Contracting and Reputation Formation

in a Repeated Investment Setting

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1. Introduction

This paper describes a laboratory experiment designed to investigate the effects of long-term contracts and reputation formation in a simple capital budgeting setting. The setting consists of two persons, an owner and a manager. All resources used in production must by supplied by the owner. If production is undertaken, the revenues are certain and common knowledge to both parties. The manager obtains private information regarding the cost of producing after production occurs, and so the owner may ask the manager to report the cost and use it to determine the compensation to the manager. Any resources not used in production may be consumed by the manager as slack. These two features combine to provide the manager with opportunity and incentive to misrepresent the cost.

This setting is analyzed in Fellingham and Young (1990) (hereafter, FY).[1] They demonstrate that if contracts are written to encompass only a single period of production, the manager's cost reports are not useful. The payment to the manager must cover the highest possible cost of production and may not be contingent on the manager's report. They then analyze a two-period setting, in which case second-period production can be made contingent on the first-period cost report. FY demonstrates that the increase in strategy space reduces the informational rents required to induce full revelation of the cost ("truth") from the manager. If this reduction in rents is sufficient, an optimal two-period contract will increase the owner's welfare and may increase productive efficiency relative to repeating two optimal one period contracts.[2]

Our experiment involves three treatments:

(1) One-shot, single-period contracts (control) (NR1)

(2) One-shot, two-period contracts (NR2)

(3) Repeated, single-period contracts (R1)

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[1] Antle and Eppen (1985) and Antle and Fellingham (1990) assume the agent acquires private information about the cost prior to production.

[2] Arya, Fellingham and Young (1994) further demonstrate that longer-term contracts may yield benefits beyond those obtained from an optimal two-period arrangement.

In NR1 and NR2, owners write contracts for the specified time period with a designated manager. After all provisions of the contract are completed, each subject is randomly assigned a new partner. This eliminates the possibility of making choices implicitly contingent on a current partner's behavior in preceding encounters. Treatment R1 is identical to NR1, except that each subject remains paired with the same partner in an unknown horizon game. This matching protocol enables the owner-manager pair to form reputations for specific behaviors that may substitute for explicit commitments that would occur in a longer-term contracting environment.

If contracting is costly, one might be interested in whether reputation can act as a viable substitute for contracting. Van Huyck et al. (1997) provide evidence that reputations may partially substitute for commitment (contracts). There is an important difference between Van Huyck et al.'s setting and ours. In their setting, explicit contracts can be used to make an efficient outcome incentive compatible, while in our setting optimal two-period contracts do not result in efficient outcomes from the owner's or society's perspective.

In our experiment, we confine our attention to a two-period setting for several reasons. First, while optimal contracts of duration longer than two periods may improve the owner's welfare, they still do not produce fully efficient outcomes (Arya et al. 1994). Second, optimal contracts of longer duration are extremely complex and difficult to construct. As a result, it is unlikely that subjects taking part in our experiment will be able to usefully employ a multi-period contracting mechanism of long duration.

The purpose of the laboratory investigation is two-fold. First, we provide empirical evidence on the predictions made in the FY model regarding the effects of long term contracts in a simple, yet interesting, capital investment setting. As noted by Antle and Fellingham (1997) in their literature review, analysis of these settings has been almost exclusively theoretical. Second, by comparing the three treatments we are able to explore the ability of player reputations to substitute for, or possibly improve on, long-term contracts.

Our results indicate the use of the institutions of one-shot, two-period contracts (NR2) or repeated, one-period contracts (R1) increase the frequency of honest communication by the managers relative to the control setting of one-shot, single-period contracts (NR1). We find that in all treatments the probability of a truthful report increases in the size of the payment offered, even in cases where it should not affect the reporting behavior of a self-interested manager. Also, both treatments significantly increase production beyond that obtained in the control setting of NR1. However, in neither treatment did owners achieve positive earnings. The owners' losses observed in the repeated contracting setting were negligible and significantly less than those in the two-period contracting setting. The inability of owners to obtain positive profits is likely due to the complexity of the two-period contracting setting and the coordination problem inherent in the repeated interaction setting.

The paper proceeds as follows. Section 2 describes the model. Section 3 outlines the experimental design. The hypotheses are described in Section 4. Section 5 contains results. The paper concludes in Section 6.

2. Model

For expositional purposes, we present a somewhat less general version of the FY model. A more detailed analysis of the model can be found there. The purpose of this section is to outline the gains to long-term contracting and potential for further gains through a reputation setting.

2.1 One-period contracts

There exist two risk neutral persons in this model, an owner and a manager. The revenue obtained from production is non-stochastic and common knowledge, while only the probability distribution of costs is known to both parties before production. After production occurs the manager alone learns the true cost of production. The owner neither learns the true cost nor has the ability to audit the cost. The manager makes a report to the owner after the production process is complete, and the owner transfers funds to the manager to cover the cost of production. Net proceeds to the manager must be non-negative (a bankruptcy constraint) and the manager may consume any excess funds over the cost of production as slack. The owner can commit to the payment the manager receives contingent on the manager's report.

The cost of production is c_i, i = H, L and $c_H > c_L$ The probability of c_i is denoted $p_i >$ 0 where $p_H + p_L =1$. Denote the expected cost by $\overline{C} = p_H c_H + p_L c_L$. Let w denote an indicator variable where w = 1 if production is chosen by the owner and 0 otherwise. If production occurs the owner obtains revenue equal to X, where we ignore the uninteresting case where $X \leq \overline{C}$. After production, the manager learns the cost and reports it to the owner as either c_H or c_L. In turn, the owner pays t_i to the manager for a report of i. The manager is free to report in whatever way makes him best off.

The revelation principle holds in this setting, so without loss of generality we employ a direct mechanism and make full revelation of the cost ("truth-telling") incentive compatible (Myerson, 1979). The individual rationality constraint (IR) ensures the manager is willing to join the firm, where U_b is his reservation expected utility level. The truth-telling constraints, (TT-H) and (TT-L), ensure that the manager (weakly) prefers revealing the true cost rather than lying. The bankruptcy constraints (B-H) and (B-L) ensure the manager receives non-negative slack.

The *owner's one-period contracting problem* is formulated as follows.

$$\max_{w,\, t_H,\, t_L} \quad wX - p_H t_H - p_L t_L$$

subject to:

$$p_H(t_H - wc_H) + p_L(t_L - wc_L) \geq U_b \qquad \text{(IR)}$$

$$t_L - w\,c_L \geq (t_H - w\,c_L) \qquad \text{(TT-L)}$$

$$t_H - w\,c_H \geq (t_L - w\,c_H) \qquad \text{(TT-H)}$$

$$t_H - c_H \geq 0 \qquad \text{(B-H)}$$

$$t_L - c_L \geq 0 \qquad \text{(B-L)}$$

$$w\ \varepsilon\ \{0, 1\} \qquad \text{(OF)}$$

The incentive compatibility constraints (TT-H) and (TT-L) together imply $t_H = t_L$. It follows immediately that the optimal solution pays information rents to the manager ($X \geq c_H$) or is inefficient ($X < c_H$). Since we wish to explore gains in productive efficiency from repeated interactions, we henceforth limit our attention to the case where $X < c_H$.

2.2 Two-period contracts

Suppose the owner can write a contract that encompasses two periods of potential production. We use w_i to denote whether *second-period* production occurs, given a cost report of i in the *first period*. In addition, let *p* denote the probability that the game continues to the second period. (FY analyze the case where p = 1.) The logic used in the one-period contract setting can be applied to demonstrate that $t_{iH} = t_{iL.}$ We therefore use t_{i2} to denote the payment to the manager in the second period given a cost report of i in the first period. FY demonstrate that truth-telling (TT) can be simplified to make the manager's first period payment and expected second period slack equal regardless how the manager reports in the first period.

The *owner's two-period contracting problem* is formulated as follows.

$$\max_{w,\, w_L,\, w_H,\, t_H,\, t_L,\, t_{H2},\, t_{L2}} \quad wX - p_H t_H - p_L t_L + p[p_H(w_H X - t_{H2}) + p_L(w_L X - t_{L2})]$$

subject to:

$$p_H(t_H - wc_H + p\,[t_{H2} - w_H \overline{C}\,]) + p_L(t_L - wc_L + p[t_{L2} - w_L \overline{C}\,]) \;\geq\; 2U_b \qquad \text{(IR)}$$

$$t_L + p[t_{L2} - w_L \overline{C}\,] \;=\; t_H + p[t_{H2} - w_H \overline{C}\,] \qquad \text{(TT)}$$

$$t_L - wc_L \;\geq\; 0 \qquad \text{(B-1L)}$$

$$t_H - wc_H \;\geq\; 0 \qquad \text{(B-1H)}$$

$$t_L - wc_L + t_{L2} - c_H w_L \;\geq\; 0 \qquad \text{(B-2L)}$$

$$t_H - wc_H + t_{H2} - c_H w_H \;\geq\; 0 \qquad \text{(B-2H)}$$

$$w, w_L, w_H \quad \{0,1\} \qquad \text{(OF)}$$

When the contracting duration is extended to two periods, the owner's ability to make second-period production contingent on first-period cost reports relaxes the truth-telling constraints in the first period (FY). In some cases they are sufficiently relaxed such that production becomes profitable for the owner where it would not have been if only single-period contracts were available.

A numerical example is provided in Table 1. The example uses the same parameter values as in the experiment and serves to highlight an important attribute of our setting.[3] While an increase in contract length from one to two periods increases the welfare of the owner and the agency, full productive efficiency cannot be achieved. The owner must guarantee that, if the first period cost is low, the manager's expected slack if he reports honestly will be at least equal to his expected slack in periods one and two if he reports the cost is high. This requirement implies that efficient production must be sacrificed in the second period if the manager reports high. Thus, unlike Van Huyck et al. (1997), optimal contracts cannot recapture all possible gains from production (1.875 + 11.25 < 17.5). Extending the contracting to periods longer than two may be beneficial, but the loss in productive efficiency does not converge to zero as the number of contracting periods is increased (Arya et al. 1994). As indicated by the example, when $X < c_H$ and two-period contracts are optimal, they improve the welfare of both the owner and manager.

Parameters:

X	=	100	p	=	1
c_H	=	105	p_H	=	0.5
c_L	=	60	p_L	=	0.5
U_b	=	0			

[3] In the experiment, each treatment last for a guaranteed number of periods (p = 1). Subsequently, the game continues to the next period with probability 5/6 (p = 5/6). The solution for p = 1 is provided in Table 1. The solution for p = 5/6 is w = 1, w_L = 1, w_H = 0, t_L = 86.25, t_H = 105, t_{L2} = 105, and t_{H2} = 0. The owner's expected two-period profit is 2.29, and the manager's expected two-period slack is 22.5.

Optimal contracts:

	Perfect information: One period	Asymmetric information: One period	Asymmetric information: Two periods
Solution	$w = 1$ $t_H = 105$ $t_L = 60$	$w = 0$ $t_H = 0$ $t_L = 0$	$w = 1$ $w_H = 0$ $w_L = 1$ $t_H = 105$ $t_L = 82.5$ $t_{H2} = 0$ $t_{L2} = 105$
Owner exp. utility	17.5	0	3.75

Per-period expected utility from optimal contracts:

	Repetition of optimal perfect information contract	Repetition of optimal one-period contract	Optimal two-period contract
Owner	17.5	0	3.75 / 2 = 1.875
Manager	0	0	22.50 / 2 = 11.250
Total	17.5	0	13.125

Table 1: Numerical example
Optimal perfect information, one-period and two-period contracts

2.3 Reputation setting

In this section we assume that owner and manager interact repeatedly in an unknown horizon game. The owner only has the ability to write one-period contracts with the manager. We derive a class of Nash equilibria characterized by positive expected production. The goal of our experiment is not to test the adherence to any particular equilibrium. The available equilibria are likely to be numerous, if not infinite, and such tests are likely to be inconclusive. Rather, we present the formal derivation in order to demonstrate that positive production in this setting is supportable under the standard assumptions of non-cooperative game theory and not reliant on notions of fairness, altruism or bounded rationality. Further, the equilibrium we provide has the interesting property of yielding, in expectation, the same level of productive efficiency as would an optimal two-period contract.

It is now useful to add additional structure to the setting. Assume the same game as the one-period contract setting. The game continues, with the *same* owner and manager, to the next period with probability p. Let O(θ) be the owner's strategy, defined over θ, the observable history of play to that point in the game. Let M(θ, t_L) be the manager's strategy defined over θ and t_L.

Definition: *An m-reward (m-r) strategy for the owner and manager is as follows:*

1. *The owner chooses full production in period 1. If the period 1 report is low(60) the owner chooses full production for the next m consecutive periods. Otherwise the owner chooses 0 production for the next m consecutive periods. Each consecutive m+1 periods beginning with period m+2, are replications of the first m+1 periods, until the game concludes.*

2. *If the owner follows 1, the manager truthfully reports in period 1 and periods (m+1)+1, 2(m+1)+1, 3(m+1)+1 . . . In all other periods for which production occurs, the manager reports a high cost. If the owner ever deviates from 1, the manager perpetually reports high.*

Observation: *Denote* $O^{m\text{-}r}(\theta)$ *and* $M^{m\text{-}r}(\theta, t_L)$ *as the m-r strategies for the owner and manager respectively. Then there exists parameters X,* c_i, p_i *such that* $(O^{m\text{-}r}(\theta), M^{m\text{-}r}(\theta, t_L))$ *is a Nash equilibrium for some values of* t_L *and m.*

Proof: See Appendix.

The proof demonstrates that the m-r strategies comprise an equilibrium for the parameters used in the numerical example and in the experiment if the players choose m = 1 and t_L = 87. The basic idea of the equilibrium is that the owner obtains current profits by promising future production and, hence, slack. Slack is valued more highly by the manager than by the owner, so a mutually beneficial trade is available. In particular, one period of production costs the owner 5, but its value to the manager is as large as 22.5.

3. Experimental Design

Our experiment consists of three treatments, described below. All subjects were recruited from undergraduate business classes at Binghamton University or Ohio State University. They were offered a small amount of extra credit for participating in the experiment, in addition to their regular earnings. In all treatments subjects earned $1.00 for every 30 points accumulated in the experiment. In addition, a flat fee payment of $10 was made in one of the treatments in order to equalize expected remuneration.

3.1 One-period contracts, No-reputation (NR1)

Each round two subjects are paired for one period of potential production. One subject assumes the role of owner and one the role of manager. In the experiment, subjects are referred to as type O and type M players. However, for ease of exposition, we will continue to refer to them as owners and managers. The pairings change each period. Therefore, there is little or no opportunity for subjects to earn a reputation for playing a particular way.

The game proceeds as follows. The owner has available an investment opportunity that yields 100 points if funded. The cost of the project is 105 or 60 points, each equally likely. After the project is completed, the manager learns the true cost of the project. The owner never learns the true cost. Instead, the owner receives a cost report from the manager. The manager has no resources; therefore, the owner must transfer sufficient funds to cover the cost of production.

We allow the owner to write an enforceable contract with the manager. Using the notation introduced in the Model section, the owner specifies t_L and w. The following constraints are imposed on the subjects: w {0,1}, $60 \leq t_L \leq 105$ and $t_H = 105$ (t_L must be in one-point increments). The restrictions on the payments respect the manager's limited liability and also eliminate the possibility of exceedingly (and irrationally) high compensation. The restriction on w is made to simplify the task in the experiment. Although we show above that in order to induce truthful reporting the manager's payments may not depend on the cost report, we allow the owner flexibility in setting t_L. Our motivation for this is that subjects in prior experimental studies have demonstrated a tendency not to fully exploit opportunities for economic rents (Roth, 1995). An owner may appeal to the manager's sense of fairness by offering $t_L > 60$, allowing the manager the opportunity to share some of the informational rents obtained in the low-cost state.

Subjects begin the experiment by playing eight training rounds in which cash is not earned. During the training phase subjects experience the role of owner and manager. The cash-earning phase follows the training phase and consists of eight games. Each game continues for six rounds after which a die is rolled. If a “one” appears, the game ends; otherwise, play continues to the next round. Subjects switch roles after each game.[4] Subjects received an additional flat fee of $10 in this treatment.

3.2 One-period contracts, Reputation (R1)

The reputation setting is identical to the one-period contracting setting with one exception. Subjects are paired continuously with the same partner during a game. Therefore, subjects have the opportunity to earn a reputation for playing a particular way within a game. After each game subjects are re-paired.

3.3 Two-Period, No-reputation (NR2)

This setting is similar to the one-period contracting setting except owners are now able to write two-period contracts. Each round is divided into two periods, and contracting takes place at the beginning of the first period. At the start of each round, the owner writes a contract specifying the following: (1) first-period production (w), (2) first-period payment to the manager contingent on a report of 60 (t_L), (3) second-period production contingent on a first period report of c_i (w_i), and (4) second-period payment to the manager (given second-period production occurs) contingent on a report of low in the second period and c_i in the first period, (t_{iL}). We impose the constraints that w and w_i {0,1}, and $t_H = t_{LH} = t_{HH} = 105$ if production occurs (or 0 if no production takes place). We employ these particular constraints in order to balance two competing demands: (1) to allow subjects flexibility in contracting,

[4] Given our design, subjects remain with the same cohort when assuming a particular role. In the first game, one half of the subjects act as owners and one half as managers. In the next game everyone switches roles.

and (2) to keep the setting simple in order to reduce noise arising from subject confusion.[5] Prior experimental studies involving endogenous contracting only allowed subjects to choose from among a menu of contracts (e. g. Berg, et al. 1992). We greatly expand the contract space while keeping the setting manageable for the student subjects.

Subjects in the role of manager observe the entire contract before making first-period reporting decisions. This is consistent with the model developed in FY. Subjects are re-paired after every round. Therefore, there is little or no opportunity for subjects to earn a reputation for playing a particular way.

The game lasts for three *two-period* rounds, after which a die is rolled. If a one or a two is observed, the game ends. Otherwise the game continues to the next round. This procedure continues until a one or a two is observed, at which point the game ends. The session lasts for eight games.[6] Subject switch roles after every game.

The experiment consists of nine sessions, three each for treatments R1, NR1 and NR2. Table 2 below depicts the experimental design with the number of subjects attending each session.

	Treatment	**Session**	**No. Subjects**
One Period Contracting	**No reputation (NR1)**	NR1-a	10
		NR1-b	12
		NR1-c	8
	Reputation (R1)	R1-a	12
		R1-b	10
		R1-c	8
Two-Period Contracting	**No Reputation (NR2)**	NR2-a	12
		NR2-b	12
		NR2-c	10

Figure 1: **Experimental design**

[5] Two additional points should be made regarding the allowable contracts. First, as in the one-period setting, we permit owners to appeal to the manager's sense of fairness by allowing second period payments to be made contingent on second period reports. Second, in addition to the constraints mentioned in the text above, we did not allow *second-period* payments for reports of 60 to be dependent on *first-period* reports if $w_H = w_L = 1$. However, because there are equal discount rates for owners and managers, this additional constraint does not restrict their expected utilities beyond those implied by the initial set of constraints.

[6] Due to time constraints, we were only able to administer six games in one of the sessions, NR2-a. All six games were completed.

4. Hypotheses

Our first set of hypotheses concerns the truthfulness of manager reports. Truthfulness is analyzed only for the cases where the cost is 60, since truthfulness when the cost is 105 is trivial. In the one-period contracting setting without reputation (NR1) and in the second period of the two-period contracting setting (NR2), managers should in theory report 105 regardless of the actual cost, except when the payment offer for a report of 60 is set to 105. In contrast, owners in R1 may implicitly make production decisions contingent on prior reporting behavior, so there may be incentives for managers to report truthfully. Hypotheses 1A and 1B are stated in their alternative form.

H1A: Excluding cases where $t_L = 105$, the relative frequency of truthful reports is greater in R1 than in NR1.

H1B: Excluding cases where $t_{iL} = 105$, The relative frequency of truthful reports is greater in R1 than in the *second period* of NR2.

Our second set of hypotheses relates to the manager's reporting behavior as a function of the owner's payment offer. The reports of self-interested manager should not depend on payment offers in NR1. However, Baiman and Lewis (1989) observed that subjects were more likely to report dishonestly when the monetary incentive for dishonesty was increased. Hence, we conjecture that higher payment offers may induce more truthful reporting behavior in NR1. In our study, higher payment offers for reports of 60 would decrease the incentives for untruthful reporting and may induce fair-minded subjects to report honestly in NR1 and in the second period of NR2.

In R1 the relationship between payment offers and reporting behavior is more nebulous. Truthful reporting may be in response to generous payment offers, consistent with the findings of Baiman and Lewis (1989). Truthful reporting may also be an attempt by managers to induce increased production in future rounds, consistent with the theory developed above. Regardless of managers' motivations, higher payment offers in R1 may reduce manager incentives for dishonest reporting. Again, we state the hypotheses in their alternative form.

H2A: In NR1 and R1, the likelihood of the manager issuing a truthful report is positively associated with the payment offer for a report of 60.

H2B: In NR2 the likelihood of the manager issuing a truthful report in period *two* is positively associated with the payment offer for a report of 60 in period two.

The expansion of contract space in the two-period setting allows for explicit incentives to be provided for truthful reports in the first period of the contract. Specifically the expectations derived from the theory are as follows. In Rounds one through three of the two-period setting, managers are predicted to report the cost as 60 when the true cost is 60, if and only if the contract specifies $w = 1$, $w_L = 1$, $w_H = 0$ and $t_L > 82$. In Rounds four and greater, managers are expected to report the cost as 60 if and only if the contract specifies $w = 1$, $w_L = 1$, $w_H = 0$ and $t_L > 86$. These predictions hold for self-interested, fully rational, risk-neutral individuals. Given some divergence from these assumptions is likely present in the subject population, we make less specific predictions in hypothesis 3.

H3A: In NR2, rounds one through three, for contracts specified as $w = 1$, $w_L = 1$, $w_H = 0$, subjects will report a cost of 60 in the *first* period of the contract truthfully more frequently when $t_L > 82$ than when $t_L \leq 82$.

H3B: In NR2, rounds four and greater, for contracts specified as $w = 1$, $w_L = 1$, $w_H = 0$, subjects will report a cost of 60 in the *first* period of the contract truthfully more frequently when $t_L > 86$ than when $t_L \leq 86$.

Hypothesis 4A derives from the theory in the Model section. The owner has the ability to provide *implicit* incentives for truthful reporting in R1, as demonstrated in the Model section. Similarly, Hypothesis 4B derives from the theory developed in the Model section. Truthful reporting (in at least some periods) should be viewed as a necessary condition for owners to choose production greater than 0, and hence increase productive efficiency. The additional contracting space available in two periods is predicted to result in greater production, by providing *explicit* incentives for truthful reporting in the first period of the contract.

H4A: Productive efficiency is greater in R1 than in NR1.
H4B: Productive efficiency is greater in NR2 than in NR1.

The question addressed in Hypothesis 5 is central to this paper. That is, which institutional feature, repeated interaction or multi-period contracts, better facilitates productive efficiency? Our theory development does not provide definitive guidance; we therefore state Hypothesis 5 in its null form.

H5: Productive efficiency is equivalent in R1 and NR2.

5. Results

Given the differences in the one and two-period settings, we first compare R1 to NR1. We subsequently compare the results of R1 and NR1 to those of NR2. We separately present the data for the two halves of the experiment (games 1-4 and 5-8), which enables us to examine and control for the effects of learning and experience. In most instances, we eschew the use of formal statistical analysis. The independence of subjects within the same session is questionable, and using a session as the unit of observation would not allow for tests of sufficient power. Therefore, we rely primarily on descriptive statistics.

5.1 One-period contract results (NR1 and R1)

5.1.1. Reporting by manager – NR1 and R1

Table 2 presents the relative frequency of truthful responses for the one-period contracting cells, given the actual cost was 60. The results support Hypothesis 1A: repeated interaction increases the relative frequency of truthful reporting. Within the NR1 and R1 treatments, reporting behavior is consistent across both halves of the experiment. This consistency across halves indicates that subjects in the role of manager quickly grasped the strategic implications of their reporting decisions. In addition, reporting behavior in NR1 appears consistent with prior experimental studies, wherein behavior that may be broadly termed as "altruistic" is seen in approximately 10 to 20 percent of observations (Roth, 1995).

	t_L = 105 (Manager should weakly prefer to report truthfully)			t_L < 105 (Manager should strictly prefer to lie)		
Games 1-4:	**No. where c_2=60**	**No. where report = 60**	**%**	**No. where c_2=60**	**No. where report = 60**	**%**
NR1	7	4	57.1%	175	29	16.6%
R1	4	3	75.0%	228	92	40.4%
Games 5-8:						
NR1	1	0	0.0	68	12	17.7%
R1	1	1	100%	205	85	42.0%

Table 2: Relative frequency of truthful reports in one-period contracts (cost is 60)

In order to examine Hypothesis 2A, we use a logistic regression with reporting behavior modeled as a function of t_L, the payment offer for a report of 60. We naturally restrict our analysis to observations where the actual cost is 60. Four separate regressions are run, one for each treatment-half combination. The logit model is given by equation (1). The results appear in Table 3, and generally support Hypothesis 2A. The fact that β_1 is positive and statistically significant indicates that in the one period setting reporting behavior appears to be an increasing function of payment offers.

$$Truth_{itg} = \ell\,(\beta_0 + \beta_1\, Pay_{itg}) + \varepsilon_{itg} \qquad (1)$$

where:
$\ell(x)$ = $e^x/(1+e^x)$
$Truth_{itg}$ = 1 (0) when manager i reports 60 (105) in round t of game g
Pay_{itg} = payment offered by owner i for a report of 60 in round t of game g

	NR1 Games 1-4	NR1 Games 5-8	R1 Games 1-4	R1 Games 5-8
$\hat{\beta}_0$	- 3.63 ** (10.30)	- 3.24 (2.11)	- 4.91 * (21.71)	- 6.94 * (24.24)
$\hat{\beta}_1$	0.03 * (3.78)	0.02 (0.60)	0.06 * (19.20)	0.08 * (22.78)

* = p-value is less than .05   ** = p-value less than .001

Table 3: Slope coefficient (Wald Chi-squared) for logit model 1

We further used the results in Table 3 to construct a model of expected owner profit as a function of the payment offer. An increase in t_L decreases owner profit if the manager reports 60, but increases the probability of receiving a low report, as seen from Table 3. We derive expected owner profits as a function of t_L, by substituting the estimated values of β_0 and β_1 from Table 3 into equation (2). We then solve for the value of t_L that maximizes (2). We find that no payment offer between 60 and 105 would yield a positive expected profit for the owner in either half of NR1. We do not conduct a similar analysis for the R1 treatment, because those managers can make their reporting strategy implicitly contingent on their entire personal history of interactions with the owner, which includes more than the current payment offer.

$$\frac{1}{2}\left\{\left[\Pr(\text{report} = c_L \mid \text{cost} = c_L)\left(100 - t_L\right)\right] + [1 - \Pr(\text{report} = c_L \mid \text{cost} = c_L)](100 - 105)\right\} + \frac{1}{2}(100 - 105) \qquad (2)$$

where $\Pr(\text{report} = c_L \mid \text{cost} = c_L) = \ell(\hat{\beta}_0 + \hat{\beta}_1 t_L)$

5.1.2. Production – NR1 and R1

Table 4 presents data on the average production per period. In theory NR1 should yield zero production, while the increased strategy space in R1 allows for the existence of equilibria characterized by positive production. These results are consistent with Hypothesis 4A, which predicts that repeated interaction increases productive efficiency. The fact that any investment was observed in NR1 may be the result of some owners' (unrealistic) expectations of reciprocal behavior by managers. As noted previously, given the managers' behavior in the experiment, there is no level of feasible payment offers such that owners in NR1 would expect to yield positive profits.

Games	No-reputation (NR1)	Reputation (R1)
1-4	45.25	72.18
5-8	20.52	58.24

Table 4: Average production per period in all one-period contracts

Table 5 presents data on R1 and NR1 subjects' experimental points earned for periods where production occurred. Our theory predicts that in NR1 owners would earn negative profits, which is supported by our data. In contrast, our theory predicts that in R1 the ability to provide implicit incentives to managers may allow owners to profit from production. Inspection of Table 5 reveals that owners in R1 also sustained losses in both halves of the experiment. However, these losses were negligible and much less than those obtained by the owners in the NR1 treatment. The inability of owners to earn positive profits in R1 may have been the result of the inherent coordination problem existing in cooperation games with multiple equilibria (Van Huyck et al., 1997). The decline in production observed in the second half of the experiment in R1 is likely the result of owners' responding to the inability to attain positive profits in the first half.

	Games	No-reputation (NR1)	Reputation (R1)
Owners	**1-4**	- 2.739	- 0.012
	5-8	- 2.814	- 0.114
Managers	**1-4**	20.056	16.762
	5-8	20.811	18.521

Table 5: Average earnings per period given production equal to 100

As a further test of the theory, we examine the use of history-contingent strategies by owners in R1. We expect a greater likelihood of production when reports of 60 have been received more frequently in prior rounds. We test this prediction using the logit model in equation (3), where production is the dependent variable and reports from the prior three periods are the independent variables. The theory would predict positive values for β_1, β_2 and β_3. In addition, dummy variables are used to control for instances of zero production in any of the prior three periods. Periods of zero production may indicate situations where subjects have abandoned attempts at cooperation, which would yield values for β_4, β_5 and β_6.

$$\text{Production}_{itg} = \ell\,(\beta_0 + \beta_1\,\text{Rep1}_{itg} + \beta_2\,\text{Rep2}_{itg} + \beta_3\,\text{Rep3}_{itg} + \beta_4\,\text{NoProd1}_{itg} + \beta_5\,\text{NoProd2}_{itg} + \beta_6\text{NoProd3}_{itg}) + \varepsilon_{itg} \quad (3)$$

where:

$\ell(x) = e^x/(1+e^x)$

Production_{itg} = 1 (0) if owner i sets production to 100 (0) in round t of game g

$\text{Rep\#}_{itg}$ = 1 (0) if manager i reports 60 (105) in round (t - #) of game g

$\text{NoProd\#}_{itg}$ = 1 (0) if owner sets production to 0 (100) in round t-# of game g

	R1 Games 1-4	R1 Games 5-8
$\hat{\beta}_0$	1.08 ** (33.42)	1.20 ** (32.43)
$\hat{\beta}_1$	2.47 ** (11.09)	3.37 ** (10.72)
$\hat{\beta}_2$	1.74 ** (9.61)	1.08 * (4.97)
$\hat{\beta}_3$	0.44 (1.19)	- 0.30 (0.61)
$\hat{\beta}_4$	- 0.51 * (3.91)	- 1.11 ** (19.57)
$\hat{\beta}_5$	- 0.91 ** (11.63)	- 0.61 ** (5.10)
$\hat{\beta}_6$	- 1.33 ** (21.83)	- 1.49 ** (31.82)

* = Significant at α = .05 ** = Significant at α = .01

Table 6: Slope coefficient (Wald Chi-squared) for logit model 2

The results in Table 6 indicate that the owner's production decisions are contingent on the manager's history of reporting behavior. Further, the owner’s “memory” appears to be short. Owners do not appear to respond to manager reports from three periods in the past. It appears that a report of 60 is rewarded with one or two periods of production while a report of 105 is punished for several periods. The short punishment period used by owners may have desirable properties such as the willingness to re-initiate cooperation with adaptable managers.

5.1.3. Summary of NR1 and R1 results

In the one-period no reputation setting, the results generally conformed to our expectations. Production and truthful reporting were low, with subjects' willingness to report truthfully insufficient to support profitable production. In the reputation setting, where there are additional incentives for the owners to induce truthful reporting from the managers, production was observed at much higher levels than in NR1. However, the mildly negative profit obtained by owners in R1 was unexpected.

5.2. Two-period contracting setting (NR2)

5.2.1 Production arrangements – NR2

We begin our analysis of the results from the two-period setting with an examination of the contracts offered by owners. Figure 3 displays the five possible production arrangements.

Production Arrangement	Production in period 1 (w)	Production in period 2 if first period report is 60 (w_L)	Production in period 2 if first period report is 105 (w_H)
DEF	0	0	0
CAUT	1	0	0
OPT	1	1	0
IRR	1	0	1
TRUST	1	1	1

Figure 3: Production arrangements

The frequency with which each production arrangement is observed is shown in Table 7. OPT (Optimal) is predicted from the theory. While the occurrence of OPT is only around 50%, it is the contract chosen most often in the first half of the experiment. In the last half of the experiment DEF (a defensive contract), which calls for no production, and hence guarantees the owner zero, becomes slightly more common than OPT. We surmise this phenomenon is the result of owners having received negative profits in early games and deciding to limit their exposure to further losses. The TRUST contract is one in which owners are willing to commit to produce in period two, regardless of the first period report. Offering this contract may be viewed as "placing a trust" (Berg et al. 1995). Owners entrust managers with firm resources in both periods and presumably expect reciprocation in the form of honest reporting by the managers. In the latter half of the game, subjects chose TRUST even less often than in the first half, consistent with managers not reciprocating at a level of frequency demanded by the owners. CAUT (cautious) is a muted form of the trust contract, wherein owners can probe managers' willingness to report truthfully without providing explicit incentives for truthfulness, yet limiting their exposure relative to TRUST.

IRR (irrational) provides incentives for dishonesty. Both DEF and CAUT are chosen quite infrequently in both halves of the experiment.

Panel A (Games 1-4)	No. contracts	%
DEF	177	34.6%
CAUT	10	2.0
OPT	284	55.5
IRR	3	0.6
TRUST	38	7.4
All contracts	**512**	100.0%

Panel B (Games 5-8)	No. contracts	%
DEF	167	48.3%
CAUT	7	2.0
OPT	156	45.1
IRR	2	0.6
TRUST	14	4.0
All contracts	**346**	100.0%

Table 7: Two-period contracts - relative frequency of production arrangement

While the production arrangement is important to the optimality of the contract from the owner's perspective, so are the payment arrangements. Payments that are too low for a report of 60 in period one will not, in theory, elicit truth under contract OPT. Payments that are too high for a low report in period one may induce truth telling but will give the owner negative expected earnings. In the first three rounds, owners can earn positive expected profit if they set $83 \leq t_L \leq 90$. In subsequent rounds, due to the random endpoint, the "rational" range for the owner is $87 \leq t_L \leq 90$. We use LB and UB to denote these upper and lower bounds. UB is found by solving for the value of t_L at which the owner's objective function is equal to zero.

Table 7A displays the proportion of the OPT contracts that offered payment schemes which could elicit truth-telling and produce positive expected earnings for the owner for the two periods. We see that when owners chose OPT the proportion of time they set t_L in the "rational" range was 30.3% in Games 1-4 and 53.2% in Games 5-8. Recall from Table 7 that OPT was chosen much less often in the second half of the experiment.

All Games	**No. contracts**	**%**
LB ≤ t_L ≤ UB	169	38.4%
t_L ≤ LB or t_L > UB	271	61.6%
Total	**440**	**100.0%**

Panel A (Games 1-4)		
LB ≤ t_L ≤ UB	86	30.3%
t_L ≤ LB or t_L > UB	198	69.7%
Total	**284**	**100.0%**

Panel B (Games 5-8)		
LB ≤ t_L ≤ UB	83	53.2%
t_L ≤ LB or t_L > UB	73	46.8%
Total	**156**	**100.0%**

Table 7A: Proportion of OPT contracts rational from the owner's perspective

5.2.2. Reporting by manager – NR2

We now consider the managers' first-period reporting behavior. Table 8 discloses, by contract type, the proportion of first-period reports that were truthful given the first-period cost is 60. From Table 8, we see that overall truthfulness was approximately 45% in each half of the experiment. Further inspection of Table 8 reveals that truthful reporting appears to be affected by contract type, as would be expected. In particular, truthfulness is higher under contract OPT where incentives can usefully be provided than under TRUST.

Panel A (Games 1-4):

Production Arrangement	**No. with c_1 = 60**	**No. truthful reports**	**% truthful**
CAUT	4	0	0.0%
OPT	145	87	60.0%
IRR	0	0	0.0%
TRUST	18	5	27.8%
All contracts	203	92	45.3%

Panel B (Games 5-8):

Production Arrangement	**No. with c_1 = 60**	**No. truthful reports**	**% truthful**
CAUT	3	0	0.0%
OPT	64	32	50.0%
IRR	0	0	0.0%
TRUST	11	3	27.3%
All contracts	78	35	44.9%

Table 8: Two period contracts - First period truthfulness by contract type

Of course, the payments promised by the owner are important to whether sufficient incentives have been provided to a self-interested manager. A self-interested manager would be willing to report honestly under OPT if and only if t_L exceeds LB. Table 9 discloses manager truthfulness under OPT contracts separated according to whether a self-interested manager should tell the truth. Inspection of Table 9 reveals that the results strongly support hypotheses 3A and 3B. OPT contracts that provide theoretically sufficient incentives for truthful reporting induce a significantly greater relative frequency of truthful first-period reports than for OPT contracts which do not provide sufficient incentives.

All Games:	**No. with c_1=60**	**No. truthful**	**% truthful**
t_L > LB (M should tell truth)	107	77	73.5%
t_L < LB (M should lie)	102	43	45.1
Total	**209**	**120**	**57.4%**
Panel A (Games 1-4):			
t_L > LB (M should tell truth)	70	52	74.3%
t_L < LB (M should lie)	75	35	46.7
Total	**145**	**87**	**60.0%**
Panel B (Games 5-8):			
t_L > LB (M should tell truth)	37	24	64.9%
t_L < LB (M should lie)	27	8	29.6
Total	**64**	**32**	**50.0%**

Table 9: Frequency of truthful first period reports under OPT

Table 10 discloses the proportion of second period reports that were truthful, given the second-period cost is 60. Tables 10 and 2 support hypothesis 1B: when the payment offer for a report of 60 is less than 105, truthfulness is greater in R1 than in the second period of NR2. Further, the incidence of truthful reporting in the second period of NR2 is similar to that in NR1 when payment offers are less than 105. In theory, the incentives for truthfulness would be identical in these two situations.

	t_{L2} = 105 (Manager should weakly prefer to report truthfully)			t_{L2} < 105 (Manager should strictly prefer to lie)		
Games 1-4:	**No. where c_2=60**	**No. where report = 60**	**%**	**No. where c_2=60**	**No. where report = 60**	**%**
CAUT	0	0	0.0%	0	0	0.0%
OPT	3	0	0.0	31	7	22.6%
IRR	0	0	0.0	0	0	0.0%
TRUST	2	0	0.0	17	2	11.8%
Total	5	0	0.0%	48	9	18.8%
Games 5-8:						
CAUT	0	0	0.0%	0	0	0.0%
OPT	9	4	44.4	6	1	16.7
IRR	0	0	0.0	0	0	0.0
TRUST	0	0	0.0	7	0	0.0
Total	9	4	44.4%	13	1	7.7%

Table 10: Frequency of truthful second-period reports under all contracts

In order to test Hypothesis H2B, we use the logit model in equation (3), which expresses the probability of receiving a truthful report in period two of NR2 as a function of the payment offer for a report of 60 in period two. We exclude observations where the payment offer for a report of 60 equal 105, because a manager would in that case be indifferent as to how he or she reports. Given the limited number of surviving observations, we report only for games one through eight, without segmenting into halves. The results in Table 11 support Hypothesis 2B: there appears to be a significant relationship between the payment offer in the second period and the relative frequency of truthful reports in the second period. This result is consistent with that seen in NR1, and further supports the notion that decreasing the incentive for dishonest reporting, increases the likelihood of a truthful report.

$$\text{Truth2}_{itg} = \ell\,(\beta_0 + \beta_1 \text{ Pay2}_{itg}) + \varepsilon_{itg} \qquad (3)$$

where:
Truth2_{itg} = 1 when manager i reports 60 (105), in period 2 of round t of game g
Pay2_{itg} = payment offered by owner i for a report of 60 in period 2 of round t in game g

	NR2 -- Games 1-8
$\hat{\beta}_0$	- 15.12 * (7.50)
$\hat{\beta}_1$	0.14 * (6.47)

* p-value = .02

Table 11: Slope coefficients (Wald Chi-squared) for logit model 3

5.2.3. Production — NR2

The average production per period in NR2 is disclosed in Table 12. In theory, OPT would yield average production of 75 per period for Rounds 1-3 and approximately 77 per period actually reached. Production is much less than predicted. One obvious explanation is the prevalence of the DEF contract, which yields zero production. Additionally, managers report dishonestly even when they are presented with a contract that in theory should induce honest reporting. As a result, second period production does not occur when it should have under OPT.

	Games 1-4	Games 5-8	All Games
All contracts	46.0	33.3	40.8

Table 12: Average production per period in all two-period contracts

In order to understand better the subject behavior in NR2, we present data on the average earnings per subject, per (two-period) round. Table 13 indicates that even when owners used the OPT contract, they experienced negative earnings. The negative earnings are caused by insufficiently high truthfulness from managers when presented with the OPT contract. Our data seem to indicate that there did not exist a feasible contract that would provide the owner with positive earnings. Therefore, owners continued to decrease production throughout the experiment. What is at first puzzling, is the decline in owner profits derived from the OPT contract in the second half of the experiment. However this can be somewhat explained by the unusual low frequency of low cost states drawn from the binomial distribution. In the first half of the experiment a cost of 60 obtained in the first period for 145 of 284 OPT contracts, while a cost of 60 in the first period was obtained in only 64 of 156 OPT contracts in the second half. This likely further discouraged owners, who do not observe the true cost but must instead rely on the reports of managers.

	Owners			Managers		
	Games 1-4	**Games 5-8**	**Total**	**Games 1-4**	**Games 5-8**	**Total**
CAUT	-5.00	-5.00	-5.00	18.00	19.29	18.53
OPT	- 0.49	-2.05	-1.04	22.39	18.81	21.12
IRR	-10.00	-10.00	-10.00	0.00	0.00	0.00
TRUST	-6.84	-7.50	-7.02	41.97	55.36	45.58
All contracts	-1.43	-2.68	-1.86	24.28	21.48	23.30

Table 13: Average earnings per two-period round in NR2 (excluding DEF)

5.2.4. Discussion of NR2 results

The level of productive efficiency in NR2 is well below that predicted by the theory. Owners seemed to quickly grasp the strategic implications of their role and adapted the theoretically truth-inducing contract early on. However a significant proportion of the managers did not respond as expected to this contract offer and as a result owner earnings were negative. As the game progressed, a decrease in truthful reporting and an increase in high cost states obtained appeared to cause a noticeable shift towards DEF, a contract in which no production occurs.

The inability of owners to earn positive profits and thereby sustain production may be attributable to two factors: confusion and risk aversion. Although a substantial effort was made to train subjects in the two-period setting, including a two-hour training session that took place a week before the cash-earning session, the setting is inherently complex. Owners construct contracts with five attributes. Managers must consider the consequence of their actions with respect to each attribute. Predictions derived from the theory are highly contingent on perfectly rational play. Expected owner profits are relatively small, and therefore slight shifts in reporting behavior may cause them to become negative.

Risk aversion, may have a significant impact on the results. There are numerous repetitions of the game, which should decrease the variance of earnings derived form any particular pattern of play. However, as argued above, small deviations from the assumptions made in the model, may have a substantial effect on the observed play. Owners have only a small range of payment offers in the OPT contract that are both truth-inducing and profitable. If even a small proportion of subjects were unwilling to report honestly due to risk aversion, this may have prevented owners from finding a profitable contract offer.

Both these issues speak to the difficulty in formulating complex contracts, in both an experimental and institutional setting. This may further enhance the attractiveness of 'looser' arrangements when parties interact over repeated periods. Empirical studies by Antle and Smith (1986) and Wolfson (1985) as well as a comparison of our contracting and reputation results, found below, support this notion.

5.3 Comparison R1 and NR2

Our motivation in conducting this study is to examine the effect on productive efficiency and owner welfare of institution design: one-shot two-period contracts vs. repeated one-period contracts. Comparing Tables 4 and 12, repeated one-period contracts yield substantially greater productive efficiency than one-shot two-period contracts. As noted above, the complexity of the two-period contracting setting may have been a primary cause of subjects not attaining the level of productive efficiency predicted by the theory in NR2. Theoretical predictions of productive efficiency in R1 are not clear, due to the multiplicity of equilibria available. However the decline in productive efficiency observed during the experiment is likely caused by the difficulty subjects had in coordinating to a pattern of play which would sustain high levels of productivity.

In both NR2 and R1 owners experienced negative profits. However, the negative earnings of the owners in the reputation setting are negligible when compared to the negative earnings in the two-period contracting setting. Compensation schemes are generally designed by central management. Therefore, central management may wish to implement a contract with less well-defined contingencies than the more structured longer-term contracts.

6. Conclusion

This experiment employs a simple capital investment setting to investigate the effect of two-period contracts and repeated interaction on productive efficiency and owner welfare. Both institutions significantly increased production beyond that obtained in the control setting of one-period contracting, but neither resulted in positive earnings for owners. This result was not predicted from our theory. However, the losses observed in the repeated interaction setting were negligible and significantly less than those in the two-period contracting setting. The inability of owners to obtain positive profits is likely due to the complexity of the two-period contracting setting and the coordination problem inherent in the repeated interaction setting.

Appendix A

Proof that, for the parameters used in the experiment, there exists a value for t_L such that ($O^{m-r}(\theta)$, $M^{m-r}(\theta, t_L)$) is a Nash equilibrium for m = 1:

Assume that p, t_L, m, $O^{m-r}(\theta)$, and $M^{m-r}(\theta, t_L)$ are defined as in the paper, and that p = 5/6. For ease of exposition, we denote the periods when the manager reports truthfully as *h* periods (the odd periods) and the periods when the manager reports a cost of 105 with certainty as the *d* periods (the even periods). Further assume that t_L = 87 in the h periods. The value of t_L may be any value in the *d* periods.

Assume the owner is following the $O^{m-r}(\theta)$ strategy. In the h periods, given an actual cost of 60, the manager may report truthfully for a gain of 27, or report 105 for a gain of 45. In the following d period the manager receives 0, if he reported 105 in the preceding period, or 22.5, in expectation, if he reported 60 in the preceding period. Given a 5/6 probability of continuing to each successive period, the net expected benefit to the manager for reporting 60 in an *h* period is 27 + (5/6)*22.5 = 45.75, which exceeds the benefit of lying, 45. Therefore assuming that the owner is using $O^{m-r}(\theta)$, the manager's best response is to follow the strategy defined by $M^{m-r}(\theta, t_L)$.

Now assume the manager is following the $M^{m-r}(\theta, t_L)$ strategy. In the *h* periods the owner can either set production to 0 or 100. Production of 0, yields the owner 0. Production of 100, yields the owner 13*.5 – 5*.5 – (5/6)*5*.5 = 1.9167, in expectation over the *h* and the immediately succeeding d period. Therefore the owner's best response is to choose production of 100. In the *d* periods, the owner may save 5 by choosing production of 0. However by not producing in a *d* period when called for by the proposed equilibrium, the owner foregoes a stream of payments with an expected net present value of 5.227, as shown below.

$$\frac{5}{6} * \left\{ \frac{1.9167}{\left(1 - \left[\frac{5}{6}\right]^2\right)} \right\} = 5.227 \qquad \text{(A1)}$$

Since 5.227 > 5, the manager's best response is to set production at 100 in the *d* periods, when called for in the equilibrium. Therefore assuming the manager is using $M^{m\text{-}r}(\theta, t_L)$, the owner's best response is to use $O^{m\text{-}r}(\theta)$.

This completes the proof for the case where *m*=1. The proofs for the cases *m* = 2 and 3 are similar and can be obtained from the authors.

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