{1 + \nu},$$

taking first order conditions of this objective function I get

$$\frac{f'(a_0^*)}{\gamma'(a_0^*)} = \frac{1}{1 + \nu}. \tag{B.1.1}$$

The result follows similarly for the case when the reference wage is such that $w(a_1^*) < \overline{w}$. The optimal wage contract is

$$w(a) = \frac{\overline{u} + \gamma(a) + \eta\nu\overline{w}}{1 + \eta\nu},$$

which is lower than the reference wage at the optimal effort level whenever $\overline{u} + \gamma(a_1^*) < \overline{w}$. The first order conditions in this case is

$$\frac{f'(a_1^*)}{\gamma'(a_1^*)} = \frac{1}{1+\eta\nu}. \tag{B.1.2}$$

For the last part of Theorem (1), I show at first that the general optimization problem (described in equation (2.3.2)) has a solution, then I characterize the solution at the point where μ is non-differentiable – that is when the reference salary and effort is such that the current wage of the agent is equal to her reference salary. The specific piecewise linear gain-loss utility function can be written as $\mu(y) = \left[(\eta - 1)\mathbb{1}\{y < 0\} + 1\right]\nu y$, substituting this into the constraint it becomes

$$w(a) - \gamma(a) + \left[(\eta - 1)\mathbb{1}\{w(a) - \overline{w} < 0\} + 1\right]\nu(w(a) - \overline{w}) \geq \overline{u}.$$

Since the principal maximizes profit this condition holds with equality, after rearranging this it follows that

$$w(a) = \frac{\overline{u} + \gamma(a) + \left[(\eta - 1)\mathbb{1}\{w(a) - \overline{w} < 0\} + 1\right]\nu\overline{w}}{1 + \left[(\eta - 1)\mathbb{1}\{w(a) - \overline{w} < 0\} + 1\right]\nu}.$$

Substituting this into the optimization problem, it becomes an unconstrained optimization problem

$$\max_a f(a) - \frac{\overline{u} + \gamma(a) + \left[(\eta - 1)\mathbb{1}\{w(a) - \overline{w} < 0\} + 1\right]\nu\overline{w}}{1 + \left[(\eta - 1)\mathbb{1}\{w(a) - \overline{w} < 0\} + 1\right]\nu}.$$

Denote the function of interest by $F(a) = f(a) - \frac{\overline{u}+\gamma(a)+\left[(\eta-1)\mathbb{1}\{w(a)-\overline{w}<0\}+1\right]\nu\overline{w}}{1+\left[(\eta-1)\mathbb{1}\{w(a)-\overline{w}<0\}+1\right]\nu}$, where the principal minimizes $F(a)$ with respect to a to determine the optimal effort a. From the assumptions made on the utility function and production function it follows that F is a concave function in a, therefore $-F$ is a proper convex function. Applying the results of Borwein and Lewis [2006] for the convex $-F$ function, it follows that the point a^* is a global maximizer of F if and only if the condition $0 \in \partial F(a^*)$ holds, where $\partial F(a^*)$ denotes the subgradients of the function F at a^*. In this part of the proof, I focus on the possible optimal effort levels a^* where μ is non-differentiable, where the current salary of the agent equals her reference-salary, since for all other cases in the first part of this proof I showed the existence of the optima. From the definition of the subgradients it follows that $\partial F(a^*) = [f'(a^*) - \frac{\gamma'(a^*)}{1+\nu\eta}, f'(a^*) - \frac{\gamma'(a^*)}{1+\nu}]$, where endpoints of the interval come from the left and right hand side derivative of the function F at a^*. Since the properties of the "gain-loss" function $\eta > 1$, it follows that this interval is non-empty. Note that the expressions for left (right) endpoints of the interval is identical to the first-order condition of the optimization problem when the agent is on the loss (gain) domain. From the first part of the proof it follows that $a_0^* < a_1^*$. From the assumptions on the functional forms of the primitives, it follows that both $f'(a^*) - \frac{\gamma'(a^*)}{1+\nu\eta}$ and $f'(a^*) - \frac{\gamma'(a^*)}{1+\nu}$ are monotone decreasing and continuous functions. Combining these, it follows that $0 \in \partial F(a^*)$ for all the points between a_0^* and a_1^*, which establishes that the general optimization problem has a solution in the case when the reference salary is such that non-differentiability of μ matters.

To characterize the solution at the point where μ is non-differentiable, I show that any contract other than the one characterized in Theorem 1 has a wage and effort combination that cannot guarantee higher profit for the principal and also satisfy the agent's participation constraints simultaneously. Therefore, if the firm hires an agent with such a reference point then the principal chooses $w = \overline{w} = \overline{u} + \gamma(a^*)$ and $a^* = \gamma^{-1}(\overline{w} - \overline{u})$. Since $\overline{w} \in [\overline{u} + \gamma(a_0^*), \overline{u} + \gamma(a_1^*)]$ and $\overline{u} + \gamma(a^*) = \overline{w}$ it follows that $a^* \in [a_0^*, a_1^*]$. I have to check two kinds of alternative contracts; an alternative contract is either pays a higher fix wage and requires a higher effort level or pays a lower fix wage and requires a lower effort level.

Any other combination is either not profit maximizing or does not satisfy the participation constraint of the agent. Lets assume an alternative contract (W, A) such that $W > \overline{w}$ and $A > a^*$. Lets assume that such contract exist which increases the principal's profit and satisfies the participation constraint of the agent, thus $f(A) - W > f(a^*) - \overline{w}$ and $W - \gamma(A) + \nu(W - \overline{w}) = \overline{u} = \overline{w} - \gamma(a^*)$. From this equation I can express $W = \frac{(1+\nu)\overline{w} - \gamma(a^*) + \gamma(A)}{1+\nu}$ which can be plugged back to the inequality which expresses that the alternative contract yields higher profit

$$f(A) - f(a^*) > \frac{(1+\nu)\overline{w} - \gamma(a^*) + \gamma(A) - (1+\nu)\overline{w}}{1+\nu}.$$

This inequality can be simplified which yields $(1+\nu)f(A) - f(a) > \gamma(A) - \gamma(a^*)$, dividing both side by $(A - a^*)$ which yields $(1+\nu)\frac{f(A)-f(a)}{A-a^*} > \frac{\gamma(A)-\gamma(a^*)}{A-a^*}$ and taking limit in A which approaches a^*, I get that $(a+\nu)f'(a^*) > \gamma'(a^*)$ which is equivalent to $\frac{f'(a^*)}{\gamma\text{''}(a^*)} > \frac{1}{1+\nu}$, which implies that $a^* < a_0^*$ which is a contradiction. Similarly I can show that there is no other contract with lower wage and required effort level which can increase the principal's profit level, which completes our proof. □

B.1.2 Proof of Theorem 2

Proof. If the initial wage offer at the optimal wage is above the reference wage $w(a_0^*) > \overline{w}$, then (2.3.3) becomes $w(a) - \gamma(a) + \nu(w(a) - \overline{w}) = \overline{u}$, from which the optimal wage contract can be expressed

$$w(a) = \frac{\overline{u} + \gamma(a) + \nu\overline{w}}{1+\nu}.$$

This is greater than the reference wage whenever $\overline{u} + \gamma(a^*) > \overline{w}$. Plugging the wage into the objective of the principal I get the following unconstrained optimization problem:

$$\max_a f(a) - \frac{\overline{u} + \gamma(a) + \nu\overline{w}}{1+\nu},$$

taking first order conditions of this objective function I get

$$\frac{f'(a)}{\gamma'(a)} = \frac{1}{1+\nu}. \tag{B.1.3}$$

Whenever ν increases the right hand side decreases thus the left hand side must decrease too, therefore the optimal effort level has to increase since $f''(.) < 0$ and $\gamma''(.) > 0$.

The result follows similarly for the case when the initial optimal wage is below the reference wage $w(a_0^*) < \overline{w}$. The optimal wage contract is

$$w(a) = \frac{\overline{u} + \gamma(a) + \eta\nu\overline{w}}{1+\eta\nu},$$

which is lower than the reference wage whenever $\overline{u} + \gamma(a^*) < \overline{w}$. The first order conditions in this case is

$$\frac{f'(a)}{\gamma'(a)} = \frac{1}{1+\eta\nu}. \tag{B.1.4}$$

When ν increases the right hand side decreases thus the left hand side must decrease too, therefore the optimal effort level has to increase since $f''(.) < 0$ and $\gamma''(.) > 0$. □

B.1.3 Proof of Theorem 3

Proof. It follows directly from comparing the profit levels under the optimal effort levels a_2^* and a_1^* induced by the optimal contracts. □

B.1.4 Proof of Theorem 4

Proof. The results follows directly from comparing the first order conditions when the reference wage is below the optimal wage (B.1.3) with the case when the reference wage is above (B.1.4). Since $\eta > 1$ the right hand side of (B.1.4) is smaller than the right hand side of (B.1.3) $\frac{1}{1+\eta\nu} < \frac{1}{1+\nu}$, therefore it follows that the optimal effort level is higher when the reference wage is above the optimal wage since the concavity of f and convexity of γ. The first order condition for the agent without reference dependence is $\frac{f'(a)}{\gamma'(a)} = 1 > \frac{1}{1+\eta\nu} > \frac{1}{1+\nu}$, thus the optimal effort level is lower than for an reference-dependent agent whose reference wage is either above or below the optimal wage. $\square$

B.1.5 Proof of Theorem 5

Proof. The results follows from comparing profit levels under the two reference wage level. The profit when the reference salary is low is $\Pi_1 = f(a^*) - \frac{\overline{u}+\gamma(a^*)+\nu\overline{w}}{1+\nu}$ and the profit with the high reference poins it $\Pi_2 = f(a^{**}) - \frac{\overline{u}+\gamma(a^{**})+\eta\nu\overline{w}}{1+\eta\nu}$, where I know from previous result that $a^{**} > a^*$. It is profitable for the principal to modify upwards the reference point whenever $\Pi_2 - \Pi_1 > \chi$ that is the profit increase associated with the higher reference salary is greater than the cost of influencing the reference point. The proof follows from rearranging this inequality. $\square$

B.1.6 Proof of Theorem 6

Proof. The proof follows directly from the observation that the optimal contract pushes the constraint to hold with equality otherwise either w could be decreased or a increased which would make the principal better off. $\square$

B.1.7 Proof of Theorem 7

Proof. Since I derived the optimal contract in equation (2.3.9), I can plug into the principal's problem which becomes an unconstrained optimization problem. Whenever $a > \overline{a}$, the maximization problem becomes $\max_a f(a) - \gamma(a) + \eta\nu(\gamma(\overline{a}) - \gamma(a)) - \overline{u}$. For which the first order condition is $\frac{f'(a^*)}{\gamma'(a^*)} = 1 + \eta\nu > 1$. Similarly for an agent whose reference point is such that $a < \overline{a}$ the first order conditions becomes $\frac{f'(a^{**})}{\gamma'(a^{**})} = 1 + \nu > 1$ for the optimal effort level. And for an agent without reference dependence the first order condition is $\frac{f'(a')}{\gamma'(a')} = 1$. Since $\nu > 0$, $\eta > 1$ $f(.)$ is concave and $\gamma(.)$ is convex functions it follows that $a^{**} < a^* < a'$. □

B.1.8 Proof of Theorem 8

Proof. The proof of the theorem follows from comparing profit level under the high reference point when the optimal effort level is a^* with the profit level when the reference point is low and the optimal effort level a^{**} is also lower. □

B.1.9 Proof of Theorem 9

Proof. I take the $\mathscr{L}$ Lagrangian and maximize it point by point Stole [2001] for each $x \in X$, therefore I want to maximize the following objective function

$$T = V(x - w(x))f(x,a) + \lambda\left[\left[u(w(x)) + \mu(u(w(x)) - u(\overline{w}))\right] f(x,a) - \gamma(a) - \overline{u}\right] +$$

$$+\beta\left[\left[u(w(x)) + \mu(u(w(x)) - w(\overline{w}))\right] f_a(x,a) - \gamma'(a)\right]$$

for each $x \in X$ separately. From the assumptions I made it follows that T is a concave objective, therefore I can take first order conditions with respect to $w(x)$

for all $x \in X$. The optimal contract satisfies the following equation

$$\frac{\partial T}{\partial w(x)} = -V'(x - w(x))f(x,a) + \lambda\left[u'(w(x)) + \mu'(u(w(x)) - u(\overline{w}))u'(w(x))\right]f(x,a) +$$

$$+\beta\left[u'(w(x)) + \mu'(u(w(x)) - w(\overline{w}))u'(w(x))\right]f_a(x,a) = 0,$$

which holds for all $x \in X$. This equation can be rearranged to get the condition for the optimal wage contract in the theorem. □

B.1.10 Proof of Theorem 10

Proof. I show that $\mathscr{L}$ is supermodular in $(w(.),\lambda,\beta,\nu)$, then by the theorem of Topkis [2001] it follows that $w(x)$ is non-decreasing for all $x \in X$. To show supermodularity of $\mathscr{L}$ I show that $\mathscr{L}$ has increasing differences in $(w(.),\lambda,\beta,\nu)$.

I analyze the Lagrangian for the corresponding maximization problem

$$\mathscr{L} = \int_{\underline{x}}^{\overline{x}} V(x - w(x))f(x,a)dx$$

$$+\lambda\Bigg[\int_{\underline{x}}^{\overline{x}} \left[u(w(x)) + ((\eta-1)\mathbb{1}\{u(w(x)) - u(\overline{w}) < 0\} + 1)\,\nu(u(w(x)) - u(\overline{w}))\right]f(x,a)dx$$

$$-\gamma(a) - \overline{u}\Bigg] + \beta\Bigg[\int_{\underline{x}}^{\overline{x}} \left[u(w(x)) + ((\eta-1)\mathbb{1}\{u(w(x)) - u(\overline{w}) < 0\} + 1)\,\nu(u(w(x)) - u(\overline{w}))\right]$$

$$\cdot f_a(x,a)dx - \gamma'(a)\Bigg].$$

I show that $\mathscr{L}$ has increasing differences pairwise in $(w(.),\lambda)$, $(w(.),\beta)$ $(w(.),\nu)$, (λ,ν), (β,ν) and (λ,β). It follows then Topkis [2001] that $\mathscr{L}$ has increasing differences in $(w(.),\lambda,\beta,\nu)$, therefore it is supermodular in $(w(.),\lambda,\beta,\nu)$. A function $g(y,z)$ has increasing differences in (y,z) if for $y_H > y_L$ and $z_H > z_L$ it follows that $g(y_H,z_H) - g(y_H,z_L) \geq g(y_L,z_H) - g(y_L,z_L)$ or equivalently $g(y_H,z_H) - g(y_L,z_H) \geq g(y_H,z_L) - g(y_L,z_L)$.

(a) $\mathscr{L}$ has increasing differences in $(w(.), \lambda)$ if for $w_H > w_L$ (I use this notation to express that $w_H(x) > w_L(x)$ for all $x \in X$) and $\lambda_H > \lambda_L$

$$\lambda_H \left[\int_{\underline{x}}^{\overline{x}} [u(w_H(x)) + ((\eta - 1)\mathbb{1}\{u(w_H(x)) - u(\overline{w}) < 0\} + 1)\, v(u(w_H(x)) - u(\overline{w}))]\, f(x,a)dx \right]$$

$$-\lambda_H \left[\int_{\underline{x}}^{\overline{x}} [u(w_L(x)) + ((\eta - 1)\mathbb{1}\{u(w_L(x)) - u(\overline{w}) < 0\} + 1)\, v(u(w_L(x)) - u(\overline{w}))] \right.$$

$$\left. \cdot f(x,a)dx \right] \geq \lambda_L \left[\int_{\underline{x}}^{\overline{x}} [u(w_H(x)) + ((\eta - 1)\mathbb{1}\{u(w_H(x)) - u(\overline{w}) < 0\} + 1)\, v(u(w_H(x)) \right.$$

$$\left. -u(\overline{w}))] f(x,a)dx \right] - \lambda_L \left[\int_{\underline{x}}^{\overline{x}} [u(w_L(x)) + ((\eta - 1)\mathbb{1}\{u(w_L(x)) - u(\overline{w}) < 0\} + 1)\, v(u(w_L(x)) \right.$$

$$\left. -u(\overline{w}))] f(x,a)dx \right].$$

Since integrating keeps the order, its enough to show that this inequality holds for all $x \in X$, after simplification I get the following inequality

$$\lambda_H \left[u(w_H(x)) + ((\eta - 1)\mathbb{1}\{u(w_H(x)) - u(\overline{w}) < 0\} + 1)\, v(u(w_H(x)) - u(\overline{w}))\right]$$

$$-\lambda_H \left[u(w_L(x)) + ((\eta - 1)\mathbb{1}\{u(w_L(x)) - u(\overline{w}) < 0\} + 1)\, v(u(w_L(x)) - u(\overline{w}))\right] \geq$$

$$\geq \lambda_L \left[u(w_H(x)) + ((\eta - 1)\mathbb{1}\{u(w_H(x)) - u(\overline{w}) < 0\} + 1)\, v(u(w_H(x)) - u(\overline{w}))\right]$$

$$-\lambda_L \left[u(w_L(x)) + ((\eta - 1)\mathbb{1}\{u(w_L(x)) - u(\overline{w}) < 0\} + 1)\, v(u(w_L(x)) - u(\overline{w}))\right]$$

for all $x \in X$. This holds for all $x \in X$ if

$$\left[u(w_H(x)) + ((\eta - 1)\mathbb{1}\{u(w_H(x)) - u(\overline{w}) < 0\} + 1)\, v(u(w_H(x)) - u(\overline{w}))\right]$$

$$-\left[u(w_L(x)) + ((\eta - 1)\mathbb{1}\{u(w_L(x)) - u(\overline{w}) < 0\} + 1)\, v(u(w_L(x)) - u(\overline{w}))\right] > 0,$$

since $\lambda_H > \lambda_L$.

If $x \in X$ is such that both $w_H(x) > \overline{w}$ and $w_L(x) > \overline{w}$ then the expressions simplifies to

$$u(w_H(x)) + v(u(w_H(x)) - u(\overline{w})) - u(w_L(x)) - v(u(w_L(x)) - u(\overline{w})) > 0,$$

which holds obviously since $u(w_H(x)) > u(w_L(x))$.

If $x \in X$ is such that both $w_H(x) < \overline{w}$ and $w_L(x) < \overline{w}$ then the expressions simplifies to

$$u(w_H(x)) + \eta\nu(u(w_H(x)) - u(\overline{w})) - u(w_L(x)) - \eta\nu(u(w_L(x)) - u(\overline{w})) > 0,$$

which holds obviously since $u(w_H(x)) > u(w_L(x))$.

If $x \in X$ is such that $w_H(x) > \overline{w}$ and $w_L(x) < \overline{w}$ then the expressions simplifies to

$$u(w_H(x)) + \nu(u(w_H(x)) - u(\overline{w})) - u(w_L(x)) - \eta\nu(u(w_L(x)) - u(\overline{w})) > 0,$$

which holds obviously since $u(w_H(x)) > u(w_L(x))$, $\nu(u(w_H(x)) - u(\overline{w})) > 0$ and $-\eta\nu(u(w_L(x)) - u(\overline{w})) > 0$.

(b) The proof that $\mathscr{L}$ has increasing differences in $(w(.), \beta)$ is similar to (a), therefore I omit here.

(c) $\mathscr{L}$ has increasing differences in $(w(.), \nu)$ if for $w_H > w_L$ (I use this notation to express that $w_H(x) > w_L(x)$ for all $x \in X$) and $\nu_H > \nu_L$

$$\lambda\left[\int_{\underline{x}}^{\overline{x}} [u(w_H(x)) + ((\eta - 1)\mathbb{1}\{u(w_H(x)) - u(\overline{w}) < 0\} + 1)\,\nu_H(u(w_H(x)) - u(\overline{w}))]\, f(x,a)dx\right.$$
$$\left.-\gamma(a) - \overline{u}\right] - \lambda\left[\int_{\underline{x}}^{\overline{x}} [u(w_L(x)) + ((\eta - 1)\mathbb{1}\{u(w_L(x)) - u(\overline{w}) < 0\} + 1)\,\nu_H(u(w_L(x)) - u(\overline{w}))]\right.$$
$$\left.\cdot f(x,a)dx - \gamma(a) - \overline{u}\right] + \beta\left[\int_{\underline{x}}^{\overline{x}} [u(w_H(x)) + ((\eta - 1)\mathbb{1}\{u(w_H(x)) - u(\overline{w}) < 0\} + 1)\,\nu_H(u(w_H(x))\right.$$
$$\left.-u(\overline{w}))] f_a(x,a)dx - \gamma'(a)\right] - \beta\left[\int_{\underline{x}}^{\overline{x}} [u(w_L(x)) + ((\eta - 1)\mathbb{1}\{u(w_L(x)) - u(\overline{w}) < 0\} + 1)\right.$$
$$\left.\cdot\nu_H(u(w_L(x)) - u(\overline{w}))] f_a(x,a)dx - \gamma'(a)\right] \geq \lambda\left[\int_{\underline{x}}^{\overline{x}} [u(w_H(x)) + ((\eta - 1)\right.$$
$$\left.\cdot\mathbb{1}\{u(w_H(x)) - u(\overline{w}) < 0\} + 1)\nu_L(u(w_H(x)) - u(\overline{w}))] f(x,a)dx - \gamma(a) - \overline{u}\right]$$

$$-\lambda C[\int_{\underline{x}}^{\overline{x}} [u(w_L(x)) + ((\eta-1)\mathbb{1}\{u(w_L(x)) - u(\overline{w}) < 0\} + 1)\, \nu_L(u(w_L(x)) - u(\overline{w}))]\, f(x,a)dx$$

$$-\gamma(a) - \overline{u}\Bigg] + \beta\Bigg[\int_{\underline{x}}^{\overline{x}} [u(w_H(x)) + ((\eta-1)\mathbb{1}\{u(w_H(x)) - u(\overline{w}) < 0\} + 1)\, \nu_L(u(w_H(x)) - u(\overline{w}))]$$

$$\cdot f_a(x,a)dx - \gamma'(a)\Bigg] - \beta\Bigg[\int_{\underline{x}}^{\overline{x}} [u(w_L(x)) + ((\eta-1)\mathbb{1}\{u(w_L(x)) - u(\overline{w}) < 0\} + 1)\, \nu_L(u(w_L(x))$$

$$-u(\overline{w}))] f_a(x,a)dx - \gamma'(a)\Bigg].$$

This inequality holds if the inequality term holds for the first two line with λ terms and the second two lines with β separately. I show that it holds for the first two lines with λ, the proof is similar for the other terms. I need to prove that

$$\lambda\Bigg[\int_{\underline{x}}^{\overline{x}} [u(w_H(x)) + ((\eta-1)\mathbb{1}\{u(w_H(x)) - u(\overline{w}) < 0\} + 1)\, \nu_H(u(w_H(x)) - u(\overline{w}))]\, f(x,a)dx$$

$$-\gamma(a) - \overline{u}\Bigg] - \lambda\Bigg[\int_{\underline{x}}^{\overline{x}} [u(w_L(x)) + ((\eta-1)\mathbb{1}\{u(w_L(x)) - u(\overline{w}) < 0\} + 1)\, \nu_H(u(w_L(x)) - u(\overline{w}))]$$

$$\cdot f(x,a)dx - \gamma(a) - \overline{u}\Bigg] \geq \lambda\Bigg[\int_{\underline{x}}^{\overline{x}} [u(w_H(x)) + ((\eta-1)\mathbb{1}\{u(w_H(x)) - u(\overline{w}) < 0\} + 1)$$

$$\nu_L(u(w_H(x)) - u(\overline{w}))] f(x,a)dx - \gamma(a) - \overline{u}\Bigg] - \lambda\Bigg[\int_{\underline{x}}^{\overline{x}} [u(w_L(x)) + ((\eta-1)\mathbb{1}\{u(w_L(x)) - u(\overline{w}) < 0\}$$

$$+1)\nu_L(u(w_L(x)) - u(\overline{w}))] f(x,a)dx - \gamma(a) - \overline{u}\Bigg].$$

Since integrating keeps the order, its enough to show that this inequality holds for all $x \in X$, after simplification I get the following inequality

$$[(\eta-1)\mathbb{1}\{u(w_H(x)) - u(\overline{w}) < 0\} + 1]\, \nu_H(u(w_H(x)) - u(\overline{w})) - [(\eta-1)\mathbb{1}\{u(w_L(x)) - u(\overline{w}) < 0\}$$

$$+1]\nu_H(u(w_L(x)) - u(\overline{w})) \geq [(\eta-1)\mathbb{1}\{u(w_H(x)) - u(\overline{w}) < 0\} + 1]\, \nu_L(u(w_H(x))$$

$$-u(\overline{w})) - [(\eta-1)\mathbb{1}\{u(w_L(x)) - u(\overline{w}) < 0\} + 1]\, \nu_L(u(w_L(x)) - u(\overline{w}))$$

has to hold for all $x \in X$.

If $x \in X$ is such that both $w_H(x) > \overline{w}$ and $w_L(x) > \overline{w}$ or $w_H(x) < \overline{w}$ and $w_L(x) < \overline{w}$ then the indicator functions cancel out and the expressions simplifies to

$$\nu_H(u(w_H(x)) - u(w_L(x))) \geq \nu_L(u(w_H(x)) - u(w_L(x))),$$

which holds trivially since $\nu_h > \nu_L$ and $u(w_H(x)) - u(w_L(x)) > 0$.

If $x \in X$ is such that $w_H(x) > \overline{w}$ and $w_L(x) < \overline{w}$, then I get the following inequality after simplification

$$\nu_H(u(w_H(x)) - u(\overline{w})) - \eta n u_H(u(w_L(x)) - u(\overline{w})) \geq \nu_L(u(w_H(x)) - u(\overline{w})) - \eta \nu_L(u(w_L(x)) - u(\overline{w})),$$

which holds, because $u(w_L(x)) - u(\overline{w}) < 0$, thus $-\eta n u_H(u(w_L(x)) - u(\overline{w})) \geq -\eta \nu_L(u(w_L(x)) - u(\overline{w}))$ and $\nu_H(u(w_H(x)) - u(\overline{w})) \geq \nu_L(u(w_H(x)) - u(\overline{w}))$ since $\nu_H > \nu_L$.

(d) $\mathscr{L}$ has increasing differences in $(\lambda), \nu)$ if for $\lambda_H > \lambda_L$ and $\nu_H > \nu_L$ I have

$$(\lambda_H - \lambda_L)\left[\int_{\underline{x}}^{\overline{x}} [u(w(x)) + ((\eta - 1)\mathbb{1}\{u(w(x)) - u(\overline{w}) < 0\} + 1)\, \nu_H(u(w(x)) - u(\overline{w}))] \cdot f(x,a)dx\right] \geq (\lambda_H - \lambda_L)\left[\int_{\underline{x}}^{\overline{x}} [u(w(x)) + ((\eta - 1)\mathbb{1}\{u(w(x)) - u(\overline{w}) < 0\} + 1)\, \nu_L(u(w(x)) - u(\overline{w}))] f(x,a)dx\right],$$

which holds since $\lambda_H - \lambda_L > 0$ and

$$\int_{\underline{x}}^{\overline{x}} [u(w(x)) + ((\eta - 1)\mathbb{1}\{u(w(x)) - u(\overline{w}) < 0\} + 1)\, \nu_H(u(w(x)) - u(\overline{w}))]\, f(x,a)dx >$$

$$> \int_{\underline{x}}^{\overline{x}} [u(w(x)) + ((\eta - 1)\mathbb{1}\{u(w(x)) - u(\overline{w}) < 0\} + 1)\, \nu_L(u(w(x)) - u(erlinew))]\, f(x,a)dx$$

since I assumed that $\overline{w}$ is such that $\int_{\underline{x}}^{\overline{x}} ((\eta - 1)\mathbb{1}\{u(w(x)) - u(\overline{w}) < 0\} + 1)\,(u(w(x)) - u(\overline{w}))f(x,a)dx > 0$.

(e) The proof that $\mathscr{L}$ has increasing differences in $(\beta), \nu)$ is similar and follows from the assumption that $\overline{w}$ is such that

$$\int_{\underline{x}}^{\overline{x}} ((\eta - 1)\mathbb{1}\{u(w(x)) - u(\overline{w}) < 0\} + 1)\,(u(w(x)) - u(\overline{w}))f_a(x,a)dx > 0,$$

therefore I do not include it here.

(f) It is obvious that $\mathscr{L}$ has increasing differences in (λ, β). $\square$

B.1.11 Proof of Theorem 11

Proof. I maximize $\mathscr{L}$ point by point for each $x \in X$ to derive a condition for the optimal wage contract. For all $x \in X$ I maximize

$$V(x - w(x))f(x,a) + \lambda\left[[u(w(x))]\, f(x,a) - \gamma(a) + \mu(\gamma(\overline{a}) - \gamma(a)) - \overline{u}\right]$$

$$+\beta\left([u(w(x))]\, f_a(x,a) - \gamma'(a)\left[1 + \mu'(\gamma(\overline{a}) - \gamma(a))\right]\right]$$

expression with respect to $w(x)$, the corresponding first order condition is

$$-V'(x - w(x))f(x,a) + \lambda u'(w(x))f(x,a) + \beta u'(w(x))f_a(x,a) = 0,$$

which does not contain any term with $\mu(.)$ which already shows that reference dependence does not have a direct impact on the optimal wage contract. Rearranging this I get the the optimal wage contract has to satisfy

$$\frac{V'(x - w(x))}{u'(w(x))} = \lambda + \beta \frac{f_a(x,a)}{f(x,a)}$$

equation for all $x \in X$, which completes our proof. $\square$

B.1.12 Proof of Theorem 12

Proof. First differentiating $\mathscr{L}$ with respect to a I get the following first order condition

$$\frac{\partial \mathscr{L}}{\partial a} = \int_{\underline{x}}^{\overline{x}} V(x-w(x))f_a(x,a)dx + \lambda\left[\int_{\underline{x}}^{\overline{x}} [u(w(x))]\, f_a(x,a)dx - \gamma'(a) - \mu'(\gamma(\overline{a}) - \gamma(a))\right] +$$

$$+\beta\left[\int_{\underline{x}}^{\overline{x}}[u(w(x))]\,f_{aa}(x,a)dx-\gamma''(a)\left[1+\mu'(\gamma(\overline{a})-\gamma(a))\right]+(\gamma'(a))^2\mu''(\overline{a})-\gamma(a))\right]=0.$$

The second term in this expression is zero

$$\lambda\left[\int_{\underline{x}}^{\overline{x}}[u(w(x))]\,f_a(x,a)dx-\gamma'(a)-\mu'(\gamma(\overline{a})-\gamma(a))\right]=0$$

because the effort level is optimal for the agent, it maximizes the agent's expected utility, therefore it obeys the (ICFOC) constraint. Plugging this into the first order conditions yields the condition in the theorem. □

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