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ABSTRACT

The "Sales Agent" Problem: Effort Choice under Performance Pay as Behavior toward Risk

We present a model and an experiment that show, in a very general setting, that effort choice under a given linear pay-for-performance contract depends on how the financial risk associated with the scheme interacts with effort. We find that, under a given contract, if risk increases with effort, risk-averse (loving) individuals exert less (more) effort. In contrast, when risk is independent of effort, risk preferences do not affect effort choice. Our findings complement the larger literature on selection into incentive pay by showing that lower effort exerted by the risk-averse under a given incentive contract is another type of behaviour toward risk.

JEL Classification: M52
Keywords: incentives, effort, risk aversion

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1. Introduction

Consider a sales agent who earns a commission for each successfully completed transaction. A transaction succeeds with a certain probability p after each customer contact. The more contacts, n, he or she makes, the higher are the agent's expected earnings (= np), but so too is the variance of those earnings (=$np(1-p)$). What is the relationship between the agent's risk attitude and the number of customer contacts he or she chooses to make?

The above sales-agent problem is inspired by two canonical decision problems: that of the risk-averse newsboy in Eeckhoudt et al. (1995) and that of the risk-averse investor in Tobin (1958). Eeckhoudt et al. (1995) consider a newsboy who has to decide how many newspapers to order given uncertain demand: ordering too many will incur a loss, while ordering too few will miss an opportunity to earn more. They show that the optimal order quantity decreases with risk aversion. As in the newsboy problem, our sales agent's decision is a trade-off between the benefits and costs of extra effort, which is affected by risk aversion. The difference is that the uncertainty of the demand faced by the newsboy is not affected by his decision, whereas the effort choice by the sales agent affects the uncertainty of the demand he or she faces.

Tobin's classic paper *Liquidity preference as behavior toward risk* (1958) considers an investor who must allocate wealth between risk-free cash and risky assets.[1] Assuming that the riskiness of an asset can be fully captured by the variance of the distribution of its returns,[2] Tobin shows that a more risk-averse investor will choose to hold a greater portion of his/her portfolio in cash, sacrificing expected return to avoid risk. Similarly, the sales agent must divide his or her time between leisure, which gives a risk-free return, and contacting potential customers, the return to which is higher but also more risky. Intuitively, just like the more risk-averse investor, the more risk-averse sales agent exhibits behavior toward risk, sacrificing expected return by choosing less effort. In this paper we generalize this intuition beyond the mean-variance framework, and test it experimentally.

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[1] Tobin's (1958) analysis assumes a given amount is to be invested in monetary assets that have no default risk and considers how to divide such assets between risk-free cash and a consolidated stock (consol) or perpetuity that is risky because of its association with some probability of capital gain or loss. Others have extended the analysis to encompass the division of wealth generally between a risk-free asset and a portfolio of risky securities on the efficient frontier (e.g., Sharpe, 1964).

[2] Either a quadratic utility function or a two-parameter distribution of returns is sufficient for this to be the case.

Among the most universally observed behaviors toward risk is the sorting of relatively risk-tolerant workers into higher-powered incentive contracts (Bellemare and Shearer, 2010; Grund and Sliwka, 2010; Lo et al., 2011; Dohmen et al., 2011). Yet, since firms typically offer standard pay contracts to all workers within a certain group, sorting is never perfect, leaving workers with varying risk preferences facing similarly risky incentives. For instance, the data from the German Socio-Economic Panel (GSOEP) show that although people receiving performance-based pay have, on average, a higher willingness to take financial risks than those whose pay is fixed (2.25 vs. 1.98 out of max. 10), the variance of risk attitudes within the two groups (4.65 and 4.66) is comparable with the overall sample variance, 4.67.[3]

The existing literature on how workers with different risk preferences respond to the same incentives is relatively thin (see section 2 for a review). In particular, the theoretical conditions under which risk preferences will or will not affect effort response have not been subjected to systematic and controlled empirical testing. Our paper contributes to this literature. Our theory (section 3) predicts that, all else equal, the link between effort and risk aversion under incentive pay will depend on how output- and consequent pay-uncertainty is related to effort. Specifically, if earnings and effort are both measurable in monetary terms so that utility depends on the difference between them, effort will not be affected by risk preferences when financial uncertainty is independent of effort level in the production function (the *additive noise* case in section 3). This is a well-known canonical result stemming from the linear agency model (e.g., Sloof and van Praag, 2008). In contrast, when noise increases with effort (the *multiplicative noise* and *all or nothing* cases), more risk-averse agents will work less. Thus, the particular combination of linear incentives, sorting imperfections and performance measurement technology that we describe will imply effort withdrawal/intensification as behavior toward risk by risk-averse/risk-loving agents. This combination is quite realistic and observed frequently enough to render our study relevant to both the research on and the practice of incentive pay.

We recreate the conditions under which our theory predicts the link between risk aversion and effort, as well as no such link, in an experiment (section 4). In it, the participants have the opportunity to purchase n "investment certificates" in each of four consecutive treatments: the

[3] Our calculations are based on the GSOEP 2009 data because 2009 was the year that the question on the willingness to take financial risks was asked. 6214 respondents answered this question, of whom 3934 received performance-based pay and 2280 received fully fixed pay.

control, administered first, and the additive noise, multiplicative noise, and all-or-nothing noise treatments administered in different orders. We choose a non-real effort task to gain control over the cost of effort, to ensure effort levels can be observed, and to make our design consistent with the assumption of the linear agency model that effort is measurable in monetary terms. This design choice allows us to begin with the canonical linear agency model with additive noise, and then extend it to examine, holding all else constant, how a change to multiplicative or all-or-nothing noise affects effort level choices. The prices and expected returns per certificate are the same in each treatment. However, the determination of actual returns varies by treatment: 10 experimental currency units (ECUs) per certificate in the control; 10 ECUs plus a mean-zero random amount added to the total in the additive noise treatment; an equiprobable draw of 0 or 20 ECUs determined independently for each certificate in the multiplicative noise treatment; and an equiprobable draw of 0 or 20 ECUs determined for all purchased certificates at once in the all-or-nothing treatment. Thus, the earnings variance is zero in the control, independent of n under additive noise, and increasing with n under multiplicative, and even more steeply, under all-or-nothing noise.

Our empirical results (section 5) support our theory. In particular, we find no relationship between self-reported risk aversion and the choice of n in the additive noise treatment, a negative relationship in the multiplicative noise treatment, and a more strongly negative relationship in the all-or-nothing treatment. Consistent with these findings, the variance in the choice of n is highest under all-or-nothing noise, lower under multiplicative noise, and still lower under additive noise. Of the 163 of our 180 participants who choose the payoff-maximizing number of certificates in the control, individual choices of n are consistent with our model across all treatments in 71.8% of cases. Of those, 81.2% are consistently risk-averse or neutral and 18.8% are risk-loving, which is close to the shares of risk types reported in earlier studies[4].

Taken together, our results imply that differences in individual effort under the same incentives cannot be explained by different costs of effort alone. In fact, under conditions that we clearly define and test, effort choice *ceteris paribus* is a behavior toward risk. Managers should take this behavior into account when deciding on incentive pay plans and corresponding

[4] 76-80% are revealed risk-averse or risk-neutral in Holt and Laury (2002), and 79-93% in Eckel and Grossman (2002, 2008). See also Reynaud and Couture (2012).

performance measures.

2. The literature on the effect of risk aversion on effort under a given linear incentive scheme

While the idea that risk preferences may affect a worker's response to an incentive scheme is not new, to our knowledge, there is little empirical research that systematically tests effort responses to given incentives under different performance measurement technologies. Starting with the theory, Baker and Jorgensen (2003) distinguish between two types of output uncertainty in their model: multiplicative noise — a random coefficient on effort in the production function, and additive noise — a random term added to the product of an agent's effort and the multiplicative-noise coefficient. For the specific case of the linear incentive scheme and constant absolute risk aversion (CARA) utility, they derive a negative relationship between the agent's optimal effort level and the product of the multiplicative noise variance and the risk-aversion parameter. Hence, holding the distribution of multiplicative noise fixed, agents who are more risk-averse will exert less effort. In contrast, Sloof and van Praag (2008) show for a more general utility function that when the cost of effort is measurable in monetary terms, and holding the strength of linear incentives fixed, risk preferences do not affect optimal effort when noise is additive to output. We replicate Sloof and van Praag's result for additive noise and derive theoretical predictions for an arbitrary utility function under multiplicative noise.

A related literature on background risk studies the effects of random fluctuations in investor wealth on the demand for risky assets. Gollier and Pratt (1996) introduce the concept of risk vulnerability meaning a higher degree of absolute risk aversion when background risk increases. They also derive the conditions for risk vulnerability for the case of additive background risk. Franke et al. (2006) do so for the case of multiplicative background risk. Beaud and Willinger (2015) test for, and find, risk vulnerability in the presence of additive background risk. Most of the participants in their experiment invest the same or a lower proportion of their portfolio in a risky asset when a zero-mean noise term is added to their wealth. Our study differs from this literature in focussing on risks endogenous to effort decisions rather than on exogenous background risk. However, we will later argue that the presence of such background risk can magnify the extent to which effort is reduced in order to mitigate risk related to effort.

Turning to the empirical literature on risk aversion and effort, Sloof and van Praag (2008, 2010) use two different real-effort experimental designs to examine the risk aversion-effort link under additive noise, and obtain contrasting results. In the 2008 study, their design requires the allocation of a fixed amount of effort between two tasks, making the opportunity cost of effort allocated to one task measurable in monetary terms as the foregone benefit of allocating that effort to the other task. The ability to measure effort in monetary terms is critical to the design because it implies that the optimal choice of effort under a compensation scheme linear in output is independent of the amount of additive noise in the environment. The experimental findings confirm their prediction: there was no change in the participants' effort levels as they moved from the low- to the high-variance treatment. In their later study, Sloof and van Praag (2010) use an experimental design in which subjects choose how much effort to exert on a single task. Thus, it is no longer possible to assume effort can be measured in monetary terms as in the 2008 study. In this environment, their experimental results show that effort *increases* both with the variance of the additive noise term and with risk aversion. In their Proposition 1, they delineate conditions under which this is consistent with a model in which effort cannot be measured in monetary terms.[5] In contrast to both of the Sloof and van Praag studies, we are concerned with comparing the effects of additive versus multiplicative and all-or-nothing noise on the decisions of individuals with differing attitudes toward risk. To provide clear contrasting predictions and meaningful empirical tests for the additive- versus multiplicative- versus all-or-nothing-noise specifications, we assume effort can be measured in monetary terms in our model and choose a simple non real-effort experimental design that is consistent with this assumption.

Cadsby et al. (2007; forthcoming) design a real-effort, multiplicative noise environment by asking subjects to solve anagrams (Cadsby et al., 2007) or do sums (Cadsby et al., forthcoming), both tasks with uncertain output per unit of effort. In both studies, participants are randomly assigned to fixed pay in some rounds and piece rates in others. While on average participants perform better under piece rates than under fixed pay, this effect is attenuated for the more risk-averse. In fact, many of the most risk-averse participants actually perform worse under piece rates than under fixed pay. Cadsby et al. (forthcoming) put forward three possible

[5] Sloof and van Praag (2010) also mention two other reasons for the differing results: a possible lack of understanding by subjects in the more complex experimental task from the 2008 study and reference-dependent preferences in the 2010 study. One of the reasons we chose a non-real-effort task was to avoid the complexity of the task used in their 2008 study, while nonetheless ensuring that effort is measurable in monetary terms.

explanations for this result. The first is the withholding of effort by more risk-averse participants in the financially uncertain piece-rate environment. The second is choking under the pressure of financial uncertainty dependent on how successfully the participant deals with the assigned real-effort task. The third is that more risk-averse subjects perform better on average under fixed pay compared to those who are less risk-averse, leaving less room for improvement under piece rates. However, because effort is not directly observed, they are unable to identify definitively the relative importance of each of these three potential explanations for their results. Zubanov (2015) examines the risk aversion-effort relationship in a real-effort experiment in which the reward per unit of output is given with a certain known probability, a design directly corresponding to the sales-agent example in the introduction. He finds a negative link, which flattens out when an earnings target is introduced. Neither Cadsby et al. (2007; forthcoming), nor Zubanov (2015) use an additive noise treatment in their experiments.

More research on risk aversion and effort under multiplicative versus additive noise is required in several directions to develop a fuller picture of the existence, relevance and importance of effort withdrawal as behavior toward risk. First, all studies examining multiplicative noise, derive their predictions for a specific utility function. It is unclear to what extent those predictions are an artefact of using CARA utility. Second, no study compares behavior under additive- versus multiplicative- and all-or-nothing-noise treatments. This comparison is necessary in order to systematically test the contrasting predictions of the underlying theory under otherwise identical circumstances. This is particularly true because of the sensitivity of the predictions for behaviour toward risk under additive noise as demonstrated by Sloof and van Praag (2008, 2010). Third, the findings of the existing studies may be partly affected by differences in unobserved personal characteristics, such as costs of effort and susceptibility to choking under pressure, both possibly correlated with risk preferences. The relationship between risk aversion and effort cannot be thoroughly tested without isolating it from these potentially confounding factors. This requires a setting in which the cost of effort is controlled, performance anxiety is minimized, and effort is directly observable rather than inferred from output. Moving forward on these three issues is the objective of this study.

3. Theory

Consider an agent working under a linear incentive contract comprising a fixed income B and a unit piece rate. The agent's total net income, $B+g(n,\varepsilon)-c(n)$, is determined by: (i) his/her chosen effort level n producing output $g(n,\varepsilon)$ at a cost measurable in monetary terms and represented by a convex function $c(n)$, and (ii) a noise term ε randomly drawn from a probability distribution with a known probability density function $f(\varepsilon,n)$. Since our experiment asks subjects to select an effort level from a menu that links each available effort level with a fixed monetary cost, the cost of effort $c(n)$ and the value of output $g(n,\varepsilon)$ are both denominated in identical monetary units. Hence, we assume that the utility function may be written as $u(B + g(n,\varepsilon) - c(n))$. The agent may be risk-averse, risk-neutral or risk-loving, in which cases his/her utility function is concave, linear and convex in net income, respectively.

The agent chooses a level of effort that maximizes his/her expected utility given the incentive contract, the costs of effort, and the noise distribution:

$$\max_n EU(n) = E_\varepsilon\big[u\big(B + g(n,\varepsilon) - c(n)\big)\big]$$
$$= \int u\big(B + g(n,\varepsilon) - c(n)\big) f(\varepsilon,n)\,d\varepsilon, \tag{1}$$

where $E_\varepsilon[\cdot]$ means expected value with respect to the noise term ε, the only random variable in our model. The optimal level of effort is determined from the following first-order condition:

$$0 = EU'(n) = \int_0^1 u'\big(B + g(n,\varepsilon) - c(n)\big)\big(g'(n,\varepsilon) - c'(n)\big) f(\varepsilon,n)\,d\varepsilon + \tag{2}$$

$$+ \int_0^1 u\big(B + g(n,\varepsilon) - c(n)\big)\frac{f'(\varepsilon,n)}{f(\varepsilon,n)} f(\varepsilon,n)\,d\varepsilon$$

$$= E_\varepsilon\big[u'\big(B + n\varepsilon - c(n)\big)\big]\cdot E_\varepsilon\big[\big(g'(n,\varepsilon) - c'(n)\big)\big] + \mathrm{cov}_\varepsilon\big[u'\big(B + n\varepsilon - c(n)\big), g'(n,\varepsilon) - c'(n)\big] + \mathrm{cov}_\varepsilon\left[u\big(B + n\varepsilon - c(n)\big), \frac{f'(\varepsilon,n)}{f(\varepsilon,n)}\right].$$

The above derivation uses the fact that the expectation of the product of two random variables equals the product of expectations plus the covariance, and that $E_\varepsilon\left[\frac{f'(\varepsilon,n)}{f(\varepsilon,n)}\right] = \int_0^1 f'(\varepsilon,n)\,d\varepsilon = 0$. Equation (2) elucidates the basic intuition behind our main result: risk preferences, captured in the $u'(\cdot)$ term above, affect the agent's optimal effort choice when the marginal product of effort changes with the noise term ε. Otherwise, the covariance between the marginal utility $u'(\cdot)$ and the marginal product of effort $g'(n,\varepsilon)$ in (2) becomes zero, and the optimal effort is determined from $E_\varepsilon\left[\left(g'(n,\varepsilon) - c'(n)\right)\right] = 0$, which does not depend on risk preferences.

In what follows, we apply this intuition to the following three specifications of noise in the production function:

ADD: *additive noise*, in which output is given by $g(n,\varepsilon) = pn + \varepsilon$, where the additive noise term ε is independent of *n*. In this case, the marginal product of effort, $g'(n,\varepsilon) = p$, does not depend on the noise, and the noise distribution does not depend on effort, $f'(\varepsilon,n) = 0$. Accordingly, just like in Sloof and van Praag (2008, p. 797), the first-order condition (2) for the optimal effort under ADD is

$$0 = EU'_{ADD}(n^{*ADD}) = \left(p - c'(n^{*ADD})\right)E_\varepsilon[u'\left(B + g(n^{*ADD},\varepsilon) - c(n^{*ADD})\right)] \tag{3}$$

MULT: *multiplicative noise*, in which $g(n,\varepsilon) = \varepsilon n$ follows a binomial distribution with mean *pn* and standard deviation $\sqrt{np(1-p)}$, approaching normal for sufficiently large *np(1-p)*, which we assume. Therefore, the empirical frequency of success, ε, follows an approximately normal distribution with mean p and standard deviation $\sqrt{p(1-p)/n}$. This specification corresponds directly to our sales agent example, in which success or failure of each contact is determined independently of other contacts. With the marginal product of effort depending on the noise, $g'(n,\varepsilon) = \varepsilon$, and the noise distribution depending on effort, the first-order condition for the optimal effort under MULT becomes

$$0 = EU'_{MULT}(n^{*MULT}) = E_\varepsilon\left[u'\left(B + n^{*MULT}\varepsilon - c(n^{*MULT})\right)\right] \cdot E_\varepsilon\left[\left(\varepsilon - c'(n^{*MULT})\right)\right] +$$

$$+\text{cov}_\varepsilon[u'\left(B + n^{*MULT}\varepsilon - c(n^{*MULT})\right), \varepsilon - c'(n^{*MULT})] +$$

$$+\text{cov}_{\varepsilon}\left[u\left(B+n^{*MULT}\varepsilon-c(n^{*MULT})\right),\frac{f'(\varepsilon,n^{*MULT})}{f(\varepsilon,n^{*MULT})}\right],$$

Noting that $\frac{f\prime(\varepsilon,n)}{f(\varepsilon,n)}=\frac{1}{2n}-\frac{(\varepsilon-p)^2}{2p(1-p)}$ for the normal distribution of ε under MULT, (4) can be simplified by replacing the functions $u'(.)$ and $u(.)$ in the covariance terms with their second-order Taylor approximations around $\varepsilon=p$, which gives[6]

$$0=EU'_{MULT}(n^{*MULT})=E_{\varepsilon}\left[u'\left(B+n^{*MULT}\varepsilon-c(n^{*MULT})\right)\right]\cdot E_{\varepsilon}\left[\left(\varepsilon-c'(n^{*MULT})\right)\right]+$$

$$+\frac{1}{2}\cdot\text{cov}_{\varepsilon}[u'\left(B+n^{*MULT}\varepsilon-c(n^{*MULT})\right),\varepsilon-c'(n^{*MULT})]. \tag{4a}$$

Alternatively, recalling equation (2) and using the identity $\text{cov}_{\varepsilon}[u'\left(B+n^{*MULT}\varepsilon-c(n^{*MULT})\right),\varepsilon-c'(n^{*MULT})]=\int_0^1 u'\left(B+g(n^{*MULT},\varepsilon)-c(n^{*MULT})\right)(\varepsilon-p)f(\varepsilon,n^{*MULT})d\varepsilon$, the same first-order condition can be rewritten as

$$0=EU'_{MULT}(n^{*MULT})=\int_0^1 u'\left(B+g(n^{*MULT},\varepsilon)-c(n^{*MULT})\right)\left(\frac{\varepsilon+p}{2}-c'(n^{*MULT})\right)f(\varepsilon,n^{*MULT})d\varepsilon. \tag{4b}$$

AON: *all or nothing*, in which $g(n,\varepsilon)=\varepsilon n$ as before, but now $\varepsilon=1$ with probability p and 0 otherwise. In this specification, the agent is facing progressively more noise than in MULT because the standard deviation of ε is larger, $\sqrt{p(1-p)}$ rather than $\sqrt{p(1-p)/n}$. In terms of the sales agent example, this specification means that all n contacts that the agent makes will simultaneously succeed with probability p and fail with probability $1-p$. As with MULT, the marginal product of effort under AON depends on the noise; however, the noise distribution is not affected by effort. Accordingly, the first-order condition for optimal effort under AON is

$$0=EU'_{AON}(n^{*AON})=pu'\left(B+n^{*AON}-c(n^{*AON})\right)\left(1-c'(n^{*AON})\right)-(1- \tag{5}$$

[6] A second-order Taylor series expansion of $u'(B+n\varepsilon-c(n))$ at $\varepsilon=p$ gives $u'(B+n\varepsilon-c(n))\approx u'(B+np-c(n))+u''(B+np-c(n))\cdot n\cdot(\varepsilon-p)+\frac{1}{2}u'''(B+np-c(n))\cdot n^2\cdot(\varepsilon-p)^2$, so that $A\equiv\text{cov}_{\varepsilon}[u'\left(B+n\varepsilon-c(n)\right),\varepsilon-c'(n)]=u''(B+np-c(n))\cdot n\cdot\text{var}(\varepsilon-p)=u''(B+np-c(n))(1-p)p$. The same procedure for $u(B+n\varepsilon-c(n))$ renders $B\equiv\text{cov}_{\varepsilon}\left[u(B+n\varepsilon-c(n)),\frac{1}{2n}-\frac{(\varepsilon-p)^2}{2p(1-p)}\right]=-\frac{1}{2p(1-p)}\cdot\frac{1}{2}u''(B+np-c(n))\cdot n^2\cdot\text{var}(\varepsilon-p)^2=-\frac{1}{2p(1-p)}\cdot\frac{1}{2}u''(B+np-c(n))\cdot n^2\cdot 2[\text{var}(\varepsilon-p)]^2=-\frac{1}{2}\cdot A$. Hence, $A+B=\frac{1}{2}\cdot A$.

$$p)u'\big(B - c(n^{*AON})\big)c'(n^{*AON}).$$

The application of our model to the cases above generates several propositions as follows.

Proposition 1: The optimal effort choice under additive noise, n^{*ADD}*, does not depend on the agent's risk attitude and is determined by the condition* $p - c'(n^{*ADD}) = 0$.

The proof follows immediately from the first-order condition (3) under additive noise.

Proposition 2: The optimal effort under all or nothing, n^{*AON}*, is lower than that under multiplicative noise,* n^{*MULT}*, which in turn is lower than that under additive noise,* n^{*ADD}*, for the risk-averse:* $n^{*AON} < n^{*MULT} < n^{*ADD}$*. For the risk-loving, the opposite is true:* $n^{*ADD} < n^{*MULT} < n^{*AON}$*. For the risk-neutral, the optimal effort is the same under all specifications for the noise in the production function so that* $n^{*AON} = n^{*MULT} = n^{*ADD}$*, and is determined from* $p - c'(n) = 0$.

Proof. $n^{*AON} = n^{*MULT} = n^{*ADD}$ for the risk-neutral follows from their utility being linear in and hence their marginal utility being constant. Their utility being linear implies $\mathrm{cov}_\varepsilon\left[u\big(B + n\varepsilon - c(n)\big), \frac{f\prime(\varepsilon,n)}{f(\varepsilon,n)}\right] = 0$ in the first-order condition (2) because $\frac{f\prime(\varepsilon,n)}{f(\varepsilon,n)}$ is an even function of $\varepsilon - p$ and $u\big(B + n\varepsilon - c(n)\big)$ can be linearly transformed into an odd function of $\varepsilon - p$. Their marginal utility being constant $\mathrm{cov}_\varepsilon\big[u'\big(B + n\varepsilon - c(n)\big), g'(n,\varepsilon) - c'(n)\big] = \mathrm{cov}_\varepsilon[constant, g'(n,\varepsilon) - c'(n)] = 0$ in (2), leaving $E_\varepsilon\big[\big(g'(n,\varepsilon) - c'(n)\big)\big] = p - c'(n) = 0$ as the only condition that the optimal effort must satisfy in all three cases: ADD, MULT, and AON.

Turning to the risk-averse, we first prove that $n^{*MULT} < n^{*ADD}$ by evaluating the first-order condition (4a) for the optimal effort under MULT at n^{*ADD}

$$\begin{aligned} EU'_{MULT}(n^{*ADD}) & \\ &= \underbrace{E_\varepsilon\big[u'\big(B + n^{*ADD}\varepsilon - c(n^{*ADD})\big)\big] \cdot E_\varepsilon\big[\big(\varepsilon - c'(n^{*ADD})\big)\big]}_{=0} \\ &+ \frac{1}{2} \cdot \underbrace{\mathrm{cov}_\varepsilon[u'\big(B + n^{*ADD}\varepsilon - c(n^{*ADD})\big), \varepsilon - c'(n^{*ADD})]}_{<0} < 0 \end{aligned} \tag{6}$$

The covariance term in (6) is negative because, for the risk-averse, the marginal utility decreases with ε whereas the marginal product of effort, $g'(n,\varepsilon) = \varepsilon$, increases with ε. Because the sign of the first-order condition (6) is negative, n^{*MULT}, which brings (6) to zero, must be less than n^{*ADD}.

To prove that $n^{*AON} < n^{*MULT}$ for the risk-averse, we introduce an expression

$$\widetilde{EU}'_{MULT}(n) = \int_0^1 u'\big(B + g(n,\varepsilon) - c(n)\big)\big(\varepsilon - c'(n)\big)f(\varepsilon,n)d\varepsilon < EU'_{MULT}(n),$$ [7]

evaluate it at n^{*AON} and compare it with $EU'_{AON}(n^{*AON})$ in (5). After some rearrangement of the terms, the difference between $\widetilde{EU}'_{MULT}(n^{*AON})$ and $EU'_{AON}(n^{*AON})$ becomes

$$\widetilde{EU}'_{MULT}(n^{*AON}) - EU'_{AON}(n^{*AON}) = (1 - c'(n^{*AON}))Z \ + c'(n^{*AON})W, \tag{7}$$

where $Z = \int_0^1 u'\big(B + n^{*AON}\varepsilon - c(n^{*AON})\big)\varepsilon f(\varepsilon, n^{*AON})d\varepsilon - pu'(B + n^{*AON} - c(n^{*AON}))$ and $W = (1-p)u'(B - c(n^{*AON})) - \int_0^1 u'\big(B + n^{*AON}\varepsilon - c(n^{*AON})\big)(1-\varepsilon)f(\varepsilon, n^{*AON})d\varepsilon$. By concavity of the utility function for the risk averse,

$$u'\big(B + n - c(n)\big) < \int_0^1 u'\big(B + n\varepsilon - c(n)\big)f(\varepsilon,n)d\varepsilon < u'(B - c(n)) \tag{8}$$

for any n. The inequalities in (8) imply $Z > 0$, since $E_\varepsilon(\varepsilon) = p$, and $W > 0$, since $E_\varepsilon(1-\varepsilon) = 1-p$. Therefore, $EU'_{MULT}(n^{*AON}) > \widetilde{EU}'_{MULT}(n^{*AON}) > EU'_{AON}(n^{*AON}) = 0$ for the risk-averse, implying $n^{*AON} < n^{*MULT}$.

For the risk-loving, whose utility function is convex, $\widetilde{EU}'_{MULT}(n) > EU'_{MULT}(n)$ and the inequalities in (8) reverse, implying $n^{*AON} > n^{*MULT}$. The statement $n^{*MULT} > n^{*ADD}$ for the risk-loving follows from (6) because their marginal utility increases with ε.

Proposition 3: The optimal effort levels under multiplicative noise and all or nothing both decrease with risk aversion.

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[7] The integrand in $\widetilde{EU}'_{MULT}(n)$ is negative while that in $EU'_{MULT}(n)$ is positive on the interval $2c'(n) - p < \varepsilon < c'(n)$, which is nonempty because $c'(n) < p$ for the risk-averse. Outside this interval, both integrands have the same sign. Hence, $\widetilde{EU}'_{MULT}(n) < EU'_{MULT}(n)$.

Proof. Pratt's (1964) Theorem 1 states that if an agent with a utility functions $u_1(x)$ has greater risk aversion than another agent with a utility function $u_2(x)$ for all x,

$$\frac{u_1(d)-u_1(c)}{u_1(b)-u_1(a)} < \frac{u_2(d)-u_2(c)}{u_2(b)-u_2(a)}$$

for all $a < b \leq c < d$. In particular, $\frac{u_1{}'(x)}{u_1{}'(y)} < \frac{u_2{}'(x)}{u_2{}'(y)}$ for all $y < x$. The above result applied to the first-order condition under AON,

$$\begin{aligned} 0 &= EU'_{AON}(n^{*AON}) \\ &= u'\big(B - c(n^{*AON})\big)\left[p\big(1 - c'(n^{*AON})\big)\frac{u'\big(B + n^{*AON} - c(n^{*AON})\big)}{u'\big(B - c(n^{*AON})\big)} \right. \\ &\quad \left. - (1-p)c'(n^{*AON})\right], \end{aligned}$$

implies the optimal effort n^{*AON} will go down as increasing risk aversion reduces the ratio $\frac{u'\left(B+n^{*AON}-c\left(n^{*AON}\right)\right)}{u'\left(B-c\left(n^{*AON}\right)\right)}$.

Turning to multiplicative noise, rewrite the first-order condition (4b) as

$$\begin{aligned} 0 & \\ = & \underbrace{\int_0^{2c'(n^{*MULT})-p} u'\big(B + \varepsilon n^{*MULT} - c(n^{*MULT})\big)\left(\frac{\varepsilon + p}{2} - c'(n^{*MULT})\right) f(\varepsilon, n^{*MULT}) d\varepsilon}_{<0} \\ + & \underbrace{\int_{2c'(n^{*MULT})-p}^{1} u'\big(B + \varepsilon n^{*MULT} - c(n^{*MULT})\big)\left(\frac{\varepsilon + p}{2} - c'(n^{*MULT})\right) f(\varepsilon, n^{*MULT}) d\varepsilon}_{>0} \end{aligned} \tag{9}$$

Pratt's (1964) theorem means that as risk aversion increases, the marginal utility in the positive part of (9) will decrease relative to the marginal utility in the negative part. Therefore, the optimal effort n^{*MULT} will decrease with risk aversion to restore the equality in (9).

Proposition 4: The difference between optimal effort levels under MULT and AON increases with risk aversion.

Proof. The proof follows from equation (7) that specifies the difference between the first-order conditions for the optimal effort under MULT and AON evaluated at n^{*AON}:

$$\widetilde{EU}'_{MULT}(n^{*AON}) - EU'_{AON}(n^{*AON}) =$$

$$(1 - c'(n^{*AON}))(\int_0^1 u'\big(B + n^{*AON}\varepsilon - c(n^{*AON})\big)\varepsilon f(\varepsilon, n^{*AON})d\varepsilon - pu'(B + n^{*AON} - c(n^{*AON})))$$

$$+c'(n^{*AON})((1-p)u'\big(B - c(n^{*AON})\big) - \int_0^1 u'\big(B + n^{*AON}\varepsilon - c(n^{*AON})\big)(1-\varepsilon)f(\varepsilon, n^{*AON})d\varepsilon)$$

By Pratt's (1964) theorem, the ratios $\frac{u'\left(B+n^{*AON}\varepsilon-c(n^{*AON})\right)}{u'(B+n^{*AON}-c(n^{*AON}))}$ and $\frac{u'\left(B-c(n^{*AON})\right)}{u'(B+n^{*AON}-c(n^{*AON}))}$ will increase with risk aversion for all $\varepsilon \in [0,1]$. Hence, $\widetilde{EU}'_{MULT}(n^{*AON}) - EU'_{AON}(n^{*AON})$ will increase with risk aversion, and so will the difference between n^{*MULT} and n^{*AON}.

Proposition 5: Holding the costs of effort the same across agents, the variance of individual effort choices increases from ADD to MULT to AON: $var(n^{*AON}) > var(n^{*MULT}) > var(n^{*ADD}) = 0$.

Proof. $var(n^{*ADD}) = 0$ by Proposition 1 that states that every agent's effort choice is determined by $p - c'(n^{*ADD}) = 0$ and is independent of risk preferences. $var(n^{*MULT}) > var(n^{*ADD})$ because under MULT, unlike ADD, effort varies with risk aversion. $var(n^{*AON}) > var(n^{*MULT})$ because Proposition 4 implies a greater variation of effort level with risk aversion under AON and hence a greater dispersion of individual effort choices.

Remark: How dependent is our theory on the assumption that effort is measurable in monetary terms so that utility is non-separable in output and costs of effort, and can be written as $u(B + g(n,\varepsilon) - c(n))$? Proposition 1 - effort under ADD being independent of risk preferences - clearly requires this assumption because otherwise marginal utility, and hence risk considerations, would be in the first-order condition for effort. In our experiment, where "effort" and rewards are both denominated in monetary units, this non-separable utility function is appropriate. This assumption coupled with the assumption of a linear compensation contract and additive noise corresponds to the canonical linear agency model as discussed by Sloof and van Praag (2008). The first part of Proposition 2 - effort under MULT is lower than under ADD for the risk-averse - holds under separable utility functions if the distributions of the multiplicative and additive noise are the same.[8] None of the other propositions require that the costs of effort be measurable in monetary terms or that the utility function be non-separable in output and effort costs. This is because the costs of effort function neither includes nor interacts with the noise and can thus be taken out of the covariance or integral operators in the expressions underlying the proofs of our propositions without changing the signs of these expressions. Hence, the effects of risk preferences on effort under MULT and AON do not hinge on the either the measurability assumption or on non-separability.

4. Experiment

4.1. Non-real vs. real effort

All three experiments (Cadsby et al., 2007; forthcoming; Zubanov, 2015) that demonstrated an inverse relationship between risk aversion and effort under linear incentives use a real-effort task. Asking participants to exert real effort has the important advantage of verisimilitude. However, the real-effort design also leads to some confounds and difficulties in interpretation.

First, it is impossible to control or even directly observe the cost of effort. This psychological cost will generally differ from person to person. It is possible that for some participants, performing the task is actually enjoyable rather than costly. Not being able either to control or to observe the cost of effort adds a great deal of noise to any attempt at ascertaining the relationship between effort and incentives for participants with differing risk attitudes. If there were an unobservable but systematic relationship between risk attitude and cost of effort,

[8] Take any point n_0 and fix the distributions of the additive and multiplicative noise to be the same at n_0. Then the expected utility net of costs of effort under ADD is $EU_{ADD}(n) = \int_0^1 u(B + pn + n_0(\varepsilon - p))f(\varepsilon)d\varepsilon - c(n)$ with the marginal expected net utility taken at n_0 $EU'_{ADD}(n_0) = \int_0^1 u'(B + n_0\varepsilon)pf(\varepsilon)d\varepsilon - c'(n_0)$, and the expected net utility under MULT is $EU_{MULT}(n) = \int_0^1 u(B + n\varepsilon)f(\varepsilon)d\varepsilon - c(n)$ with the marginal expected net utility taken at n_0 $EU'_{MULT}(n_0) = \int_0^1 u'(B + n_0\varepsilon)\left(\frac{\varepsilon+p}{2}\right)f(\varepsilon)d\varepsilon - c'(n_0)$ (recall equation 4b). The difference $EU'_{MULT}(n_0) - EU'_{ADD}(n_0) = \int_0^1 u'(B + n_0\varepsilon)\left(\frac{\varepsilon-p}{2}\right)f(\varepsilon)d\varepsilon = \mathrm{cov}\left(u'(B + n_0\varepsilon), \frac{\varepsilon-p}{2}\right)$, is negative for the risk-averse because $u'(B + n_0\varepsilon)$ decreases, whereas $\frac{\varepsilon-p}{2}$ increases, with ε. Hence, the optimal effort under MULT is always lower than under ADD for the risk-averse even under separable utility.

the implications of an apparent relationship between risk attitude and effort-based performance could be misinterpreted.

Second, in real-effort experiments, we can generally observe performance, which is the result of effort. However, it is more difficult to measure effort accurately. For example, while the number of attempts at a task can be measured and used to represent effort, it is often unclear how focused and serious a participant's attempts actually were. Focus and seriousness, while clearly an aspect of effort, are thus not captured by simple tallies of the number of attempts at a task. Using performance as a proxy for effort may be problematic also because the relationship between effort and performance may itself be affected by a participant's attitude toward financial risk.

Finally, there is an element of anxiety that may affect observed performance under incentive pay. When a participant is paid a fixed salary, he or she does not have to worry about financial uncertainty since the payoff of each participant is predetermined and independent of performance. However, under a pay-for-performance scheme, financial uncertainty becomes a potentially important concern because pay is now uncertain and contingent on performance, which is a product of effort and the probability of success. A more risk-averse participant is by definition a person who dislikes financial uncertainty. Such a person may therefore feel uncomfortable in the financially uncertain pay-for-performance environment. This discomfort may translate into choking under pressure. Despite his or her best efforts, such a person may choke and perform poorly (Baumeister, 1984; Baumeister and Shower, 1986; Cadsby et al., 2007; forthcoming; Ariely et al., 2009). In contrast, a risk-tolerant person might thrive in such an environment. Thus, in a real-effort experiment, it is very difficult to identify whether an observed inverse relationship between risk aversion and performance responsiveness to incentives is due to the hypothesized inverse relationship between risk aversion and effort, to a relationship between risk aversion and choking under pressure, or to both.

In order to avoid these confounds and focus on the proposed relationship between risk attitude and effort, we perform a laboratory experiment that eschews real effort in favor of a menu-based effort-selection design (e.g., Bull, Schotter, and Weigelt, 1987; Fehr, Kirchsteiger, and Riedl, 1993). The menu specifies the same cost-of-effort function for all participants, thereby avoiding the problems that arise when this cost is not transparent to the researcher. Since participants select costly effort without having to actually perform, their effort choices are directly observable and not confounded with potential choking. The results of the experiment will shed light on the relationship between risk aversion and the performance response to incentives observed in the cited real-effort experiments. If the hypothesized inverse relationship between risk-aversion and effort is empirically corroborated, such a relationship likely underlies at least in part the relationship between risk aversion and performance observed in the real-effort environment. If in contrast no such relationship is found in our menu-based effort-selection experiment, it is likely that the observed relationship in the real-effort context was due to choking under pressure or an unobserved relationship between individual risk attitudes and the cost of effort.

4.2 Experimental procedures

The experiment was run at Zhejiang University in Hangzhou, China. Participants were recruited by posting an announcement on an electronic university bulletin board. A total of 180 undergraduate and graduate students from various majors participated in the study. There were 64 males and 116 females with an average age of 21.90 years. The experiment was programmed and conducted using z-Tree software (Fischbacher, 2007). Each experimental session lasted about an hour, and the average earnings were 34.2 RMB for each participant inclusive of a 5 RMB show-up fee.[9] The average hourly student wage for a part-time job was about 20 RMB at Zhejiang University at the time of the experiment. Thus, the earnings were salient and attractive to our participants.

To compare the behavioral responses of each participant in a noiseless control treatment with their responses to the additive, multiplicative and all-or-nothing treatments, we adopted a within-person design. Specifically, there was a control treatment with no noise and three contrasting experimental treatments: additive noise, multiplicative noise, and all-or-nothing noise. Every participant went through all four treatments in a single session, each of which was administered in a separate decision period of about 10 minutes. In each period, all participants were endowed with a sum of 100 Experimental Currency Units (ECUs with 1 ECU = 0.20 RMB) and their task was to decide how much of that endowment to invest in certificates that would earn them income in the manner specified for that period. The total cost (TC) of investment was

[9] At the time of the experiment, 34.2 RMB was equal to about $5.56.

an increasing function of the number of certificates purchased (n), specifically TC = $0.5n^2$. Thus, the unit cost (UC) of a certificate also increased with the number of certificates purchased, since UC = $0.5n$. Participants were given not only the cost function itself, but also a table delineating both the per-unit and total costs corresponding to the number of certificates purchased from 0 to 14.

The rules determining income from investment differed by treatment, and were explained in the written instructions presented just prior to the period in which the treatment was administered.[10] After reading the instructions for each period, participants answered two numerical quiz questions to ensure that they understood the instructions correctly. To minimize various possible confounds that are often associated with within-person experimental designs we implemented the following procedures. First, to avoid wealth effects, the outcomes of earlier periods were neither realized nor communicated to participants until all periods were completed. Second, at the end of the experiment only one of the four decision periods was chosen at random for payment. Third, to control for possible learning effects, we randomly matched each of the six possible orderings of the three experimental treatments to one of six separate sessions. The control treatment was always administered first. There were exactly 30 subjects in each session. In all four treatments, purchasing ten certificates maximizes the expected monetary payoff. Thus, a risk-neutral agent would buy ten certificates under all four treatments.

For the Control treatment (denoted CON in what follows), participants were instructed as follows: "For each certificate you purchase, you will receive 10 ECUs in revenue. Thus, your total earnings in this period will be calculated as follows: Total Earnings = Endowment + Total Revenue – Total Cost = $100 + (10 \times n) – n \times (0.5 \times n)$, where n = the number of certificates purchased."

For the Additive Noise treatment (denoted ADD), participants were told: "For each certificate you purchase, you will receive 10 ECUs in revenue in this period. Thus, your provisional earnings in this period will be calculated as follows: Provisional Total Earnings = Endowment + Total Revenue – Total Cost = $100 + (10 \times n) – n \times (0.5 \times n)$, where n = the number of certificates purchased. A random process will then determine whether your

[10] All instructions used are included in the supplementary material.

provisional earnings will be 1) reduced by 31.6 ECUs, or 2) increased by 31.6 ECUs, with both outcomes having equal probability. Think of the random process as the outcome of a fair coin toss for which your Final Total Earnings equal your Provisional Earnings – 31.6 ECUs if the outcome is a head and your Final Total Earnings equal your Provisional Earnings + 31.6 ECUs if the outcome is a tail." The additive noise value of 31.6 ECUs was selected so that the variance of the additive noise process would equal the variance of the multiplicative noise process at $n = 10$, the optimal number of certificates for a risk-neutral agent maximizing his/her expected payoff in the multiplicative noise treatment.

For the Multiplicative Noise treatment (denoted MULT), participants were informed: "For each certificate you purchase, you will receive either 20 or 0 ECUs in revenue with equal probability in this period. Think of the revenue from each certificate as the outcome of a fair coin toss for which the revenue will be 20 ECUs if the outcome is a head, and 0 ECUs if the outcome is a tail. Note that the revenue outcome for each individual certificate does not in any way depend on the outcome for any other certificate. This means that whether you receive 20 or 0 ECUs for one of your certificates has no bearing on whether you will receive 20 or 0 ECUs for any of the other certificates you purchase. Suppose that you purchase n certificates. Of those, suppose it turns out that you earn 20 ECUs for s certificates and 0 ECUs for the remainder. Then your earnings will be calculated as follows: Total Earnings = Endowment + Total Revenue – Total Cost = $100 + (20 \times s) - n \times (0.5 \times n)$."

For the All-or-Nothing treatment (denoted AON), we told the participants: "For all the certificates you purchase, you will receive either 20 or 0 ECUs per certificate in revenue with equal probability in this period. Think of the revenue as the outcome of a fair coin toss for which you will receive 20 ECUs times the number of certificates purchased as revenue if it is a head, and 0 ECUs if it is a tail. Suppose that you purchase n certificates. Then your earnings will be calculated as follows: Total Earnings = Endowment + Total Revenue – Total Cost = 100 + [($20 \times n$) OR 0 with equal probability] – $n \times (0.5 \times n)$."

At the end of the experiment, we collected demographic information such as gender, age and study major from all participants. In addition, we asked participants to respond to the following question: "How do you see yourself: are you generally a person who is fully prepared to take risks or do you try to avoid taking risks? Please tick a box on the scale 0 (not at all willing to take risks) to 10 (very willing to take risks)". The response to this question has been used as a measure of risk aversion (Dohmen et al., 2011; Nosic and Weber, 2010), and has been found to correlate reliably with behavior involving risk in real situations. We chose this attitudinal measure over a behavioral elicitation of risk because the experimental treatments themselves elicit behavior toward different forms of risk.

5. Results

Table 1 reports descriptive statistics by treatment separately for each of the six ordering sequences, and in aggregate. It also reports analogous results for responses to the question concerning willingness to take risks. In the last column of Table 1, *F* tests of equality of means indicate that neither the average number of certificates purchased in a given treatment nor the mean participant-reported willingness to take risks varies significantly by the ordering of the treatments. Non-parametric Kruskal-Wallis tests yield qualitatively identical results.[11] We therefore pool the data from the different sessions for analysis. Figure 1 displays the distribution of the number of certificates purchased by treatment. We focus first on the CON treatment for which the profit-maximizing choice is to purchase 10 certificates regardless of risk preferences. It is reassuring that n = 10 was chosen by 163 out of 180 participants, 90.6% of the total. The mean number of certificates purchased by all 180 participants was equal to 9.844, which a *t*-test reveals to be not significantly different from 10. We now proceed to discuss the rest of the results, numbered to correspond with the theoretical propositions.

[Table 1 here.]

[Figure 1 here.]

Result 1: The number of certificates purchased (effort) under ADD is independent of individual risk attitudes and is close to 10, which maximizes both the expected monetary payoff and expected utility.

154 participants, representing 85.6% of the total, purchased ten certificates under ADD. A *t*-test reveals that the mean number of 9.689 certificates purchased under ADD does not differ

[11] We also performed Kolmogorov-Smirnov tests on each pair of sequences. In no case could we reject the null hypothesis that the pair of sequences comes from the same underlying distribution.

significantly from 10. The first two columns of Table 2 report regression results for the ADD treatment. Our focal explanatory variable is risk aversion, measured by reverse coding participant responses to our question about willingness to take risks (WTR); that is, higher values of the "Risk Aversion" variable indicate lower WTR. In column (1), risk aversion is the sole explanatory variable. In column (2), to check the robustness of our results, we add age, gender, major and treatment sequence as controls. Age is entered as the reported age of the participant, gender is specified as a dummy variable, a series of four dummy variables are used to indicate five broad major categories (biology and medical, arts, science, social science, and other majors) and five dummies are used for the different treatment sequences. In neither regression is risk aversion materially related to the number of certificates purchased. None of the controls matter either.

[Table 2 here.]

Result 2: Of the 163 participants who purchase 10 certificates under CON as predicted, 117 (71.8%) exhibit behavior consistent with our model. Specifically, 30 (18.4%) exhibit consistent risk-neutral behavior, 65 (39.9%) exhibit consistent risk-averse behaviour, and 22 (13.5%) exhibit consistent risk-loving behaviour in accordance with Propositions 1 and 2.

Proposition 2 was derived using a continuous function for exertion of effort. In the experiment, effort was represented by a discrete choice variable: the integer number of certificates purchased. The model predictions, adapted for the discrete nature of the choices made by the participants in our laboratory environment are as follows: A risk-neutral participant will maximize expected earnings by purchasing 10 certificates regardless of treatment, i.e. under ADD, MULT, and AON. Thus, risk-neutrality implies $n^{*\mathrm{AON}} = n^{*\mathrm{MULT}} = n^{*\mathrm{ADD}} = 10$. A slightly risk-averse or slightly risk-loving participant might make identical choices because it is not permitted to purchase fractional numbers of certificates. For convenience, we categorize all participants exhibiting such behavior as risk-neutral. For a risk-averse participant, $n^{*\mathrm{AON}} \leq n^{*\mathrm{MULT}} \leq n^{*\mathrm{ADD}} = 10$. For a sufficiently risk-averse participant, at least one of these inequalities will be strict, and for convenience we require this to categorize a participant as risk-averse. Analogously, for a risk-loving participant, $n^{*\mathrm{AON}} \geq n^{*\mathrm{MULT}} \geq n^{*\mathrm{ADD}} = 10$ with at least one strict inequality required to be classified as risk-loving under our categorization. Of those behaving in accordance with the predictions of our model, it is not surprising to find the majority of participants exhibit risk-averse behaviour, consistent with many other studies (e.g., Binswanger, 1980; Holt and Laury, 2002).

The distributions of the willingness-to-take-risks (WTR) scores differ by revealed risk preference type. Participants exhibiting revealed risk aversion/risk loving behaviour have lower/higher average WTR scores than risk-neutral ones. The revealed risk preference types are correlated, albeit imperfectly, to the reported WTR scores. Figure 2 shows the distributions of the WTR score by revealed risk preference type. Compared to the entire sample, the WTR distribution for the risk-neutral is truncated at both tails. Thus, there are no participants claiming to be extremely risk-loving or risk-averse among the revealed risk-neutral. There is an overall shift to the left in the WTR distribution for the risk-averse who tend to claim lower WTR, and to the right for the risk-loving who correspondingly tend to claim a greater willingness to take risks. The Kolmogorov-Smirnov test for equality of two distributions rejects the hypothesis that WTR distributions of the risk-averse and risk-loving are the same at $p < 0.001$. The same test applied to compare the WTR distributions for risk-neutral and risk-averse, and for risk-neutral and risk-loving, gives p-values of 0.314 and 0.001 respectively. The mean WTR significantly differs by type: 5.77 for risk-neutral, 4.96 for risk-averse, and 8.23 for risk-loving, while the equal mean test yields F = 25.7 with $p < 0.001$.

[Figure 2 here.]

Result 3: The number of certificates purchased (= our experimental effort) under both MULT and AON decreases with risk aversion.

The third and fourth columns of Table 2 report regression results for the MULT treatment. In column (3), risk aversion, again measured by reverse coding the responses to our WTR question is the sole explanatory variable. In column (4), to check the robustness of our results, we add age, gender, major and treatment sequence as controls. In both cases, the coefficient on risk aversion is negative and significant at the one percent level as predicted by Proposition 3. None of the controls is significant.

The fifth and sixth columns of Table 2 report analogous regression results for the AON treatment. Once again, the coefficient on risk aversion is negative and significant at the one percent level both with and without controls. The gender control is significant at the 5% level, indicating that males on average purchase significantly more certificates than females, controlling for risk aversion as measured by responses to the WTR question.

Result 4: The difference between the number of certificates purchased under MULT and the number purchased under AON increases with risk aversion.

The seventh and eighth columns of Table 2 report regression results using MULT−AOM as the dependent variable with and without controls respectively. In both cases, this difference increases with risk aversion, which is significant at the 1% level. Reflecting the impact of gender on certificate purchases in the AOM treatment, this difference is significantly lower at the 5% level for males than for females.

Result 5: The variance of the numbers of certificates purchased in the AON treatment is significantly greater than the variance in the MULT treatment, and the variance in the MULT treatment is significantly greater than the variance in the ADD treatment as predicted. However, the variance in the ADD treatment is 1.705 > 0 contrary to Proposition 5.

The variances for the number of certificates purchased under each treatment are presented in Table 1. A two-sample variance-comparison test indicates that the variance of 3.913 in the AON treatment is significantly different from the lower variance of 2.955 in the MULT treatment ($p < 0.001$). Moreover, the variance in the MULT treatment is significantly different from the lower variance of 1.705 in the ADD treatment ($p < 0.001$). Levene's robust test statistic leads to identical conclusions. The variance in the ADD treatment is not equal to zero as predicted by Proposition 5 because of the 26 out of 180 participants who did not purchase 10 certificates as predicted by Proposition 1.

6. Discussion and conclusion

Effort choice under a given pay-for-performance compensation scheme may be affected by the way in which financial uncertainty or risk associated with this scheme interacts with effort. We develop a model to illustrate how this can occur, and run an experiment to investigate whether people make effort choices consistent with our model. Our experiment was designed to focus on how risk attitude affects selected effort levels under different risk specifications. We show that if financial uncertainty increases with the amount of effort exerted, as in the multiplicative noise and all-or-nothing treatments, risk-averse individuals will exert less effort and accept a lower expected return to mitigate risk, while risk-loving individuals will exert more effort, accepting greater risk and a lower expected return in pursuit of the chance of a large payoff. We also show that when financial uncertainty is not affected by effort, as in the additive noise treatment, risk preferences do not affect effort choices. We find that 163 out of our 180 participants select the payoff-maximizing level of costly effort from a menu of choices in a no-noise control treatment. Of those, 71.8% make decisions consistent with the predictions of our model in all three experimental treatments. Specifically, 39.9% are consistently risk-averse, 13.5% are consistently risk-loving, and 18.4% are consistently risk-neutral. Effort decisions in the face of multiplicative or all-or-nothing risk, both of which increase with effort, may be thought of as analogous to the decision of an investor choosing the proportion of wealth to hold in a safe asset versus a risky portfolio. This is because conservation of costly effort has a safe and certain return, while exerting more effort produces an increasingly uncertain payoff.

In order to avoid potential confounds in testing experimentally the effect of risk attitude on effort under different risk specifications, it was important to control the cost of effort, and to avoid requiring the performance of a task that might be affected by choking under the pressure of financial uncertainty. This was accomplished by means of a menu-based effort-selection design, which is complementary to the previous real-effort approaches to studying the impact of risk attitude on the response to pay-for-performance incentives. The strong corroboration of an inverse relationship between risk aversion and effort under both multiplicative and all-or-nothing noise suggests that such a relationship is an important mediating component of the previously observed inverse relationship between risk aversion and the performance response to incentives in the real-effort case.

Rooted in the workers' utility function and the methods firms use to measure and reward performance, the relationship between risk aversion and effort is likely to be enduring and important for management practice for two reasons. First, multiplicative noise, under which this relationship holds, occurs whenever the marginal product of effort is uncertain at the time of effort choice. Examples of such situations are many and include effort spent on research and development of new technologies and products, effort spent on marketing campaigns as well as the sales agent example used to motivate this study.

Second, linking our study with the related literature on background risk (Gollier and Pratt, 1996; Beaud and Willinger, 2015) suggests that additive background risk may amplify the effect of multiplicative noise on effort. In real world settings, many workers making effort choices face such background risk. Consider an environment that exposes an employee to both additive background risk and multiplicative or all-or-nothing risk that increases with his/her choice of effort level. An increase in additive background risk in the presence of multiplicative or all-or-nothing risk will increase absolute risk aversion thereby causing the risk vulnerable to reduce their effort. Similarly, multiplicative or all-or-nothing risk would have a stronger effect on the effort exerted by the risk vulnerable when they are already experiencing uncontrollable additive risk.

Since it is the result rather than effort per se that is often rewarded, it is vital that incentive compensation schemes reflect the link between risk aversion and effort. There are several practical alternatives to the linear output-based incentives under multiplicative noise considered in this study. One is to reward effort rather than output, that is, to pay the sales agent per customer contact rather than per successful transaction. In our example, when the probability of a deal is independent of effort, paying a risk-averse agent per contact is an improvement over paying per successful transaction because it removes all risks from the agent's pay. However, when the probability of a successful outcome does depend on effort, paying per contact will lead to all effort being spent on making new contacts and none on cultivating existing ones. An element of pay per successful transaction would therefore be required as part of total compensation, bringing the negative risk aversion-effort link back to the fore.

Another alternative is to offer convex output-based incentives, whereby the agent's pay grows faster than his/her output to compensate for the increasing costs of bearing multiplicative risk. However, such convex incentives may encourage excessive risk taking by less risk-averse agents, in much the same way as they have done in the hedge fund industry (de Figueiredo et al., 2013). An alternative to globally convex incentives are locally convex ones, which encourage extra effort from the risk-averse agents who would otherwise have chosen low effort while not giving extra incentive for risk taking to the harder-working, less risk-averse agents. A typical example of locally convex incentives is a target bonus paid on top of the usual earnings once output reaches the target. Our work helps to understand why such locally convex incentive schemes exist and suggests that their parameters should take account of the performance measurement technology as well as risk preferences.

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Table 1 Descriptive Statistics

	Overall		Means by treatment sequence						
Number of certificates purchased (n):	Mean	Variance	1	2	3	4	5	6	*t* tests of equal means *p*-value
CON: no noise	9.844	1.157	9.800	9.967	9.655	10.129	9.800	9.700	0.378
ADD: additive noise	9.689	1.705	9.667	9.800	10.000	9.645	9.533	9.500	0.634
MULT: multiplicative noise	9.472	2.955	9.100	9.967	9.379	9.774	9.400	9.200	0.852
AON: all or nothing	7.561	3.913	7.267	8.200	8.103	6.355	7.667	7.833	0.413
Personal assessment of willingness to take risks (r) (0=not willing, 10=very willing)	5.839	2.128	5.333	6.467	5.621	5.290	6.233	6.100	0.156

Table 2 Regression Results of Certificates Purchased (Effort) on Risk Aversion and Controls

	ADD (1)	ADD (2)	MULT (3)	MULT (4)	AON (5)	AON (6)	MULT - AON (7)	MULT - AON (8)
Risk Aversion	-0.030	-0.024	-0.377	-0.424	-0.947	-0.915	-0.568	-0.491
	(0.043)	(0.042)	(0.115)	(0.113)	(0.107)	(0.115)	(0.147)	(0.153)
Age		-0.131		-0.053		-0.034		-0.019
		(0.010)		(0.110)		(0.132)		(0.163)
Male		0.334		0.718		1.645		-0.927
		(0.229)		(0.486)		(0.592)		(0.697)
Major	no	yes	no	yes	no	yes	no	yes
Treatment sequence	no	yes	no	yes	no	yes	no	yes

Notes: 180 obs. Robust standard errors are in parentheses. Risk aversion is measured as the willingness to take risks (WTR) recoded so that low values of risk aversion correspond to high values of WTR.

Figure 1 Distribution of the number of certificates purchased by treatment.

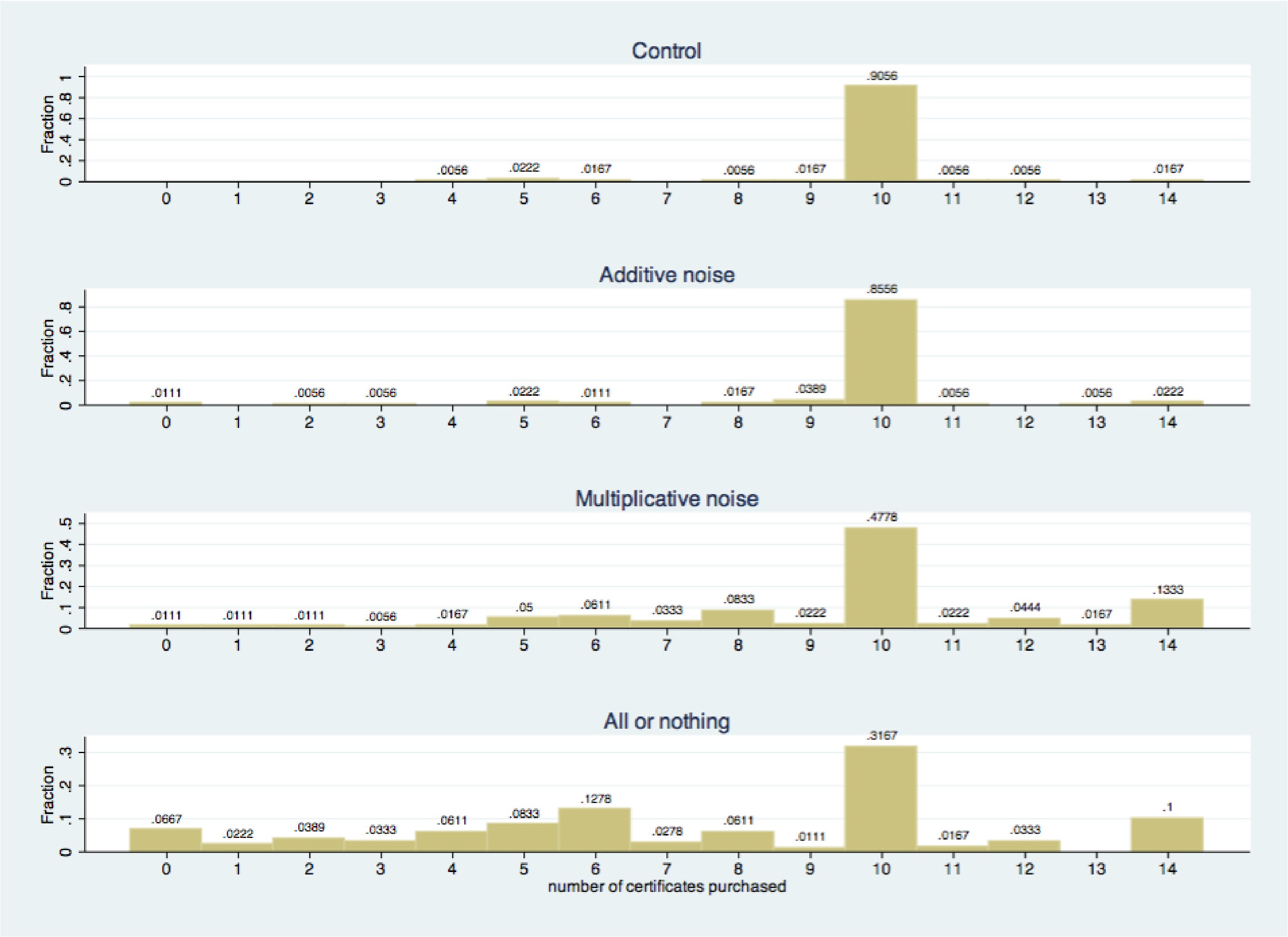

Figure 2 Distribution of the willingness to take risks (WTR) by revealed risk preference type.