2020-05

Risk Preferences and Contract Choices

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Mars/ March 2020

Centre de recherche sur les risques
les enjeux économiques et les politiques publiques

www.crrep.ca

ABSTRACT

We conducted a series of field experiments to investigate the ability of experimentally measured risk preferences to predict the contractual choices of workers in the real labour market. In a first set of experiments we measured workers' risk preferences using the lottery approach of Holt and Laury (2002). We did this twice: once for low-stakes lotteries (LSL) and once for high-stakes (HSL). Each worker subsequently made 12 decisions, choosing between his/her regular piece-rate contract and a series of fixed wage contracts, each offereing a different fixed wage. One of the twelve decisions was then chosen at random and the worker was paid according to his/her choice for that decision over a period of two working days. The risk preferences measured from the HSL effectively predict the contract choices; those from the LSL are irrelevant. We also find that high-ability workers prefer piece-rate contracts.

JEL Classification: C93, D86, J33.

Keywords: Risk preferences, Incentives, Contracts, Sorting, Field experiments.

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We thank Sylvain Dessy, Claude-Denis Fluet, Bernard Fortin, Sonia Laszlo, and Luca Tiberti for helpful comments and suggestions. We also thank participants at the Canadian Economic Association Meetings (McGill, 2018) and the Societé canadienne des sciences économiques (Ottawa, 2017). Financial support from SSHRC (Shearer), FRQSC (Shearer) and CRREP (Bago) is gratefully acknowledged.

1 Introduction

Risk and risk preferences play a central role in economic models of incentive contracts. Providing incentives implies risk sharing, imposing costs on risk-averse workers and raising contracting costs in risky settings (Prendergast, 1999). The empirical importance of risk in determining contracts is less clear (Prendergast, 2000). Empirical applications suffer from the fact that risk preferences are unobserved, complicating the testing of theoretical comparative static results. This has led some researchers to use proxies for risk preferences in contractual-choice regressions, with mixed results (Allen and Lueck, 1999; Ackerberg and Botticini, 2002). An alternative approach is to use experimental measures of risk preferences (Holt and Laury, 2002) and incorporate them into contractual choice models. Bellemare and Shearer (2013) take such an approach, combining risk-preference revealing experiments with payroll data to identify and estimate a structural principal-agent model. They use their estimates to evaluate the potential gains to matching workers to risk settings within the firm, based on workers' risk preferences.

The validity of such an approach depends on the ability of the experiments to identify risk preferences that are relevant to contractual choices. We address this issue by testing whether or not experimentally measured risk preferences can predict contractual choices in the real labour market. To do so, we exploit multiple field experiments, conducted within a real firm. In the first set of experiments, we measure workers' risk preferences, using Holt-Laury methods. We repeat these experiments twice on each worker: once using low-stakes lotteries (LSL) and once using high-stakes lotteries (HSL). We then use the measured risk preferences to predict worker choices between piece-rate and fixed-wage contracts. Importantly, these choices have real consequences: workers were paid the chosen contract for a period of two working days.

Our experiments took place within a tree-planting firm, located in British Columbia, Canada. Workers in this firm are hired to plant trees on recently logged blocks of land and are typically paid piece rates – daily earnings are the product of the piece rate and the number of trees planted. Since the number of trees a worker can plant depends on elements that are beyond his/her control (such as weather, the slope and the hardness of the ground) workers are exposed to daily income risk under a piece-rate contract. Fixed-wage contracts eliminate that risk to workers.

During the contract-choice experiments, workers were asked to repeatedly decide between their regular piece-rate contract and a series of twelve fixed-wage contracts, distinguished by the wage which ranged from $100 to $700 per day. Once their twelve decisions were made, one of these decisions was randomly selected and the worker was paid the contract that he/she selected for that decision. This contract remained in effect for the next two days of planting.

We develop a model of optimal contract choice as a function of a worker's risk preferences and ability. We use the model to derive a worker's certainty equivalent – the fixed wage that renders the worker indifferent between a piece rate contract and a fixed wage contract. We show that the certainty equivalent is a decreasing function of the level of risk aversion of a worker and an increasing function of a worker's ability. We distinguish those results that are specific to the functional forms of our model and those that hold more generally and can therefore be considered predictions.

We test the predictions using the experimental measures of risk aversion and payroll data, used to identify worker ability. We find that the aggregate distribution of measured risk preferences among participants is stable across the LSL and the HSL. However, measures of individual risk attitudes change between the LSL and the HSL. We explore the ability of the estimated risk preference parameters from each lottery to predict workers' choices between the piece-rate the fixed-wage contracts. The results show that the risk preferences measured from the HSL effectively predict the contract choice decisions, while the risk preference parameters measured from the LSL are statistically irrelevant to contract choices. Worker ability, as measured by average earnings in the firm's payroll data, previous to the experiment, is also an effective predictor of contract choice, significantly increasing the propensity to select the piece-rate contract.

Our work contributes to the literature investigating the relationship between risk and contracts. It presents evidence that risk preferences are an important determinant of contract choice in the real labour market, reinforcing theoretical models based on the risk-incentives tradeoff; eg., Holmstrom (1979); Stiglitz (1975). It also supports the work of Ackerberg and Botticini (2002) and Bellemare and Shearer (2010, 2013), providing direct evidence of heterogeneity in risk preferences among workers and that those preferences are relevant to contract choices.[1] This reinforces evidence of the external validity of experimentally measured risk preferences (Dohmen et al., 2011).

Our results also contribute to questions over the stability of risk preferences (Schildberg-Hörisch, 2018). As in Holt and Laury (2002), the stakes affect behaviour. We survey possible

[1]Such heterogeneity has been noted in other contexts as well; see, for example, (Bombardini and Trebbi, 2012) and Petrolia et al. (2013).

explanations for this provided in the literature, but we also suggest that participants took the lottery experiment more seriously at higher stakes, thus revealing their true preferences. Our results on the ability of these measures to predict contract choices are consistent with this interpretation. More generally, our work adds to a number of studies that have found that monetary stakes affect experimental behaviour in, for example, identifying risk preferences (Bombardini and Trebbi, 2012), ultimatum games (Andersen et al., 2011) and trust games (Johansson-Stenman et al., 2005).[2]

Finally, our work contributes to the literature on contracts and sorting. Lazear (1986) analysed sorting over ability when workers are faced with piece-rate and fixed-wage contracts. He showed that high-ability workers would be attracted to piece-rate contracts when workers are risk neutral. His subsequent empirical work (Lazear, 2000) verified these results. Theoretical predictions for sorting over ability are less clear cut when workers are heterogeneous over risk preferences. As in Dohmen and Falk (2011), we empirically verify that high-ability workers are attracted to piece-rate contracts.

Other papers looking at similar issues are Petrolia et al. (2013), who find that estimated risk preferences are correlated with decisions to purchase flood insurance in the US, and Belzil and Sidibé (2016), who use estimated risk and time preferences to explain the take-up decision of higher education grants.

The rest of the paper is organized as follows: Section 2 provides institutional details on the tree-planting industry in British Columbia. Section 3 presents the experimental design while Section 4 examines the data. In section 5, we develop the theoretical model of contract choices. Section 6 analyses the stability of the measured risk preferences across lotteries, while section 7 discusses the external validity of the experimental measures of risk preferences. Section 8 concludes the paper.

2 Tree-planting industry in British Columbia

Tree-planting companies are hired by the government, or private logging companies, to plant trees on tracts of recently logged land. Hiring is done through a competitive bidding process. This takes place in the fall preceding each planting season, which lasts from spring to summer.

[2] There is little consensus over the importance of scale effects – other studies have found little effect; see, for example, Hoffman et al. (1996) and Cameron (1999).

Before bidding on a contract, tree-planting firms estimate the cost of reforestation, based on their observations of the characteristics of the land to be planted. Firms then submit a bid and the firm submitting the lowest bid wins the contract. The winning firm hires workers to plant the trees and typically pays them piece-rates.[3] Under this contract, a worker's earnings are proportional to his/her output measured by the number of trees planted.[4] The land to be planted is subdivided into blocks which can range from 10 to more than 100 person days of planting. In formulating their bid, the firm determines a piece rate for each block which determines the cost of fulfilling the contract. Land that is steep or rocky and uneven is more difficult to plant and requires a higher piece rate in order to attract workers; see Paarsch and Shearer (1999) for a detailed discussion. These costs form the basis of the firm's strategy when bidding on contracts.

Typically, a group of 10 planters works under a supervisor whose task is to monitor and supply trees to the workers, and to control the quality of trees planted. Workers transport trees in a bag that fits around their hips and they work with a shovel. To plant a tree, the worker digs a hole in the ground with a specially designed shovel. The tree is vertically positioned in the hole which is then filled with soil, making sure that the roots are well covered. There are also rules concerning the distance between the planted trees. The firm monitors the quality of planted trees and workers must replant if the proportion of poorly planted trees exceeds a government-set limit.[5]

3 Experimental design

We conducted two field experiments within the firm, designed to test if experimentally measured risk preferences predict contract choices.

[3] Occasionally workers will be paid a fixed wage, if, for example, conditions on a block are very poor or a block is unexpectedly added to a contract; see Paarsch and Shearer (2000) for a discussion.

[4] Firms are required by law to pay the British Columbia minimum wage. This involves topping up a worker's earnings if the worker does not plant enough trees to earn the minimum wage. Workers who are consistently incapable of doing so are fired.

[5] The firm is subject to fines if government inspections uncover too many poorly planted trees.

3.1 Risk-preference experiment

We used the methods of Holt and Laury (2002) to measure workers' risk preferences under both a low-stakes lottery (LSL) and a high-stakes lottery (HSL). An advantage of Holt and Laury measures is that they relate choices directly to risk preferences of specific utility functions. They have also been used to measure preferences in contractual (Bellemare and Shearer, 2013) and other settings, (eg. Andersen et al., 2008; Dohmen et al., 2010; Petrolia et al., 2013) giving a natural point of comparison. One potential disadvantage is the design complexity, leading to possible misunderstandings on the part of participants and mistakes, or inconsistent choices (Dave et al., 2010; Charness et al., 2013). This has been problematic in some settings. For example, Jacobson and Petrie (2009) found over 50% of their sample made at least one inconsistent choice in a study using lotteries to investigate risk preferences in Rwanda. In contrast, we find very few inconsistent choices. In the LSL two individuals filled in forms inconsistently, whereas in the HSL, none did (see Table 2 and Section 4, below).

The experiment involved 63 workers from the tree-planting firm and took place over six days.[6] Each morning, one of us (Shearer) met with approximately twenty workers before they left for planting. Participation was voluntary.[7] In the LSL experiment, planters were informed that they could earn between $2 and $77, depending on their choices and random chance. Participants were given a decision sheet to complete which involved making 10 decisions. Each decision involved a choice between a low-risk lottery (lottery A), that paid either $40 or $32, and a high-risk lottery (lottery B), that paid either $77 or $2. These payoffs remained fixed for all ten decisions, however the probability of earning the high payoff ($40 for lottery A and $77 for lottery B) increased by 0.1 for each decision.[8] The probability of winning the high payoff was 0.1 for decision 1, 0.2 for decision 2 and so on, reaching 1 for decision 10. This increased the expected value of the high-risk lottery relative to the low-risk lottery and all rational participants will eventually select the high-risk lottery. The point at which a participant switches is informative over their risk preferences (Holt and Laury, 2002). The HSL paralleled the LSL, but with doubled stakes: lottery A paid either $80 or $64, lottery B paid either $144 or $4.

Planters were informed that once their decision sheet was completed, one of the ten de-

[6]A complete description of the experimental protocol is available in the Appendix 2.

[7]For this, and all successive meetings, planters were compensated $20 for their time, typically 20-25 minutes. All planters participated.

[8]The decision sheets are presented in Appendix 2.

cisions would be randomly chosen (by drawing a numbered poker chip from an opaque bag). Their lottery choice for that decision would then be played by drawing a second numbered chip from the bag (after the first chip was replaced). The number on the second chip determined the lottery earnings of the planter. These earnings were added to the planters' next pay cheque.

We measure each participant's risk preferences by the number of times he/she chose the safe lottery (lottery A) before switching to the risky lottery (lottery B). For example, a risk-neutral worker would choose lottery A at decision 4 and lottery B at decision 5, when the expected value of lottery B is higher than that of lottery A. A participant who made less than 4 safe choices is classified as risk-loving, and a participant who made more than 5 safe choices is classified as risk-averse. These are represented in Table (1) for a utility function representing constant relative risk aversion.

Table 1: *Safe choices and Risk preferences.*

Safe choices	$U(x) = \frac{1}{\delta}x^{\delta}$	Risk preference classification
0-1	$\delta \geqslant 1.95$	Extreme risk lover
2	$1.49 \leqslant \delta \leqslant 1.95$	High risk lover
3	$1.14 \leqslant \delta \leqslant 1.49$	Risk lover
4	$0.85 \leqslant \delta \leqslant 1.14$	Risk neutral
5	$0.59 \leqslant \delta \leqslant 0.85$	Slightly risk averse
6	$0.32 \leqslant \delta \leqslant 0.59$	Risk averse
7	$0.029 \leqslant \delta \leqslant 0.32$	Highly risk averse
8	$-0.37 \leqslant \delta \leqslant 0.029$	Very highly risk averse
9-10	$\delta \leqslant -0.37$	Extremely risk averse

3.2 Contract-choice experiment

In the days following the lottery experiment, we conducted a contract choice experiment with the same workers. This experiment took place over three days and involved 50 workers. The realistic environment limits the sample size.[9] Yet, it also accords benefits, allowing us to observe workers' contractual choices in the real labour market and in an actual economic firm. During this experiment, workers were asked to make 12 consecutive decisions, each between a risky contract paying piece rates and a fixed-wage contract for which their pay is independent of their production. The piece-rate contract was the regular piece rate that the planters would

[9] All workers who were present participated in the experiment. A number of workers were unexpectedly moved to another crew between the two experiments which explains the attrition.

receive from the firm and was constant across decisions. The workers did not know what that piece rate was at the time of their decision, although it had been determined by the firm. The value of the fixed wage changed across decisions, ranging from \$100 to \$650 by increments of \$50 (see Table 10). At each decision, workers were asked to choose between the piece rate contract and the proposed fixed-wage contract. They were further told that one of their twelve decisions would be selected at random (by drawing a numbered poker chip from a bag) and that their choice for that decision would determine the manner in which they would be paid for the next two working days.[10] For example, in the fifth decision, each worker chose between earning a fixed wage of \$300 per day and their regular piece-rate. If decision five was selected at random and the worker had chosen the fixed wage for decision five, he/she would receive \$300 per day, independent of his/her production, for the next two days of work. If, however, the worker had chosen the piece rate at decision five, he/she would receive his/her regular piece-rate contract over the next two days.

The average daily earnings of workers in this firm was \$400 per day. The range of fixed wages was chosen so that workers would eventually switch to fixed wages and reveal their certainty equivalent – the earnings level at which the worker is indifferent between the two contracts.

4 Data

Our data come from two sources: the experimental data (from both the lottery experiment and the contract-choice experiment) and the firm's payroll data.

4.1 Experimental data

4.1.1 Risk-preference Lotteries

The results of the risk-preference lotteries are presented in Table (2). Descriptive statistics show that 40% of participants make choices that are consistent with either risk-loving or risk-neutral preferences and 60% make decisions that are consistent with risk-averse preferences in the LSL experiment. This increases to 65.63% in the HSL experiment. These results are similar to those

[10] A worker who did not want to be paid under fixed wages could simply choose his/her regular piece rate at each decision.

in Bellemare and Shearer (2010), who reported that 39% of a sample of tree planters made choices consistent with risk loving preferences and 73% were consistent with risk loving or risk neutral preferences. Below we will provide formal tests of whether or not behaviour changed between the low-stakes and the high-stakes experiments. The column labelled "Consistent" shows the distribution of safe choices if we consider only those workers who have made consistent choices[11]. Only two workers made inconsistent decisions in the LSL, and none did so in the HSL.

Table 2: *Distribution of Safe Lottery Choices.*

		HSL		LSL	
Safe choices	$U = \frac{1}{\delta}x^{\delta}$	All	Consistent	All	Consistent
0-1	$\delta \geqslant 1.946$	1.56	1.56	4.76	4.92
2	$1.486 \leqslant \delta \leqslant 1.947$	1.56	1.56	6.35	6.56
3	$1.142 \leqslant \delta \leqslant 1.487$	17.19	17.19	25.40	26.23
4	$0.853 \leqslant \delta \leqslant 1.143$	40.63	40.63	42.86	40.98
5	$0.588 \leqslant \delta \leqslant 0.854$	65.63	65.63	61.90	60.66
6	$0.323 \leqslant \delta \leqslant 0.589$	85.94	85.94	85.71	85.25
7	$0.029 \leqslant \delta \leqslant 0.323$	95.31	95.31	96.83	96.72
8	$-0.368 \leqslant \delta \leqslant 0.029$	98.44	98.31	98.41	98.36
9-10	$\delta \leqslant -0.368$	100	100	100	100
All participants		64	64	63	61

4.1.2 Contract choice experiment

Figure 1 presents the distribution of the number of piece-rate contracts preferred by each worker. The average is 7.4, which implies a certainty equivalent between 400$ and 450$. One worker chose the piece-rate contract for all twelve of his/her decisions, thus guaranteeing that he/she

[11] The worker's choices are said to be consistent if he/she switches only once from lottery A to lottery B.

worked under the piece-rate contract[12].

Figure 1: *Distribution of the number of piece rates selected during the contract choice experiment.*

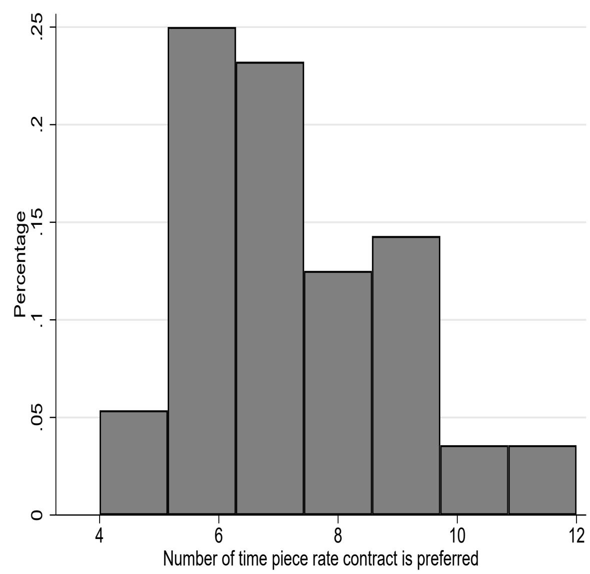


Table 3 summarizes the statistics from the contract choice experiment. The results indicate 76% of workers were ready to accept fixed-wage contracts that were greater than or equal to $400 per day. This contract pays just below the average daily earnings , which are $420.90 per day.

4.2 Payroll data

The firm's payroll data contain information on the daily production of each worker (the number of trees planted), the piece rate and worker characteristics: age, sex, tenure, experience and level of education. These data include information on 4147 daily observations on 108 workers.[13] The descriptive statistics of the payroll data are presented in Table 4. Employees worked an average of 41 days during this planting season. Daily earnings ranged from $90 to $1065, with an average of $420.5. Workers planted an average of 2003 trees per day with a standard deviation of 623.1.

[12] Discussions with this worker revealed that he/she would have chosen the fixed-wage contract only if the guaranteed wage was greater than 700$.

[13] We only use observations for which earnings are greater than the minimum wage of $83.6 in British Columbia. This excludes planters who worked part of a day.

Table 3: *Contract choices*

Number of piece rates contract preferred	Bound for certainty equivalent	Cumulative distribution
0-4	$W^{*} \leq 200$	2,00
5	$200 < W^{*} \leq 350$	6,00
6	$350 < W^{*} \leq 400$	34,00
7	$400 < W^{*} \leq 450$	60,00
8	$450 < W^{*} \leq 500$	74,00
9	$500 < W^{*} \leq 550$	90,00
10	$550 < W^{*} \leq 600$	94,00
11	$600 < W^{*} \leq 650$	98,00
12	$W^{*} > 650$	100

Note: The first column represents the number of piece-rate contracts the participant chose before switching to the fixed contract. The second column defines the interval for the certainty equivalent of the piece-rate contract. The last column represents the corresponding cumulative distribution.

Payroll statistics during the experimental period are given in the bottom part of the table. Average daily productivity is lower under fixed wage contracts (388.9 trees per day) than under piece rate contracts (608.5 trees per day), representing a reduction in the order of 36%. This difference captures both incentive effects and selection, which may explain why it is larger than the 17% reduction reported in Shearer (2004). In that study all workers were observed under both piece rates and fixed wages. In contrast, the workers in our study had partial control over their contract. For example, a worker could ensure working under piece rates by selecting that contract for all decisions in the contract-choice experiment. If low-productivity workers find fixed-wages more attractive they will be over represented under those contracts. Similar considerations cause the average earnings of workers under piece-rate contracts ($486.3) to be lower than under fixed-wage contracts ($528.80). Workers chose the fixed-rate contracts when the fixed wage was high, which generates a rent in earnings. The counterfactual calculates the average daily earnings that fixed wage workers would have received if their production under fixed wages was multiplied by the regular piece rate paid on the block on which they planted. This average counterfactual average earnings was $343.7 per day, much lower than average earnings among piece-rate workers. The standard deviation of trees planted was much higher under piece rates (608.5) than under fixed wages (388.9), consistent with more variable effort levels under piece rates.

Table 5 presents the descriptive statistics of the individual characteristics. These statistics

Table 4: *Summary of the payroll data*

	Obs-day	Mean	Std. dev.	Min	Max
All (n=108)					
Earnings per day	4 147	421.5	115.8	90	1 065
Trees planted	4 147	1 999	623.1	300	4 915
Days worked per planter	4 147	41.30	6.836	2	50
Piece-rate contracts (n=108)					
Piece rate	4 111	0.213	0.037	0.150	0.380
Trees planted	4 111	2 003	623.7	300	4,915
Earnings per day	4 111	420.5	115.7	90	1,065
Piece-rate contracts (experimental dates, n=32)					
Piece rate	63	0.193	0.011	0.180	0.220
Trees planted	63	2 516	608.5	1,290	4,000
Earnings per day	63	486.3	115.0	232.2	757.2
Fixed-wage contracts (n=18)					
Trees planted	36	1 606	388.9	585	2,450
Earnings per day	36	528.8	74.70	400	650
Counterfactual					
Earnings counterfactual	36	343.7	83.23	125.2	524.3

show that the workers in this firm are heterogeneous. Their ages range between 20 and 47 years old, and 45.76% of them are women. In terms of the workers' education level, we observe that 66.1% of employees have a university degree and another 25% have some university education. Average experience in the industry is 8.9 years, with a maximum of 28 years and a minimum of 1 year. The variable "tenure" represents the number of years that the worker has worked in the firm. The average tenure among these workers is 4.4 years, but values range from 1 year to 26 years.

5 Model

We model worker behaviour and contracts under asymmetric information. The worker selects effort having observed planting conditions completely. The contract for a given block is determined by the firm, having observed an imperfect signal of planting conditions on that block. Our model is based on the work of Paarsch and Shearer (2000), Shearer (2004) and Bellemare and Shearer (2013). It is stylized to capture the important and relevant details of production in the tree-planting industry. Workers are heterogeneous in terms of risk preferences and ability.

Table 5: *Individual characteristics*

Variable	Obs	Mean	Std. Dev.	Min	Max
Age	59	29.136	4.543	20	47
Experience	59	8.983	4.984	1	28
Tenure	59	4.373	4.410	1	26
Gender					
Female	59	0.458	0.503	0	1
Male	59	0.542	0.503	0	1
Education Level					
Secondary	59	0.051	0.222	0	1
Some Post-secondary	59	0.017	0.130	0	1
Post-secondary degree	59	0.017	0.130	0	1
Some university	59	0.254	0.439	0	1
University degree	59	0.661	0.477	0	1

For tractability, the model assumes specific functional forms for utility and the distribution of shocks that allow closed-form solutions for effort and indirect utility in the presence of heterogeneous risk preferences. In deriving comparative static results we are careful to identify those that are specific to the chosen functional forms and those that hold more generally. In Appendix 1 we investigate the extension of our results to more general representations of risk preferences.

Planting contracts are divided into blocks $j \in \{1, ...J\}$. Each morning, workers are randomly assigned to plant an area of a particular block. We model a block as a distribution of productivity shocks, dentoted S_{ij}, which represent elements that affect worker productivity, but are beyond the worker's control. When workers are assigned to plant on a particular block, they draw a particular value of S, from that distribution before choosing their effort level. The daily production of worker i on block j, denoted $Y_{ij} > 0$, is written

$$Y_{ij} = E_{ij} S_{ij} \tag{1}$$

where E represents worker effort. The productivity shock S_{ij} is independent across individuals and time within a block. Its variance is constant across blocks so that variation in planting conditions across blocks is solely due to changes in μ_j.[14] We assume

$$ln(S_{ij}) \sim N(\mu_j, \sigma^2).$$

Worker preferences over earnings, W, and effort are represented by a separable, Constant Relative Risk Aversion (CRRA) utility function

$$U(W_{ij}, E_{ij}) = \begin{cases} \frac{1}{\delta_i}[W_{ij} - C_i(E_{ij})]^{\delta_i} & \text{if } W_{ij} > C_i(E_{ij}) \\ -\infty & \text{otherwise,} \end{cases} \tag{2}$$

where $C_i(E) = \frac{1}{\eta}\kappa_i E^\eta$ is the cost of effort for worker i. The parameter κ_i is the worker's monetary cost of effort; it is inversely related to the worker's ability. The parameter δ_i is a constant risk-preference parameter, $\eta > 1$ defines the curvature of the cost of effort function.

We begin by modelling behaviour under piece rates, the standard contract in the firm. We then turn to fixed-wage contracts, and ultimately the choice between them.

5.1 Piece rate contracts

Daily earnings under a piece-rate contract are determined by the observed production Y_{ij} and the piece rate r_j:

$$W_{ij} = r_j Y_{ij}$$

The timing is as follows.

1. For a given block, j to be planted, nature chooses (μ_j, σ^2), the actual conditions on the block.

2. The firm knows σ^2, but observes $\tilde{\mu}_j$, a noisy signal of μ_j:

$$\mu_j = \tilde{\mu}_j + \epsilon_j \tag{3}$$

   where $\epsilon_j \sim N(0, \sigma_\epsilon^2)$.

[14] The assumption of a constant variance ensures that workers are ex-ante indifferent among piece-rate contracts across blocks (see equation (11) below). This allows us to concentrate on the effect of risk preferences on the choice between piece rates and fixed wages in a simplified setting. If σ^2 varies across blocks, calculating the risk associated with any contract requires integrating over possible values of σ^2, considerably complicating the theoretical analysis.

3. Given the values of σ^2 and $\tilde{\mu}_j$, the firm offers the worker a piece-rate contract;

4. The worker observes the same noisy signal $\tilde{\mu}_j$, σ^2 and accepts or rejects the piece-rate contract.

5. If the worker accepts the contract, he/she observes s_{ij}, a particular draw of S_{ij} and chooses his/her effort level e^p_{ij}, producing Y_{ij}.

6. The firm observes production Y_{ij} and pays earnings.

To solve the model we work backwards. Optimal effort is

$$e^p_{ij} = \left[\frac{r_j s_{ij}}{k_i}\right]^\gamma \text{ where } \gamma = \frac{1}{\eta - 1}. \tag{4}$$

Effort is independent of the risk preferences because it is determined after observing s_{ij}.[15] Earnings under the piece-rate contract on block j are

$$W(s_{ij}) = \frac{r_j^{\gamma+1}}{\kappa_i^\gamma} s_{ij}^{\gamma+1}, \tag{5}$$

the cost of effort $C(e_{ij})$ is

$$C(e_{ij}) = \frac{\gamma}{\gamma+1}\frac{r_j^{\gamma+1}}{\kappa_i^\gamma} s_{ij}^{\gamma+1}, \tag{6}$$

giving indirect utility of worker i on block j as

$$V^p(s_{i,j}) = \frac{1}{\delta_i}\frac{r_j^{\delta_i(\gamma+1)}}{(\gamma+1)^{\delta_i}\kappa_i^{\delta_i\gamma}} s_{ij}^{\delta_i(\gamma+1)}. \tag{7}$$

If a worker observed μ_j their indirect utility from planting on block j would be:

$$\mathcal{E}\left[V^p_{ij}(\mu_j)\right] = \frac{1}{\delta_i}\frac{r_j^{\delta_i(\gamma+1)}}{(\gamma+1)^{\delta_i}\kappa_i^{\delta_i\gamma}} \exp^{\delta_i(\gamma+1)\mu_j + \frac{1}{2}(\gamma+1)^2\delta_i{}^2\sigma^2} \tag{8}$$

where $\mathcal{E}$ denotes the expectation operator. However, the firm only observes $\tilde{\mu}_j$. Substituting from (3) and taking expectations gives the firm's expectation of worker indirect utility when the contract is bid

[15]The second order condition is satisfied for $\kappa_i > 0, \eta > 1 (\gamma > 0)$.

$$\frac{1}{\delta_i}\frac{r_j^{\delta_i(\gamma+1)}}{(\gamma+1)^{\delta_i}\kappa_i^{\delta_i\gamma}}\exp^{\delta_i(\gamma+1)\tilde{\mu}_j+\frac{1}{2}(\gamma+1)^2\delta_i{}^2(\sigma^2+\sigma_\epsilon^2)}. \tag{9}$$

Following Paarsch and Shearer (1999) we assume that the firm selects the piece rate on block j to satisfy the marginal worker's participation constraint, who we assume to be risk neutral.[16] The marginal worker is defined as the worker who is indifferent between any piece-rate contract and his/her alternative, defined by $\bar{w}$ (all other workers earn rents). The piece rate r_j satisfies

$$\frac{r_j^{(\gamma+1)}}{(\gamma+1)k_h^\gamma}\exp^{((\gamma+1)\tilde{\mu}_j+\frac{1}{2}(\gamma+1)^2(\sigma^2+\sigma_\epsilon^2))} = \bar{w}$$

or

$$r_j^{\gamma+1} = \bar{w}(\gamma+1)k_h^\gamma \exp^{-\left[(\gamma+1)\tilde{\mu}_j+\frac{1}{2}(\gamma+1)^2(\sigma^2+\sigma_\epsilon^2)\right]} \tag{10}$$

Substituting from (10) into (9), the expected utility for individual i of the piece-rate contract on any block j is

$$\mathcal{E}\left[V_{ij}^p(\delta_i,\kappa_i)\right] = \frac{1}{\delta_i}\left[\bar{w}\left(\frac{k_h}{\kappa_i}\right)^\gamma\right]^{\delta_i}\exp^{\frac{1}{2}\delta_i(\gamma+1)^2(\delta_i-1)(\sigma^2+\sigma_\epsilon^2)} \tag{11}$$

Equation (11) is constant across blocks. It therefore gives a worker's indirect utility from the piece rate contract prior to knowing where he/she will be planting. It depends on the planter's risk preferences and ability.The block-specific terms now represent perception errors rather than variances. Risk is measured by the term $\sigma^2+\sigma_\epsilon$, which captures variability in the daily shock that the worker receives and misperception of planting conditions (and hence improper pricing) on a particular block.

Expected earnings under piece rates are found from (5) and (10)

$$E\left[w_{ij}^p((\delta_i,\kappa_i)\right] = \bar{w}(\gamma+1)\left(\frac{k_h}{\kappa_i}\right)^\gamma \tag{12}$$

[16]Unlike Bellemare and Shearer (2013), we do not estimate the marginal workers' risk preferences within a structural model. Setting the marginal worker's risk parameter to 1 does not therefore affect our results. It will however affect our ability to generalize the theoretical predictions to more general representations of risk preferences; see Appendix 1. It is also consistent with the firm's personnel policy and discussions with the firm manager. The firm sets the piece rate to ensure that earnings are constant across blocks which is consistent with our model (see equation (12) in the text).

which are constant across contracts and collapse to $\bar{w}(\gamma + 1)$ for the marginal worker.

To understand (12), notice the expected cost of effort under a piece-rate contract is

$$E\left[C(e_{ij}^{p})\right] = \gamma\bar{w}\left(\frac{k_h}{\kappa_i}\right)^{\gamma} \tag{13}$$

The marginal worker is compensated for his/her alternative $\bar{w}$ and additional effort costs which, from (13) is equal to $\gamma\bar{w}$. Other workers's expected earnings are prorated by the term κ_h/κ_i reflecting their ability relative to that of the marginal worker.

5.2 Fixed-wage contracts

Under the fixed-wage contract the worker receives a payment of W^f, independent of his/her production. We assume that the worker agrees to provide a minimum effort level e^{fw} upon observing $\tilde{\mu}_j$, that can be enforced through monitoring. This allows us to focus on contract choice in a relatively simple framework.[17] We specify that effort levels under fixed wages are proportional to the expected effort level under piece rates:

$$e_{ij}^{fw} = \psi_i \mathcal{E}(e_{ij}^{p}) \quad 0 < \psi_i < 1.$$

Using (4) and taking expectations, worker effort under fixed wages is

$$e_{ij}^{fw}(\tilde{\mu}_j) = \psi_i \frac{r_j^{\gamma} \exp^{\gamma\tilde{\mu}_j + \frac{1}{2}\gamma^2(\sigma^2+\sigma_{\epsilon}^2)}}{\kappa_i^{\gamma}}. \tag{14}$$

Utility under a contract paying W_f is equal to

$$V_{ij}^{f} = \frac{1}{\delta_i}\left[W_f - c(e_{ij}^{fw})\right]^{\delta_i} \tag{15}$$

Substituting from (14) and using (10), indirect utility under the fixed-wage contract, W_f is

$$\mathcal{E}\left[V_{ij}^{f}(\delta_i, \kappa_i, W_f)\right] = \frac{1}{\delta_i}\left[W_f - \gamma\psi_i^{\frac{\gamma+1}{\gamma}}\bar{w}\left(\frac{k_h}{\kappa_i}\right)^{\gamma}\exp^{-\frac{1}{2}(\gamma+1)(\sigma^2+\sigma_{\epsilon}^2)}\right]^{\delta_i}, \tag{16}$$

[17] Incentive models generate positive effort levels under fixed wages through termination contracts that introduce dynamic elements into the setting. Shapiro and Stiglitz (1984) and Macleod and Malcomson (1989) are well-known examples. Shearer (2004) provides an empirical application.

which is constant across blocks. We note that equilibrium utility is decreasing in σ^2, even for risk averse workers. This is because earnings are fixed, hence σ^2 only affects effort (and their costs). The direct effect is to increase effort through (14), which more than offsets the decrease in r_j to satisfy the marginal workers participation constraint (10).

5.3 Contract choice and predictions

The worker selects a contract before knowing which block he/she will be planting on. Given the expected utility of planting under piece rates and under fixed wages is constant across blocks, the worker's choice is simply based on a comparison of (11) and (16). Recall the worker was offered a sequence of fixed-wage contracts, each specifying a different W_f.

For a given W_f, the worker's decision rule is

$$\text{Choose} \begin{cases} \text{Fixed-Wage Contract} & \text{if } \mathcal{E}\left[V_{ij}^{f}(\delta_i, \kappa_i, W_f)\right] > \mathcal{E}\left[V_{ij}^{p}(\delta_i, \kappa_i)\right] \\ \text{Piece-Rate Contract} & \text{if } \mathcal{E}\left[V_{ij}^{f}(\delta_i, \kappa_i, W_f)\right] < \mathcal{E}\left[V_{ij}^{p}(\delta_i, \kappa_i)\right]. \end{cases} \tag{17}$$

The worker is indifferent between contracts at W_f^*, his/her certainty equivalent. Equating utilities and rearranging gives

$$W_f^*(\kappa_i, \delta_i) = \bar{w}\left(\frac{k_h}{\kappa_i}\right)^{\gamma}\left[\exp^{\frac{1}{2}(\gamma+1)^2(\sigma^2+\sigma_\epsilon^2)(\delta_i-1)} + \gamma\psi_i^{\frac{\gamma+1}{\gamma}} \exp^{-\frac{1}{2}(\gamma+1)(\sigma^2+\sigma_\epsilon^2)}\right]. \tag{18}$$

The piece rate contract in (12) is based on the marginal worker's indifference across contracts. It adjusts worker i's earnings to compensate for his/her cost of effort relative to his/her alternative $\bar{w}$. The certainty equivalent is based on worker i's indifference between piece-rate and fixed-wage contracts. It therefore adjusts (12) to take into account individual i's attitude towards risk and the fact that effort under fixed wages is not zero. Inspection of equation (18) shows that the certainty equivalent consists of two parts. The first part captures the risk of earnings under piece rates from (12), prorated for worker i's risk preferences relative to the risk-neutral marginal worker. The second part captures the expected cost of effort under fixed wages.

Given utility under the fixed-wage contract is strictly increasing in W_f, the worker prefers all fixed-wage contracts offering $W_f > W_f^*(\kappa_i, \delta_i)$. The decision rule (17) can therefore be written

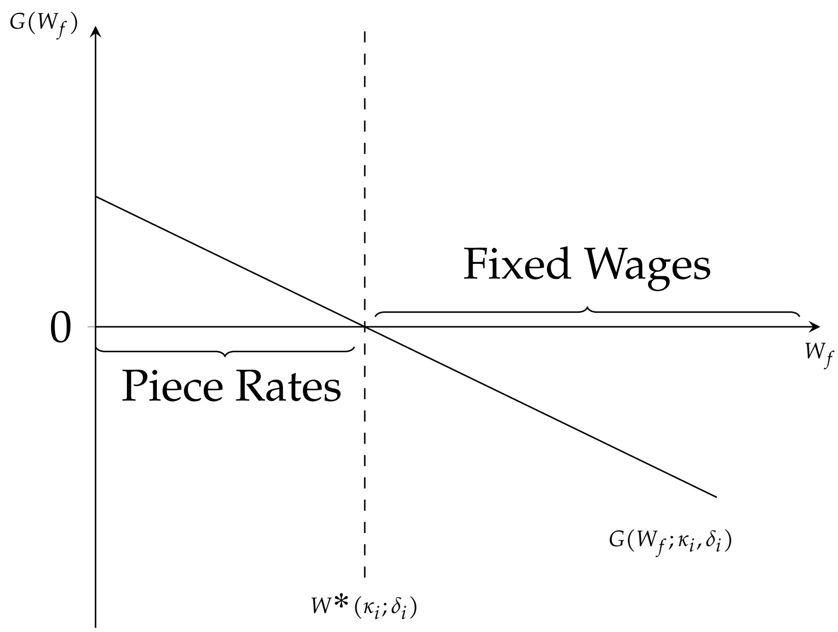
$$\text{Choose} \begin{cases} \text{Fixed-Wage Contract} & \text{if } W_f > W_f^*(\kappa_i, \delta_i) \\ \text{Piece-Rate Contract} & \text{if } W_f \leqslant W_f^*(\kappa_i, \delta_i) \end{cases} \tag{19}$$

This is shown in Figure 2, where we graph the function

$$G(W_f; \kappa_i, \delta_i) = W_f^*(\kappa_i, \delta_i) - W_f, \tag{20}$$

as a function of W_f (which we take as representing the different fixed wages offered in our contract-choice experiment). Fixed wage contracts are preferred whenever $W_f > W_f^*(\kappa_i, \delta_i)$, or $G(W_f; \kappa_i, \delta_i) < 0$. The piece-rate contract is preferred whenever $W_f < W_f^*(\kappa_i, \delta_i)$, or $G(W_f; \kappa_i, \delta_i) > 0$.

Figure 2: *Contract Choice Rule*



5.3.1 Predictions

Comparative statics can be conducted to investigate how changes in risk tolerance and ability affect W^*. Equation (19) describes the set of fixed-wage contracts that is preferred to the piece-rate contract for a given set of risk preferences, δ_i, and ability, κ_i. The results are presented graphically for our specific model and functional forms. More general cases are treated in Appendix 1.

Prediction 1: The number of piece-rate contracts chosen increases with the degree of risk tolerance:

$$\frac{\partial W^*(\kappa_i, \delta_i)}{\partial \delta_i} > 0. \tag{21}$$

Figure (3) shows this effect. An increase in risk tolerance (an increase of δ_i) increases the expected utility of the piece-rate contract and the certainty equivalent. The function $G(W_f, \kappa_i, \delta_i)$ shifts to the right and the worker prefers more piece-rate contracts and fewer fixed-wage contracts. This result can be generalized to more general representations of risk preferences. Appendix 1 presents a formal treatment for local increases in risk aversion. A complete treatment is available in Pratt (1964).

Prediction 2: The number of piece-rate contracts chosen increases with ability (a lower value of κ_i):

$$\frac{\partial W^*(\kappa_i, \delta_i)}{\partial \kappa_i} < 0. \tag{22}$$

Figure (4) shows the effect of an increase of κ_i (a decrease in ability). The function $G(W_f, \kappa_i, \delta_i)$ shifts to the left, decreasing the certainty equivalent (W^*) and the worker selects fewer piece-rate contracts and more fixed-wage contracts. This prediction aligns with Lazear's (1986), sorting arguments wherein high-ability workers are attracted to piece rate contracts. In our context, high-ability workers have a higher certainty equivalent. However, caution must be exercised in interpreting this result. When ability interacts with risk preferences this effect is ambiguous and must be determined empirically; see Appendix 1.

5.3.2 The cost of risk in contracting

The model is also informative over the contracting costs of risk. Interpreting $\mathcal{R} = \sigma^2 + \sigma_\epsilon^2$ as risk, and differentiating (18), we have

$$\frac{\partial W_f^*(\kappa_i, \delta_i)}{\partial \mathcal{R}} = \bar{w}\left(\frac{k_h}{\kappa_i}\right)^\gamma \left[\frac{1}{2}(\gamma+1)^2(\delta_i - 1)\exp^{\frac{1}{2}(\gamma+1)^2(\sigma^2+\sigma_\epsilon^2)(\delta_i-1)} \right. \tag{23}$$

$$\left. - \frac{1}{2}(\gamma+1)\gamma\psi_i^{\frac{\gamma+1}{\gamma}} \exp^{-\frac{1}{2}(\gamma+1)(\sigma^2+\sigma_\epsilon^2)}\right]. \tag{24}$$

Figure 3: *Effect of an increase in risk tolerance* ($\delta_i^1 > \delta_i^0$)

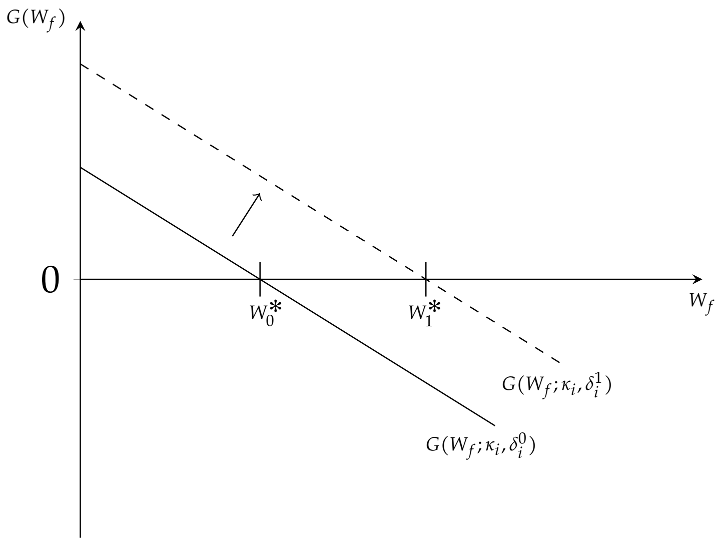
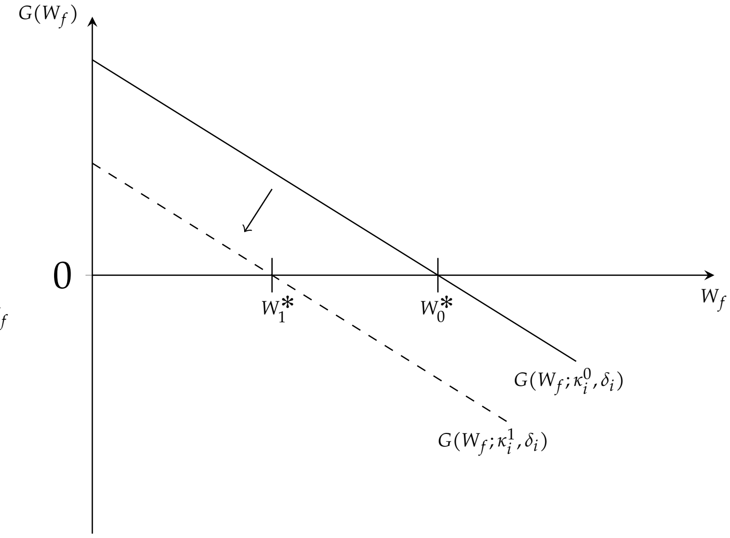


Figure 4: *Effect of an increase in* κ_i ($k_i^1 > k_i^0$)



The first term reflects the increased contracting costs due to risk. It is negative for risk-averse workers ($\delta_i < 1$), suggesting such workers would be willing to accept a lower fixed wage at higher risk levels. For risk-averse workers, riskier settings imply higher relative costs of providing incentives.

6 Measuring Risk Preferences

We begin by comparing workers' responses across the low-stakes lottery (LSL) and the high-stakes lottery (HSL) experiments. Previous studies have found mixed results on the stability of responses as the experimental stakes increased. Holt and Laury (2002) reported that the number of safe choices increased as the stakes (or scale) increased, a result consistent with increasing relative risk aversion. In contrast, using field experiments, Bellemare and Shearer (2010) found no evidence of scale effects among tree planters.

To study this question, we test whether the number of safe choices is affected by the size of the payoffs using the Wilcoxon matched-pairs signed-ranks test. The null hypothesis of the test is that the distribution of the number of safe choices is identical in both the LSL and the HSL experiments[18]. The calculated statistic of the test is Z=-0.80, giving a p-value of 0.424. This implies that the null hypothesis is not rejected.[19] There are no statistically significant differences

[18]The test was conducted using the signrank command in Stata

[19]The chi-squared test and the Kolmogorov-Smirnov test also failed to reject the null hypothesis that the distri-

in the distribution of safe choices between HSL and LSL experiments. This confirms the visual evidence on the distributions presented in Figures (5) and Figure (6) which show very little difference in the distributions of the number of safe choices across lotteries. However, these

Figure 5: *Distributions of the number of safe choices*

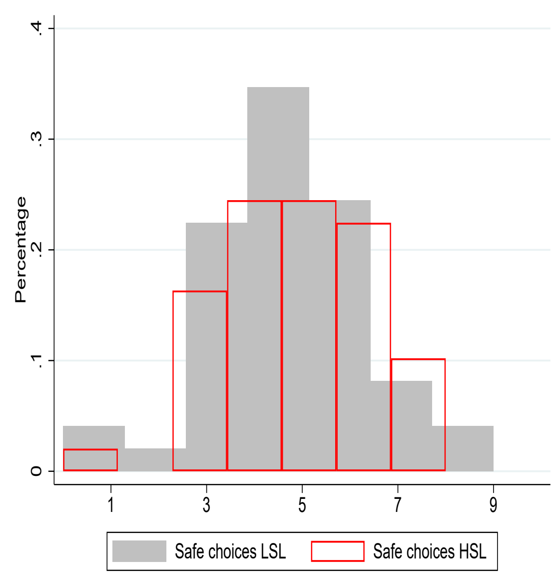
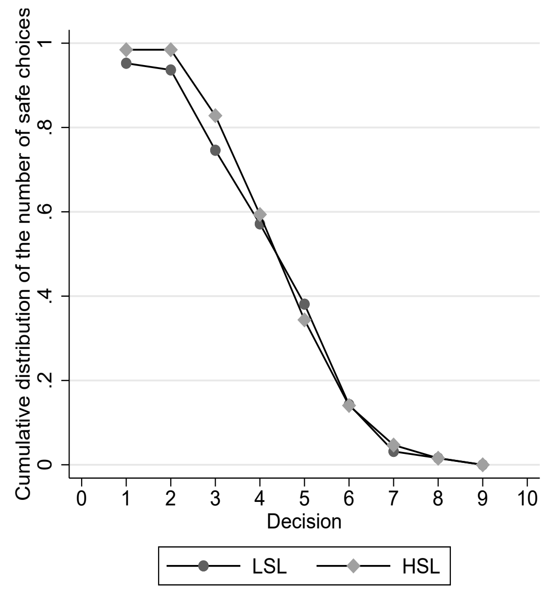


Figure 6: *Cumulative number of safe choices for each decision.*



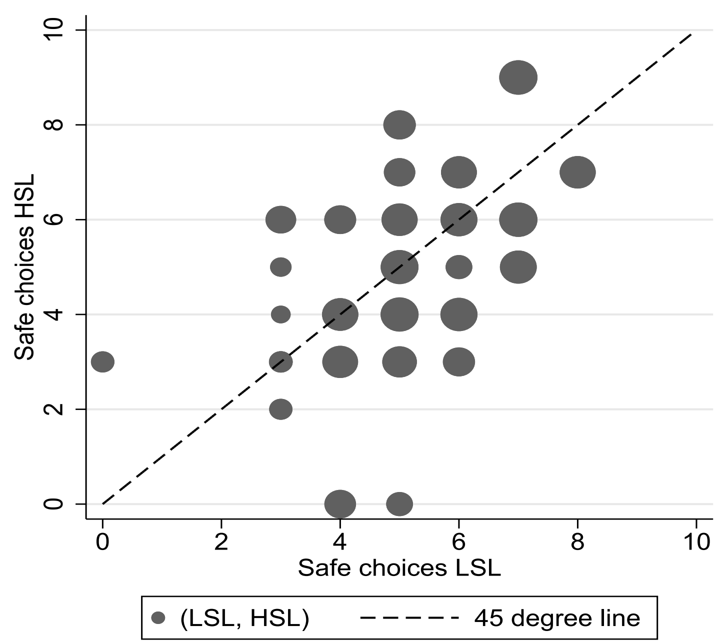
results do not necessarily imply that the individual risk preferences estimated from the two experiments are equal, or that participants do not change their decisions according to the stakes of the lotteries. To address that issue we look at individual responses across lotteries.

Figure 7 shows the number of safe choices for the HSL and the LSL per individual. Each point represents a combination of the number of safe choices in the LSL and the number of safe choices in the HSL made by one or more participants. The size of each point is proportional to the number of individuals who made that combination of choices. The dashed (45-degree) line represents observations for which the number of safe choices in both experiments is equal. If none of the participants changed their decisions across the two experiments, all the points would be on this line. The fact that several points deviate from the 45-degree line, suggests changes in individuals' choices from one experiment to another that are not detected in the aggregate distribution of choices.

To analyse this issue in more detail, we consider a linear regression of the number of safe choices in HSL experiment (CS_{HSL}) on the number of safe choices in LSL experiment (CS_{LSL}).

butions were identical.

Figure 7: *Distribution of safe choices*



We include in our sample only those workers who made consistent choices in both lotteries.

$$CS_{HSL} = \beta_0 + \beta_1 CS_{LSL} + \epsilon \tag{25}$$

If workers' behaviour did not change, all observations would lie on the 45-degree line. Statistically, one would expect observations to be tightly concentrated around this line, implying $\beta_1 = 1$ and $\beta_0 = 0$. The results of this regression are presented in Table (6). The estimated value of β_1 is 0.38, with a standard deviation of 0.1. We reject the null hypothesis $\beta_1 = 1$ at all standard significance levels of significance (the p-value of the t-test is zero). We estimate the value of β_0 at 3.09, with a standard deviation of 0.48. The null hypothesis $\beta_0 = 0$ is rejected at all standard significance levels (the p-value of the t-test is zero). Fisher's joint test of the two restrictions also rejects the null hypothesis $H_0 : \beta_0 = 0$ and $\beta_1 = 1$.[20] We conclude that a significant number of participants have changed their behaviour towards risk in the presence of high-stakes lotteries, but this is hidden in the aggregate distribution.

There are a number of possible explanations for the observed change in behaviour as the stakes increased. Changing risk preferences (Holt and Laury, 2002) is one possibility, although

[20] We also considered robust regression techniques, using the rreg command in Stata to run this regression. The results were virtually unchanged.

Table 6: *Internal validity*

	β_1	β_0	Fisher joint test $H_0 : \beta_0 = 0$ et $\beta_1 = 1$
Coefficients and test	.38***	3.09***	F(2,60) = 21.42
	(0.1)	(0.48)	Prob > F = 0.0000
60 observations			
*** significant at 1%			

it is not clear why the risk preferences measured in the HSL would be more relevant for predicting contract choices than those from the LSL (see Section 7, below). Order effects (Harrison et al., 2006) could also be present. While we do not rule these out, we note that earnings from the LSL have no predictive power over HSL choices.[21] It is also possible that individual's strategies evolved as they learned about how to play the lottery. Many experimental studies include preliminary practice rounds to allow participants to learn (Lusk and Shogren (2007) provide a discussion of the benefits of this in the experimental auctions literature). Again, while we do not rule this out, we note that a natural measure of learning is comparing the number of mistakes (or inconsistent choices) that were made in filling out the lottery sheet. In our case, the number of inconsistent choices was negligible in both LSL and HSL, suggesting that learning was not a primary consideration. Another possiblity is that participants took the lottery more seriously at higher stakes, revealing their true risk preferences. Levitt and List (2007b) argue that as stakes rise, monetary considerations take a more prominent place in individuals' utility functions, affecting experimental responses. While the issues and setting are somewhat different,[22] this interpretation is consistent with their argument.[23]

7 Predicting contract choices

We use regression models to investigate the ability of the experimentally measured risk preferences to predict contract choices. The model regresses the certainty equivalent wage of worker i, denoted W_i^* on a vector of personal characteristics. The certainty equivalent for individual i

[21] The coefficient on earnings in the LSL is statistically insignificant in a regression explaining the number of safe choices in the HSL. The p-value is over 0.6.

[22] Levitt and List (2007b) were concerned in explaining the importance of social preferences in low-stakes experiments.

[23] We also received a number of comments from participants during the HSL expressing how much more exited and nervous they were in drawing their chips. While anecdotal, this is consistent with participants taking this lottery more seriously.

is measured as the mid-point of the last piece-rate contract he/she accepted, before switching to fixed wages. The vector $\mathbf{Z}_i$, includes worker i's: risk preferences (measured by the number of safe choices made during the lottery experiment), ability (measured by i's average earnings, divided by 100, prior to the experiment) age, gender experience, tenure and education.[24]

The results from the regression model on the certainty equivalent wage are presented in Table 7. Column 1 includes the results when the number of safe choices in the LSL is the only explanatory variable. Increases in the number of safe choices reflect less risk tolerance on the part of the worker. From Prediction 1, they should reduce the certainty equivalent and the number of piece-rate contracts that were chosen. The coefficient on *Safe choices* is negative, as expected, but statistically insignificant. Column 2 includes the number of safe choices from the LSL as well as observable characteristics: ability, age, gender, experience, tenure and education. The number of safe choices is still insignificant, but now with a positive sign. Ability has a positive and statistically significant effect on the certainty equivalent, consistent with Prediction 2. Higher ability workers have higher certainty equivalents and select piece rates more often.

The results are more encouraging when using the risk preferences from the HSL to predict contract choices. These are presented in Columns 3 and 4 of Table 7. Here, the number of safe choices has a negative (and statistically significant) effect on the certainty equivalent, consistent with Prediction 1. Ability has a positive (and statistically significant) effect, consistent with Prediction 2.

[24] We also analysed these data using Poisson regression models, relating the number of times individual i chose the piece-rate contract to observable characteristics, $\mathbf{Z}_i$. The results (not included) closely parallel those presented and are not included in the paper. They are available from the authors on request.

Table 7: *Predicting the certainty equivalent*

	Dependant variable: Certainty equivalent.			
VARIABLES	Low-stake Lottery		High-stake Lottery	
Safe choices	-0.551	4.635	-26.91***	-12.45*
	(7.064)	(2.943)	(7.871)	(6.347)
Ability		69.06***		65.21***
		(14.29)		(13.85)
Age		0.688		1.731
		(2.909)		(3.238)
Female		-7.049		-3.325
		(15.37)		(15.62)
Experience		2.782		2.407
		(2.830)		(3.091)
Tenure		-1.204		-4.692*
		(2.432)		(2.365)
Education level				
Post-secondary		37.56**		65.90***
		(16.84)		(17.40)
Some University		50.96***		34.05**
		(16.45)		(15.48)
University Degree		50.59**		29.70
		(22.33)		(17.67)
Constant	444.9***	47.78	570.9***	145.0
	(38.20)	(73.72)	(43.51)	(103.4)
Observations	49	47	49	47

Robust standard errors in parentheses
*** p<0,01, ** p<0,05, * p<0,1

8 Conclusion

We have examined the ability of experimental measures of risk preferences to predict workers' contract choices in a real-world setting. We estimated the workers' risk-preference parameters using the methods developed by Holt and Laury (2002), with both low-stakes lotteries and high-stakes lotteries. Subsequently, we conducted a contract-choice experiment on the same workers. In this experiment, each worker made 12 decisions, choosing, for each decision, between his/her regular piece-rate contract and a fixed wage contract. The fixed-wage contracts were distinguished by an increasing sequence of fixed wages. These choices led to real consequences for the workers. After completing the contract-choice experiment, one of the twelve decisions was chosen at random, and the worker was paid according to his/her choice for that decision over a period of two working days. In our empirical work, we analysed the lottery choices of the workers, both in terms of their consistency across the lotteries and their ability to predict contract choices.

Our empirical work contains many interesting results concerning experimental measures of risk preferences and contracting models. First, the aggregate distribution of risk preferences is stable when the scale of the lotteries is increased, but this stability hides important variation at the individual level. This suggests that tests based on the aggregate distribution of choices should be interpreted with caution. The aggregate distribution can hide changes in behaviour at the individual level, causing such tests to lack power. Second, only the measure of risk preferences from the high-stakes lottery predicts the contractual choices of the workers. This confirms that experimental lotteries can be used to measure risk preferences in empirical work on contracts, but the scale of the lotteries is an important determinant of their success. One interpretation of this result is that workers took the lottery more seriously at higher stakes and better revealed their true risk preferences, although more research is need on this issue. A related question is how large the stakes must be in order for the lottery to predict choices. Our experiment only included two levels of stakes and are therefore largely silent on this subject. Replicating this type of experiment using a wider range of stakes would be an interesting area for future work.

Our results also have implications for the role of risk in contracting models. Prendergast (2000) pointed to a lack of empirical evidence showing that risk affects contracts. As in Ackerberg and Botticini (2002) and Bellemare and Shearer (2010, 2013) our results suggest that heterogeneity of risk preferences plays an important role in this. Workers in our experiment react to the riskiness of piece-rate contracts in precisely the manner that is predicted by economic theory. The less tolerant they are of risk, the more attractive they find fixed-wage contracts and the higher is the relative cost of providing incentives. Our empirical results also show that high-ability workers have higher certainty equivalents and are more likely to select a piece-rate contract. Lazear (2000) studied a firm that changed its compensation system from fixed wages to piece rates and found turnover patterns that were consistent with sorting over ability. Dohmen and Falk (2011) found evidence of sorting over ability in a laboratory experiment, within the context of multidimensional heterogeneity. Our empirical results suggest that similar sorting forces operate in the field.

Finally, our results also have implications for experimental economics. Much has been written on the generalizability of laboratory results to the field; see, for example, Gneezy and List (2006), Levitt and List (2007a), Levitt and List (2007b), Falk and Heckman (2009) and Cramerer (2015). One interpretation of our risk-preference revealing experiment is as an artefactual laboratory experiment (Harrison and List, 2004), conducted in the field. Whether or not our setting replicates that of a laboratory is debatable, nevertheless the results clearly show that methods commonly used in laboratory experiments to estimate risk preferences produce results that are generalizable, at least when the stakes are large enough.

References

Ackerberg, D. A. and M. Botticini (2002). Endogenous matching and the empirical determinants of contract form. *Journal of Political Economy 110*(3), 564–591.

Allen, D. W. and D. Lueck (1999). The role of risk in contract choice. *Journal of Law, Economics, and Organization 15*(3), 704–736.

Andersen, S., S. Ertaç, U. Gneezy, M. Haffman, and J. A. List (2011). Stakes matter in ultimatum games. *American Economic Review 101*(7), 3427–39.

Andersen, S., G. W. Harrison, M. I. Lau, and E. E. Rutström (2008). Eliciting risk and time preferences. *Econometrica 76*(3), 583–618.

Bellemare, C. and B. Shearer (2010). Sorting, incentives and risk preferences: Evidence from a field experiment. *Economics Letters 108*(3), 345–348.

Bellemare, C. and B. Shearer (2013). Multidimensional heterogeneity and the economic importance of risk and matching: evidence from contractual data and field experiments. *The RAND Journal of Economics 44*(2), 361–389.

Belzil, C. and M. Sidibé (2016). Internal and external validity of experimental risk and time preferences. *Working paper IZA*, 10348.

Bombardini, M. and F. Trebbi (2012). Risk aversion and expected utility theory: An experiment with large and small stakes. *Journal of the European Economic Association 10*(6), 1348–1399.

Cameron, L. A. (1999). Raising the stakes in the ultimatum game: experimental evidence from indonesia. *Economic Inquiry 37*, 47–59.

Charness, G., U. Gneezy, and A. Imas (2013). Experimental methods: Eliciting risk preferences. *Journal of Economic Behavior & Organization 87*, 43–51.

Cramerer, C. (2015). The promise and success of lab–field generalizability in experimental economics: A critical reply to levitt and list. In G. Fréchette and A. Schotter (Eds.), *Handbook of Experimental Economic Methodology*, Volume 362.

Dave, C., C. Eckel, C. Johnson, and C. Rojas (2010). Eliciting risk preferences: When is simple better? *Journal of Risk and Uncertainty 87*, 219–243.

Dohmen, T. and A. Falk (2011). Performance pay and multidimensional sorting: Productivity, preferences, and gender. *The American Economic Review 101*(2), 556–590.

Dohmen, T., A. Falk, D. Huffman, and U. Sunde (2010). Are risk aversion and impatience related to cognitive ability? *American Economic Review 100*(June), 1238–1260.

Dohmen, T., A. Falk, D. Huffman, U. Sunde, J. Schupp, and G. G. Wagner (2011). Individual risk attitudes: Measurement, determinants, and behavioral consequences. *Journal of the European Economic Association 9*(3), 522–550.

Falk, A. and J. Heckman (2009). Lab experiments are a major source of knowledge in the social sciences. *Science 362*, 535–538.

Gneezy, U. and J. A. List (2006). Putting behavioral economics to work: Testing for gift exchange in laobr markets using field experiments. *Econometrica 74*, 1365–1384.

Harrison, G. W., E. Johnson, M. M. McInnes, and E. E. Rutström (2006). Risk aversion and incentive effects: Comment. *American Economic Review 95*(3), 897–901.

Harrison, G. W. and J. A. List (2004). Field experiments. *Journal of Economic Literature 42*(4), 1009–1055.

Hoffman, E., K. McCabe, and V. Smith (1996). On expectations and the monetary stakes in ultimatum games. *International Journal of Game Theory 25*, 289–301.

Holmstrom, B. (1979). Moral hazard and observability. *Bell Journal of Economics 10*(1), 74–91.

Holt, C. A. and S. K. Laury (2002). Risk aversion and incentive effects. *The American Economic Review 92*(5), 1644–1655.

Jacobson, S. and R. Petrie (2009). Learning from mistakes: What do inconsistent choices over risk tell us? *Journal of Risk and Uncertainty 38*(2), 143–158.

Johansson-Stenman, O., M. Mahmud, and P. Martinsson (2005). Does stake size matter in trust games? *Economics Letters 88*, 365–369.

Lazear, E. P. (1986). Salaries and piece rates. *The Journal of Business 59*(3), 405–431.

Lazear, E. P. (2000). Performance pay and productivity. *The American Economic Review 90*(5), 1346–1361.

Levitt, S. and J. A. List (2007a). Viewpoint: On the generalizability of lab behaviour to the field. *Canadian Journal of Economics 40*(2), 347–370.

Levitt, S. and J. A. List (2007b). What do laboratory experiments measuring social preferences reveal about the real world? *Journal of Economic Perspectives 21*(2), 153–174.

Lusk, J. L. and J. F. Shogren (2007). *Experimental Auctions: Methods and Applications in Economic and Marketing Research*. Cambridge University Press.

Macleod, W. B. and J. M. Malcomson (1989). Implicit contracts, incentive compatibility, and involuntary unemployment. *Econometrica 57*(2), 447–480.

Paarsch, H. J. and B. Shearer (2000). Piece rates, fixed wages, and incentive effects: Statistical evidence from payroll records. *International Economic Review 41*(1), 59–92.

Paarsch, H. J. and B. S. Shearer (1999). The response of worker effort to piece rates: evidence from the british columbia tree-planting industry. *Journal of Human Resources*, 643–667.

Petrolia, D., C. Landry, and K. Coble (2013). Risk preferences, risk perceptions and flood insurance. *Land Economics 89*(2), 227–245.

Pratt, J. W. (1964). Risk aversion in the small and in the large. *Econometrica 32*, 122–136.

Prendergast, C. (1999). The provision of incentives in firms. *Journal of economic literature 37*(1), 7–63.

Prendergast, C. (2000). What trade-off of risk and incentives? *The American Economic Review 90*(2), 421–425.

Schildberg-Hörisch, H. (2018). Are risk preferences stable? *Journal of Economic Perspectives 32*(2), 135–154.

Shapiro, C. and J. E. Stiglitz (1984). Equilibrium unemployment as a worker discipline device. *American Economic Review 74*(3), 433–444.

Shearer, B. (2004). Piece rates, fixed wages and incentives: Evidence from a field experiment. *The Review of Economic Studies 71*(2), 513–534.

Stiglitz, J. E. (1975). Incentives, risk , and information: Notes towards a theory of hierarchy. *Bell Journal of Economics 6*(2), 552–579.

9 Appendix 1: General Risk Preferences

Utility is defined over earnings, W, and effort $E \in [0, \infty)$. We assume a separable utility function

$$U_i(W, E) = U_i\left(W - C_i(E)\right), \tag{26}$$

where

$$\begin{aligned} W &= rY & (27)\\ Y &= ES & (28)\\ C_i(E) &= \frac{\gamma}{\gamma+1}\kappa_i E_i^{\frac{\gamma+1}{\gamma}} & (29)\\ \ln S &\sim N(\mu, \sigma^2) & (30) \end{aligned}$$

We assume that $U' > 0$. Risk attitudes are captured by the function U''. Workers choose their effort level *after* all uncertainty is revealed.

9.1 Piece Rates

Under piece rates, $W = rY = rES$. Optimal effort is given by (4) in the text:

$$e_{ij}^p = \left[\frac{rS_{ij}}{\kappa_i}\right]^\gamma$$

Substituting optimal effort back into (26), we define

$$w_i^p(r_j, S_{ij}, \kappa_i) = re_{ij}^p S_{ij} - C_i(e_{ij}^p) = \frac{r^{\gamma+1} S_{ij}^{\gamma+1}}{\kappa_i^\gamma(\gamma+1)} \tag{31}$$

to be random earnings net of effort costs under piece rates for an individual with cost of effort κ_i. Indirect utility is

$$U_i(r_j e_{ij}^p S_{ij} - C_i(e_{ij}^p)) = V_i(w_i^p(r_j, S_{ij}, \kappa_i))$$

which inherits the properties of U with respect to risk preferences.

The piece rate is chosen to render a risk-neutral marginal worker indifferent to working at the firm and his/her alternative $\bar{u}$, for which effort is zero.

$$\mathcal{E}\left[re^{p}S - C_{h}(e^{p}_{hj})\right] = \bar{u}, \text{ or} \tag{32}$$

$$\frac{r^{\gamma+1}\mathcal{E}\left[S_{ij}^{\gamma+1}\right]}{\kappa_{h}^{\gamma}(\gamma+1)} = \bar{u}. \tag{33}$$

Inverting gives

$$r^{\gamma+1} = \frac{\bar{u}}{\kappa_{h}^{\gamma}\mathcal{E}\left[S_{ij}^{\gamma+1}\right]} \tag{34}$$

Substituting into (31) gives

$$w_{i}^{p}(r_{j}, S_{ij}, \kappa_{i}) = \bar{u}\left(\frac{\kappa_{h}}{\kappa_{i}}\right)^{\gamma}\frac{S_{ij}^{\gamma+1}}{\mathcal{E}\left[S_{ij}^{\gamma+1}\right]}$$

Taking expectations gives

$$\bar{w}_{i}^{p}(r_{j}, S_{ij}, \kappa_{i}) = \mathcal{E}\left[w_{i}^{p}(r_{j}, S_{ij}, \kappa_{i})\right] = \bar{u}\left(\frac{\kappa_{h}}{\kappa_{i}}\right)^{\gamma}$$

A second-order taylor-series expansion of $V(w_{i}^{p})$ around $\bar{w}_{i}^{p}$, gives

$$V(w_{i}^{p}) \approx V_{i}(\bar{w}_{i}^{p}) + V'(\bar{w}_{i}^{p})(w_{i}^{p} - \bar{w}_{i}^{p}) + \frac{1}{2}V_{i}''(\bar{w}_{i}^{p})(w_{i}^{p} - \bar{w}_{i}^{p})^{2}$$

Taking expectations, and using the fact that $\mathcal{E}[w_{i}^{p}] = \bar{w}_{i}^{p}$ and $\mathcal{E}[(w_{i}^{p} - \bar{w}_{i}^{p})^{2}] = \sigma_{i}^{2}$, gives

$$\mathcal{E}\left[V(w_{i}^{p})\right] \approx V_{i}(\bar{w}_{i}^{p}) + \frac{1}{2}V_{i}''(\bar{w}_{i}^{p})\sigma_{i}^{2}. \tag{35}$$

We subscript σ_{i}^{2} to denote that the variance will depend on κ_{i} in this setting. Writing

$$\begin{aligned}\sigma_{i}^{2} &= \mathcal{E}\left[(w_{i}^{p} - \bar{w}_{i}^{p})^{2}\right] \\ &= \bar{u}^{2}\left(\frac{\kappa_{h}}{\kappa_{i}}\right)^{2\gamma}\mathcal{E}\left[\frac{S^{\gamma+1} - \mathcal{E}\left[S_{ij}^{\gamma+1}\right]}{\mathcal{E}\left[S_{ij}^{\gamma+1}\right]}\right]^{2}\end{aligned}$$

which is independent of j whenever the coefficient of variation of the random variable $S^{\gamma+1}$ is constant across contracts. This restriction is satisfied by the log-normal distribution that is assumed in the text and we continue to assume it here.[25] [26]

9.2 Fixed Wages and the Certainty Equivalent

Under fixed wages, workers are paid W^f, supply a non-random effort level $e^f(\kappa_i)$ and earn utility equal to

$$U_i(W_f - C_i(e^f)) = V_i(W_f - C(e_i^f)).$$

We define a worker's certainty equivalent wage, W_i^*, as satisfying

$$\begin{aligned} V_i(W_i^* - C(e_i^f)) &= \mathcal{E}[V_i(w_i^p)] \\ &\approx V_i(\bar{w}_i^p) + \frac{1}{2}V_i''(\bar{w}_i^p)\sigma_i^2 \end{aligned} \tag{36}$$

from (35). Taking a first-order Taylor-series expansion of the left-hand side of (36) around $\bar{w}_i^p$ gives

$$V_i(W_i^* - C(e_i^f)) \approx V_i(\bar{w}_i^p) + V_i'(\bar{w}_i^p)\left(W_i^* - C(e_i^f) - \bar{w}_i^p\right)$$

Equating with the right-hand-side of (36) and rearranging, we have

$$W_i^* = \bar{w}_i^p + C(e_i^f) - \frac{1}{2}\delta_i\sigma_i^2 \tag{37}$$

where

$$\delta_i = -\frac{V_i''(\bar{w}_i^p)}{V_i'(\bar{w}_i^p)} \tag{38}$$

is the Arrow-Pratt measure of risk aversion. The certainty equivalent adjusts earnings for the difference in effort costs between piece rates and fixed wages, and risk.

[25] In general, any distribution for which the standard deviation is proportional to the mean satisfies this restriction. Examples include the Gamma distribution and the exponential distribution.

[26] It is straightforward to show that the results continue to hold in the presence of perceptions of errors in the setting of piece rates, ignored here for simplicity.

9.3 Comparative Statics

1. Risk Tolerance

   Holding ability fixed, workers who are more risk averse have lower certainty equivalents.

   $$\frac{\partial W_i^*}{\partial \delta_i} = -\frac{1}{2}\sigma_i^2 < 0. \tag{39}$$

   The terms $\bar{w}_i^p$ and $C(e_i^f)$ are independent of risk preferences because effort is chosen after all uncertainty is revealed and ability is fixed. An increase in δ decreases the worker's risk tolerance. This renders piece rate contracts less attractive relative to fixed wage contracts and the certainty equivalent wage decreases. Workers of lower risk tolerance will therefore select fewer piece-rate contracts in the second phase of the experiment.

2. Ability

   An increase in ability has an ambiguous effect on the certainty equivalent since ability can affect all arguments in (37). It is straightforward to show that $\bar{w}_i^p$ is increasing in ability, and it seems reasonable to assume e_i^f is as well, while the effect of ability on risk preferences (which operates through its effect on $\bar{w}_i^p$) depends on the sign of U'''. Even σ_i^2, the variance of $\bar{w}_i^p$, depends on ability in this setting. This is because workers select effort after the uncertainty is revealed and high-ability workers react more to shocks than low-ability workers. Ex-ante, workers do not know the shock that they will receive and hence their effort level. The resulting variance creates costs to contracting, depending on ability and risk preferences.

Appendix 2: Experimental Protocol

Lottery Experiments

Each morning, a member of the research team met with a group of twenty workers before they left for planting. Participation was voluntary. For this, and all successive meetings, planters were compensated $20 for their time, typically 20-25 minutes. All planters participated. The team member introduced himself to the workers as an economist who was conducting a field study on workers' attitudes towards risk. Planters were invited to participate in the study on a voluntary basis. The workers were informed that by participating they would receive $20 as compensation for their time. They were informed that by participating they would partake in a lottery in which they would earn between $2 and $77. They were also told that each participant could earn a different amount and that the exact amount that each participant earned would depend on the choices that he/she made and on chance. Finally the participants were asked to make all decisions on their own and not to discuss their choices with their colleagues. They were informed that their earnings would be added to their next pay cheque.

Participants were given an instruction sheet, a decision sheet and a pen. The instruction sheet was then read aloud to the participants by the team member. Once the reading was finished, the participants were asked if they had any questions. Each participant then filled in the decision sheet by himself/herself, making 10 decisions. Each decision was between a safe lottery and a risky lottery. The decision sheet for the LSL is given in Table 8. The safe lottery paid either a high payoff of $40 or a low payoff of $32, while the risky lottery paid either a high payoff of $77 or a low payoff of $2. The decision sheet for the HSL is given in Table 9. Here, the safe lottery paid either a high payoff of $80 or a low payoff of $64, while the risky lottery paid either a high payoff of $144 or a low payoff of $4.. Once they had all filled in the decision sheet, planters drew two poker chips (with replacement), numbered 1-10, from an opaque bag. The first draw determined the decision to be used for the experiment. The second draw determined the earnings of the participant. For example, for the LSL, if the first chip was numbered 4 and the second chip was numbered 2, the participant would win $40 if he/she had selected Lottery A for decision 4 and would win $77 if he/she had selected Lottery B for decision 4.

Table 8: *Decision Sheet for the Low-stakes-lottery Experiment*

Your name in capital letters: ________________________

	Option A	My choice is A	Option B	My choice is B
Decision 1	$40.00 if chip is 1 $32.00 if chip is 2 to 10		$77.00 if chip is 1 $2.00 if chip is 2 to 10	
Decision 2	$40.00 if chip is 1 to 2 $32.00 if chip is 3 to 10		$77.00 if chip is 1 to 2 $2.00 if chip is 3 to 10	
Decision 3	$40.00 if chip is 1 to 3 $32.00 if chip is 4 to 10		$77.00 if chip is 1 to 3 $2.00 if chip is 4 to 10	
Decision 4	$40.00 if chip is 1 to 4 $32.00 if chip is 5 to 10		$77.00 if chip is 1 to 4 $2.00 if chip is 5 to 10	
Decision 5	$40.00 if chip is 1 to 5 $32.00 if chip is 6 to 10		$77.00 if chip is 1 to 5 $2.00 if chip is 6 to 10	
Decision 6	$40.00 if chip is 1 to 6 $32.00 if chip is 7 to 10		$77.00 if chip is 1 to 6 $2.00 if chip is 7 to 10	
Decision 7	$40.00 if chip is 1 to 7 $32.00 if chip is 8 to 10		$77.00 if chip is 1 to 7 $2.00 if chip is 8 to 10	
Decision 8	$40.00 if chip is 1 to 8 $32.00 if chip is 9 to 10		$77.00 if chip is 1 to 8 $2.00 if chip is 9 to 10	
Decision 9	$40.00 if chip is 1 to 9 $32.00 if chip is 10		$77.00 if chip is 1 to 9 $2.00 if chip is 10	
Decision 10	$40.00 if chip is 1 to 10		$77.00 if chip is 1 to 10	

Table 9: *Decision Sheet for the High-stake lottery Experiment*

Your name in capital letters: ______________________

	Option A	My choice is A	Option B	My choice is B
Decision 1	$80 if chip is 1 $64.00 if chip is 2 to 10		$154.00 if chip is 1 $4.00 if chip is 2 to 10	
Decision 2	$80.00 if chip is 1 to 2 $64.00 if chip is 3 to 10		$154.00 if chip is 1 to 2 $4.00 if chip is 3 to 10	
Decision 3	$80.00 if chip is 1 to 3 $64.00 if chip is 4 to 10		$154.00 if chip is 1 to 3 $4.00 if chip is 4 to 10	
Decision 4	$80.00 if chip is 1 to 4 $64.00 if chip is 5 to 10		$154.00 if chip is 1 to 4 $4.00 if chip is 5 to 10	
Decision 5	$80.00 if chip is 1 to 5 $64.00 if chip is 6 to 10		$154.00 if chip is 1 to 5 $4.00 if chip is 6 to 10	
Decision 6	$80.00 if chip is 1 to 6 $64.00 if chip is 7 to 10		$154.00 if chip is 1 to 6 $4.00 if chip is 7 to 10	
Decision 7	$80.00 if chip is 1 to 7 $64.00 if chip is 8 to 10		$154.00 if chip is 1 to 7 $4.00 if chip is 8 to 10	
Decision 8	$80.00 if chip is 1 to 8 $64.00 if chip is 9 to 10		$154.00 if chip is 1 to 8 $4.00 if chip is 9 to 10	
Decision 9	$80.00 if chip is 1 to 9 $64.00 if chip is 10		$154.00 if chip is 1 to 9 $4.00 if chip is 10	
Decision 10	$80.00 if chip is 1 to 10		$154.00 if chip is 1 to 10	

Contract-Choice Experiment

Table 10: *Sheet for the contract choice experiment*

Your name in capital letters: ________________________

	Option A	My choice is A	Option B	My choice is B
Decision 1	Piece rate		Daily fixed wage of 100$ per day	
Decision 2	Piece rate		Daily fixed wage of 150$ per day	
Decision 3	Piece rate		Daily fixed wage of 200$ per day	
Decision 4	Piece rate		Daily fixed wage of 250$ per day	
Decision 5	Piece rate		Daily fixed wage of 300$ per day	
Decision 6	Piece rate		Daily fixed wage of 350$ per day	
Decision 7	Piece rate		Daily fixed wage of 400$ per day	
Decision 8	Piece rate		Daily fixed wage of 450$ per day	
Decision 9	Piece rate		Daily fixed wage of 500$ per day	
Decision 10	Piece rate		Daily fixed wage of 550$ per day	
Decision 11	Piece rate		Daily fixed wage of 600$ per day	
Decision 12	Piece rate		Daily fixed wage of 650$ per day	