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Welfare effects of payment truncation in piece rate tournaments

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Abstract This article analyzes the optimal response of a principal to the regulatory proposal which would truncate agents' bonus payment in a piece rate tournament at zero. In a model with risk-neutral and heterogenous abilities agents, we analyze the principal's problem of optimal choice of contract parameters under both regular and truncated tournament scenarios. The results show that the principal could significantly mitigate potential welfare losses due to tournament truncation by adjusting the payment scheme. The optimal adaptation to tournament truncation results in a situation where both higher and lower ability players would benefit from the policy while average ability players would lose.

Keywords Tournaments · Incentives · Production contracts · Regulation

JEL Classification M52 · Q18 · D86

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1 Introduction

Tournament contests are prevalently used in sporting events but occasionally also in business settings such as labor contracts or agricultural production contracts. Tournaments are relative compensation mechanisms where the prize or compensation is determined by comparing the performances among competitors. One type of tournament is an ordinal or rank-order tournament which awards contestants according to their performance ranks within the group (e.g., Lazear and Rosen 1981; Green and Stokey 1983). Another type is a cardinal tournament in which the prizes are determined not only based on rankings but also on the magnitudes of performance measures among contestants (Nalebuff and Stiglitz 1983; Shleifer 1985). The main advantage of tournaments over absolute compensation schemes, such as piece rates, is that they filter out the impacts of unobservable common shocks and balance the trade-off between incentives and risks.[1] Yet another type of tournament, known as a piece rate tournament, combines a piece rate with a cardinal tournament. This mechanism is in fact a variable piece rate scheme with the individual rate determined as the difference between an individual contestant's performance and the group average performance. This mechanism is frequently used in agricultural contracts for the purposes of settling production contracts (in particular broiler chickens) between contract growers and integrator companies (e.g., Tsoulouhas and Vukina 1999).

The existing literature on production tournaments emphasizes their favorable theoretical properties. For example, Knoeber (1989) argued that tournaments optimally shift risk from small farmers to large companies, they contribute to self-selection of high ability agents and facilitate adoption of new technologies without complicated contract renegotiations. Tsoulouhas and Vukina (1999) showed theoretically that, absent bankruptcy concerns, a two-part piece rate tournament is in fact a linear approximation of the optimal incentive contract. Despite these favorable properties, many contract producers complain about contract settlements that are based on tournaments. The essence of these complaints is what Levy and Vukina (2004) termed the "league composition effect." The problem arises from the possibility that consecutive batches produced by the same producer with similar production costs may receive substantially different payments because of different composition and, hence, performance of the tournament group. Contract producers also raised complaints about biased distribution of varying quality production inputs by the companies who control them, frequent mandatory requests for upgrades of housing facilities and production equipment, lack of transparency in contract disputes, retaliations against outspoken contract producers, etc.

Out of concern for such grower discontent, a number of states and the US Federal government have over the years considered various legislations and regulations to protect the interests of contract growers.[2] In June 2010, the Grain Inspection, Packers and

[1] Quite a few empirical papers compare behavioral and welfare implications of tournaments relative to other incentive schemes, see Bull et al. (1987), Knoeber and Thurman (1994), Wu and Roe (2005), Agranov and Tergiman (2013), Zheng and Vukina (2007) and Marinakis and Tsoulouhas (2012).

[2] Most of those were deflected by the successful lobbying of the interest groups aligned with livestock industry, see Tsoulouhas and Vukina (2001), and Vukina and Leegomonchai (2006).

Stockyards Administration (GIPSA) of the US Department of Agriculture (USDA), among other regulations, proposed a rule that would prevent poultry companies from offering contracts where differentiated piece rates could fluctuate freely above or below the contracted base payment rate (GIPSA 2010). This effectively meant changing the compensation scheme from a standard piece-rate tournament to a truncated tournament in which the bonus payment is truncated at zero. In other words, below average performance outcomes would no longer get penalized, only above average performance outcomes would be rewarded. That way, the minimum payment per pound of live chickens delivered would be the contractually agreed base payment. As it turned out, the Final Rule that came out in December 2011 (GIPSA 2011) did not adopt the controversial proposal on tournament payment modification. However, GIPSA plans to seek additional public comments related to tournament system with an objective to reconsider possible finalization of this rule in the future.

The main objective of this article is to evaluate the welfare implications of the proposed truncated tournament policy from both theoretical and empirical perspectives. The effects of bonus truncation on agents' equilibrium efforts and payments and principal's profit are analyzed using a model with risk-neutral, heterogeneous abilities players. We showed that the bonus truncation would induce agents to lower their efforts but the reduction in effort would be smaller for higher ability types. Agents' welfare would increase driven by higher expected payments and lower efforts while the principal profit would decrease. The closed-form solution to optimally redesigned contract parameters does not exist and had to be obtained by empirical estimation of the model primitives and simulation.

This paper is related to the contract theory literature which deals with limited liability (bankruptcy) constraints. Even more relevant is the strain of literature dealing with liquidity constraints on the agents' side of the contract which introduce *e*x-post limitations on the minimum compensation that the agent can receive or the maximum penalty that can be imposed upon her (Innes 1990, 1993). However unlike, for example, in Marinakis and Tsoulouhas (2012) whose main objective is the welfare comparison of cardinal tournaments and piece rates with liquidity constraint agents, we deal with the regulation of a piece-rate tournament where only the tournament bonus is constrained to be non-negative whereas the piece rate can vary freely. In addition, our analysis is focused on the heterogeneity of agent types which is critical in understanding the origins and the political economy behind the proposed regulatory policy, whereas Marinakis and Tsoulouhas (2012) assume homogenous, yet risk-averse agents.

In the empirical part of our paper we use contract settlement data from five different broiler production contracts from a major broiler company in the US. The empirical analysis involves three steps. First, we estimate grower's time-invariant abilities and variances of common shocks and idiosyncratic shocks by estimating an unbalanced two-way fixed effects model. Second, growers' optimal effort responses under different tournament slope parameters are simulated to see how changing incentives influence optimal growers' efforts. Finally, the welfare impacts of the proposed regulation are calculated for both parties to the contract. The simulation results show that the principal can partially offset the negative welfare impacts of the payment truncation through changing contract parameters and the expected short-run welfare gain for growers will be significantly diminished. The proposed policy will also have unanticipated distributional effects in the sense that only low and high ability growers are expected to benefit, whereas average ability growers are likely to lose.

2 Theoretical framework

A large number of broiler production contracts worldwide are settled using a two-part piece rate tournament shown in Eq. (1). The payment consists of a fixed base payment b and a bonus payment based on grower's relative performance. The bonus payment is determined as a fraction β (usually between 0.5 to 1) of the difference between his/her own performance and the average performance of all growers in the same tournament. The performance evaluation is based on the so called adjusted prime cost (APC) rating which measures the average cost accrued to the integrator (principal) of producing each pound of live broilers. It is computed as total settlement cost C_i, which is the sum of cost of chicks, feed, fuel, medications, vaccinations and other customary flock costs charged to grower i, divided by the total pounds of live weight moved from the grower's farm Q_i. The calculation of the tournament average APC includes all growers whose flocks were harvested within the same week. The total compensation R_i for grower i is calculated as the product of the variable piece rate and the total live weight of birds harvested from the grower's farm. It follows that growers receive bonuses when they achieve above average performances (below average APC) and penalties when they record below average performances (above average APC).

$$R_i = \left[b + \beta \left(\frac{1}{n} \sum_j \frac{C_j}{Q_j} - \frac{C_i}{Q_i} \right) \right] Q_i \tag{1}$$

The empirically observed compensation scheme (1) reveals that a production tournament is a two-margin contest; i.e. producers are simultaneously competing to lower the total settlement cost and increase the quantity of output. Following Knoeber and Thurman (1995), Tsoulouhas and Vukina (1999) and Levy and Vukina (2004), we assume that targeted output level is fixed and normalized to 1 and growers are competing in who can produce the target output level at the lowest possible cost. This approach simplifies the piece rate tournament compensation scheme to a regular cardinal tournament in which the base payment b is no longer a base piece rate but a base salary, as shown in (2),

$$r_i{}^u(q_i) = b + \beta(q_i - \bar{q}), \tag{2}$$

where superscript u indicates untruncated (unregulated) scenario.[3] Performance of grower i is measured by q_i which equals to the negative of adjusted prime cost (APC), $q_i = -\frac{C_i}{Q_i}$ and $\bar{q}$ represents the average performance of all growers in the same

[3] Notice that in the exact version of this model (with two margins), the effort becomes vector-valued where one element impacts the feed conversion and the other mortality, which would cause intractable modeling complexity (especially in the truncated case). As far as the analysis of the existing contracts is concerned, the assumption about fixed output is reasonable because the dispersion of individual producers birds' weight around the average target weight is typically quite narrow which indicates that the effect of effort on the second margin (mortality) has to be quite small (mortality appears to be random) and consequently the incentive effect of b should be muted.

tournament. To tease out the influence of grower i's performance on tournament group average, it is useful to rewrite Eq. (2) as $r_i{}^u(q_i) = b + \frac{n-1}{n}\beta(q_i - \bar{q}_{-i})$, where $\bar{q}_{-i}$ is average performance without grower i and n is number of growers in the tournament group. Then, imposing the proposed regulation, the tournament scheme becomes

$$r_i{}^t(q_i) = \begin{cases} b + \frac{n-1}{n}\beta(q_i - \bar{q}_{-i}) & \text{if } q_i > \bar{q}_{-i} \\ b & \text{if } q_i < \bar{q}_{-i} \end{cases} \quad (3)$$

where superscript t indicates tournament truncation scenario.

The approach followed in this paper takes contracts as given and model the impact of regulation on the behavior of the principal and agents under the observed contractual terms without assuming optimal contract design. This approach is justified because we already know that the observed contracts are not optimal. Even in the simplest model with fixed output and feed which stochastically depends on effort, the optimal second-best (because of moral hazard) contract is customized to fit individual grower characteristics (i.e. feed distributions). Yet, the actual contracts that we observe are not customized but rather of *one size fits all* type.[4] The analysis is also predicated on the assumption that the proposed regulation would not prompt the integrators to abandon tournaments as the means of settling broiler production contracts in favor of an alternative payment mechanism. Instead they would continue using tournaments in their regulated form but with the flexibility to alter contract parameters of that truncated scheme in response to contract regulation.

Finally, we assume risk-neutrality on both sides of the contract. Whereas assuming a risk-neutral principal is noncontroversial because poultry companies are typically large publicly traded companies who can easily diversify risk, the assumption about risk-neutral agents requires some explanation especially because it eliminates the rationale for the use of tournaments that provide income insurance for risk-averse types by filtering away common production uncertainty.[5] However, the risk sharing is not the only rationale for using a tournament scheme. At least two other important advantages of tournaments justify their use in broiler contracts. Both of those work to lower the costs of contracting and are therefore useful in explaining the prevalence of production contracts and near complete absence of company owned chicken farms (Knoeber 1989). First, payments schemes based on tournaments require no change as technology improves. Since technological change is largely embodied in feed and chicks supplied by the integrator to all growers in a tournament, they represent a common shock that is differenced out and the contract payments does not have to be renegotiated as technology improves. Second, tournaments commit the integrator to a fixed average payment per pound of live weight (because bonuses and penalties cancel each other out precisely by construction) and hence the integrator has no incentive to misrepresent the productivity of any individual grower or all growers together.

4 Tsoulouhas and Vukina (1999) have shown that the observed contract can be interpreted as a first-order Taylor series approximation of the optimal rule. Needless to say, adding more realism to the model would bring the observed contract even further away from the optimal scheme.

5 Risk-neutral agents have been assumed in many empirical and experimental tournaments papers, e.g., Bull et al. (1987), Knoeber and Thurman (1994), Wu and Roe (2005), Vukina and Zheng (2011), to mention only a few.

2.1 Existing contracts

The first objective is to investigate the impact of proposed regulation on the existing contracts to see who would benefit and who would lose under regulation. In order to capture the critical feature of any type of tournament that is played multiple times, our models is based on agents which are heterogeneous in abilities. We need heterogenous players because in a homogenous-agents model (either risk-averse or risk-neutral), in equilibrium, all players exerts the same effort and whether a player wins or loses a tournament depends only on the random idiosyncratic shock. Therefore, in large number iterations all players would become approximately equally successful and there would be no reason for any kind of regulatory intervention that was mentioned in the introduction to this paper.[6]

The performance in a tournament is assumed to be a random variable that can be decomposed additively as follows

$$q_i = e_i + a_i + u + w_i, \tag{4}$$

where e_i is effort, a_i is what we call ability, u is the production shock common to all participants in the same tournament and w_i is idiosyncratic shock. The two shocks are independent of each other and are assumed normally distributed with means 0 and variances σ_u^2 and σ_w^2 and probability density functions $f_u(u)$ and $f_w(w_i)$ respectively. All shocks are realized at the end of the production period. For the purposes of this analysis we extend the traditional definition of abilities a_i as innate characteristics or acquired skills based on education, experience, etc., to include any time-invariant agent idiosyncracies such as geographic location, the vintage and quality of production facilities, or similar factors. Such abilities, assumed to be common knowledge among all players, have impacts on players' measurable performances and enter the players' performance function additively. This specification results in constant marginal product of effort for all contestants.

Each agents decides on how much effort she needs to apply by maximizing her expected utility which is assumed to be linear in payment:

$$\begin{aligned} &\max_{e_i} \; \mathbb{E}(U(r_i{}^u) - c(e_i)) \\ &\quad = \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} \left[b + \frac{n-1}{n} \beta (e_i + a_i + w_i - \bar{e}_{-i} - \bar{a}_{-i} - \bar{w}_{-i}) \right] \\ &\quad\quad \times f_w(w_i) f_{\bar{w}}(\bar{w}_{-i}) \, \mathrm{d}w_i \, \mathrm{d}\bar{w}_{-i} - c(e_i) \end{aligned} \tag{5}$$

where $\bar{e}_{-i}$, $\bar{a}_{-i}$ and $\bar{w}_{-i}$ are average effort level, average ability and average idiosyncratic shock of all other players in the same tournament excluding player i. $\bar{a}_{-i}$ is known to grower i before she exerts effort. $f_{\bar{w}}(\bar{w}_{-i})$ is the probability density func-

[6] The main reason for numerous complaints about tournaments as a means of settling production tournaments is the fact that some producers win whereas others loose disproportionate number of contests. Those on the losing side are the most vocal advocates of tournaments regulation or even their outright ban.

tion of $\bar{w}_{-i}$ which can be derived from the distribution of w_i.[7] Notice that common production shock u has been canceled out from the expected utility by virtue of tournament competition. Agents' cost of effort $c(e_i)$ is strictly convex ($c' > 0$, $c'' > 0$) with $c(0) = c'(0) = 0$.

The first order condition for this maximization problem:

$$\frac{n-1}{n}\beta = c'(e_i) \tag{6}$$

indicates that, in equilibrium, all agents exert the same level of effort even though their abilities are different and that the marginal benefit of effort β exceeds the marginal cost of effort $c'(e_i)$. This is because the marginal product of each player's effort affects the average performance of all players which is then used as the performance benchmark that his own performance is measured against. Therefore, some extra reward is required to provide sufficient incentives to exert high effort which is beneficial to the principal.

Now, under the proposed truncation policy, agent i receives both the base payment and the bonus payment when her performance is greater than the average (i.e. when $w_i > \bar{e}_{-i} + \bar{a}_{-i} + \bar{w}_{-i} - e_i - a_i$) but only the base payment when her performance is smaller than the average. Therefore, player i's maximization problem under truncation becomes:

$$\begin{aligned}
&\max_{e_i}\ \mathbb{E}(U(r_i{}^t) - c(e_i)) \\
&\quad = \int_{-\infty}^{+\infty}\int_{\bar{e}_{-i}+\bar{a}_{-i}+\bar{w}_{-i}-e_i-a_i}^{+\infty}\left[b + \frac{n-1}{n}\beta(e_i + a_i + w_i - \bar{e}_{-i} - \bar{a}_{-i} - \bar{w}_{-i})\right] \\
&\qquad \times f_w(w_i) f_{\bar{w}}(\bar{w}_{-i})\,\mathrm{d}w_i\,\mathrm{d}\bar{w}_{-i} \\
&\qquad + \int_{-\infty}^{+\infty}\int_{-\infty}^{\bar{e}_{-i}+\bar{a}_{-i}+\bar{w}_{-i}-e_i-a_i} b f_w(w_i) f_{\bar{w}}(\bar{w}_{-i})\,\mathrm{d}w_i\,\mathrm{d}\bar{w}_{-i} - c(e_i)
\end{aligned} \tag{7}$$

The first order condition shows that player's optimal effort depends on one's ability:

$$\frac{n-1}{n}\beta \int_{-\infty}^{+\infty}\int_{\bar{e}_{-i}+\bar{a}_{-i}+\bar{w}_{-i}-e_i-a_i}^{+\infty} f_w(w_i) f_{\bar{w}}(\bar{w}_{-i})\,\mathrm{d}w_i\,\mathrm{d}\bar{w}_{-i} \ = \ c'(e_i). \tag{8}$$

By comparing the first order condition for the standard tournament (6) and the truncated tournament (8), denoting e_i^u and e_i^t the optimal effort levels under non-truncated and truncated tournament respectively, we can state the following proposition:

Proposition 1 *With risk neutral and heterogeneous abilities agents and linear and additive performance function $q_i = e_i + a_i + u + w_i$, the optimal effort for any player in the truncated tournament is smaller than in the standard tournament, $e_i^t < e_i^u$, $\forall i$.*

[7] Since idiosyncratic shocks w_i are assumed identical and independently normally distributed with mean 0 and variance $\sigma_w{}^2$, the average idiosyncratic shock $\bar{w}_{-i} = \frac{\sum_{j \neq i} w_j}{n-1}$ is also normal with mean 0 and variance $\sigma_w{}^2/(n-1)$. The pdf of $\bar{w}_{-i}$ is $f_{\bar{w}}(\bar{w}_{-i}) = \frac{\sqrt{n-1}}{\sigma_w\sqrt{2\pi}} exp(-\frac{(n-1)\bar{w}_{-i}^2}{2\sigma_w{}^2})$.

The reduction in effort for low ability players is greater than for the high ability players in the same tournament, $e_j^t < e_i^t, \forall a_j < a_i$.

Proof First we prove that optimal efforts in the truncated tournament are lower than in the standard tournament for all growers. Combining first order conditions (6) and (8) we need to show that $MU^t(e_i, a_i) < \frac{n-1}{n}\beta, \forall e_i, a_i$, or

$$\begin{aligned} MU^t(e_i, a_i) =& \frac{n-1}{n}\beta \int_{-\infty}^{+\infty} \int_{\bar{e}_{-i}+\bar{a}_{-i}+\bar{w}_{-i}-e_i-a_i}^{+\infty} f_w(w_i)\,\mathrm{d}w_i\, f_{\bar{w}}(\bar{w}_{-i})\,\mathrm{d}\bar{w}_{-i} \\ <& \frac{n-1}{n}\beta \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} f_w(w_i)\,\mathrm{d}w_i\, f_{\bar{w}}(\bar{w}_{-i})\,\mathrm{d}\bar{w}_{-i} = \frac{n-1}{n}\beta \end{aligned} \tag{9}$$

Since optimal efforts in both cases must satisfy first order conditions, $MU^t(e_i^t, a_i) = c'(e_i^t)$ and $\frac{n-1}{n}\beta = c'(e_i^u)$, it follows that $c'(e_i^t) < c'(e_i^t)\ \forall e_i$. Because $c'(\cdot)$ is a strictly increasing function, it is obvious that $e_i^t < e_i^u\ \forall e_i$. Hence, all growers choose lower efforts under the truncated tournament policy.

Next we need to show that under truncation, high ability players exert higher effort than low ability players within the same tournament group. From first order condition (8), define $L(e_i, a_i)$ as the difference between agent's marginal utility and marginal cost of effort:

$$L(e_i, a_i) = \frac{n-1}{n}\beta \int_{-\infty}^{+\infty} \int_{\bar{e}_{-i}+\bar{a}_{-i}+\bar{w}_{-i}-e_i-a_i}^{+\infty} f_w(w_i) f_{\bar{w}}(\bar{w}_{-i})\,\mathrm{d}w_i\,\mathrm{d}\bar{w}_{-i} - c'(e_i). \tag{10}$$

Relying on the implicit function theorem, we need to evaluate the sign of the following derivative:

$$\begin{aligned} \frac{\mathrm{d}e_i}{\mathrm{d}a_i} &= -\frac{\partial L/\partial a_i}{\partial L/\partial e_i} \\ &= -\frac{\frac{n-1}{n}\beta \int_{-\infty}^{+\infty} f_w(\bar{e}_{-i}+\bar{a}_{-i}+\bar{w}_{-i}-e_i-a_i) f_{\bar{w}}(\bar{w}_{-i})\,\mathrm{d}\bar{w}_{-i}}{\frac{n-1}{n}\beta \int_{-\infty}^{+\infty} f_w(\bar{e}_{-i}+\bar{a}_{-i}+\bar{w}_{-i}-e_i-a_i) f_{\bar{w}}(\bar{w}_{-i})\,\mathrm{d}\bar{w}_{-i} - c''(e_i)}. \end{aligned} \tag{11}$$

The numerator is positive since the integrand is a product of two positive probability density functions. The denominator must be negative which is guaranteed by the second order condition for the agent's maximization problem under truncated tournament. Therefore, because of the negative sign in front of the entire ratio, the whole expression is positive implying the positive relationship between effort and ability. □

Figure 1 illustrates the results stated in Proposition 1. Three properties of the marginal utility curve under truncation $MU^t(e_i, a_i)$ are worth mentioning. First, $MU^t(e_i, a_i)$ is strictly smaller than the horizontal line $\frac{n-1}{n}\beta$ and converges to $\frac{n-1}{n}\beta$ as e_i goes to infinity. Second, $MU^t(e_i, a_i)$ is a strictly increasing function of e_i. Third, $MU^t(e_i, a_i)$ is an increasing function of ability for any given level of effort. Therefore, $MU^t(e_i, a_i)$ curve of a high ability player always lies above that of a low ability player for all possible e_i.

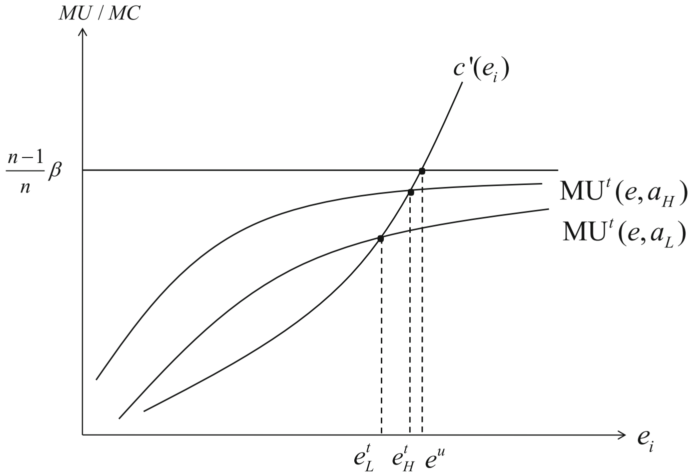


Fig. 1 Optimal efforts for heterogeneous growers with/without truncation

In Fig. 1, the intersection of the horizontal line $\frac{n-1}{n}\beta$ and the marginal cost function $c'(e_i)$ determines the optimal effort e^u that all agents exert in the regular tournament. With truncation in place, all agents are expected to decrease their efforts because the new marginal utility function $MU^t(e_i, a_i)$ lies strictly below the $\frac{n-1}{n}\beta$ line. Moreover, there is a divergence of optimal efforts between high ability and low ability agents with higher ability agents exerting higher efforts than lower ability agents. The intuition behind this result is straightforward. Because players with lower than average performance (usually low ability agents) would not receive any punishment for bad performance under the truncated tournament, they would not have adequate incentives to work as hard as before. Since contestants with above average performance (usually high ability agents) would realize that their competitors are less motivated, they would also lower their efforts because they know they can still win even with lower efforts. However, these high ability types still face some motivation to work hard since their positive rewards (if they win) are based on their performance. Therefore, they will not lower their efforts as much as lower ability types.

Finally, let's analyze the welfare consequences of the proposed regulation. First, we look at agents' expected payments. Under the standard tournament, heterogeneous ability players exert the same level of optimal effort, i.e. $e_i^u = \bar{e}_{-i}^u$, and their expected payment is solely determined by the difference between her ability and the average ability of all other contestants in the same tournament:

$$\mathbb{E}(r_i{}^u) = b + \frac{n-1}{n}\beta(a_i - \bar{a}_{-i}). \tag{12}$$

As seen from Eq. (12), in any given tournament, players with lower than average abilities are expected to receive compensation smaller than base payment b, while better than average ability players receive expected payment in excess of b.

Now, in truncated tournaments, heterogeneous ability agents will exert different levels of effort and the expected compensation is given by the following expression:

$$\mathbb{E}({r_i}^t) = b + \frac{n-1}{n}\beta \int_{-\infty}^{+\infty} \int_{\bar{e}^t_{-i}+\bar{a}_{-i}+\bar{w}_{-i}-e^t_i-a_i}^{+\infty} (e^t_i + a_i + w_i - \bar{e}^t_{-i} - \bar{a}_{-i} - \bar{w}_{-i}) \times f_w(w_i) f_{\bar{w}}(\bar{w}_{-i})\, \mathrm{d}w_i\, \mathrm{d}\bar{w}_{-i} \tag{13}$$

from which we can see that the expected compensation is strictly greater than base payment b even for agents with lower than average abilities. As a result, lower than average ability players expect to receive higher compensations in the truncated tournament than in the standard (non-truncated) tournament. The same is true for agents with higher than average abilities such that their expected payments also increase with truncation. As shown in Proposition 1, the optimal efforts and abilities are positively correlated in truncation. Therefore, agents with higher than average abilities exert higher than average effort, $e^t_i > \bar{e}^t_{-i}$, and receive higher payments compared to the regular tournament:

$$\begin{aligned}\mathbb{E}({r_i}^t) &> b + \frac{n-1}{n}\beta \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} (e^t_i + a_i + w_i - \bar{e}^t_{-i} - \bar{a}_{-i} - \bar{w}_{-i}) \\ &\quad f(w_i) f(\bar{w}_{-i})\, \mathrm{d}w_i\, \mathrm{d}\bar{w}_{-i} \\ &= b + \frac{n-1}{n}\beta(a_i - \bar{a}_{-i}) + \frac{n-1}{n}\beta(e^t_i - \bar{e}^t_{-i}) \\ &= \mathbb{E}({r_i}^u) + \frac{n-1}{n}\beta(e^t_i - \bar{e}^t_{-i}). \end{aligned} \tag{14}$$

To complete the analysis, let's see how the truncation policy affects the principal's expected payoff. We assume that the principal sells each unit of output in the perfectly competitive market with fixed unit price p which is assumed unaffected by regulation. After paying for all production inputs that enter into the settlement cost and the compensations to contract producers, he remains the residual claimant on the profits. It is straightforward to see that the expected profit of the principal will decrease because of the higher settlement cost caused by agents' lower effort and larger compensations.

2.2 Principal's response

In order to mitigate or possibly eliminate the anticipated adverse effect of regulation on its profit, the integrator should react by proposing a new contract. Our analysis is based on the following set of assumptions: (a) the principal designs a uniform contract for all agents; (b) agents' heterogeneous abilities are assumed to be common knowledge among all agents and the principal, hence adverse selection does not exist; (c) the principal does not discriminate among agents based on their abilities in the sense of trying to match different ability agents with different quality or type of inputs;[8]

[8] Leegomonchai and Vukina (2005) showed that poultry integrators never discriminate by delivering different quality inputs to different abilities contract growers even in production technologies where growers separation based on abilities is theoretically possible.

(d) the composition of agents in a given contract will not change as the result of regulation, i.e., the principal will continue contracting with the same pool of agents as before the regulation was imposed;[9] (e) agent's reservation utility $\underline{\mathrm{U}}_i$ is strictly increasing in ability and the marginal contribution of ability to utility enhancement is larger in the chosen option relative to all other outside options, i.e. $\frac{\partial \underline{\mathrm{U}}_i}{\partial a_i} \leq \frac{\partial \mathbb{E} U_i}{\partial a_i}, \forall a_i$. The assumption that $\underline{\mathrm{U}}_i$ is increasing in ability is reasonable because more able agents should have better outside opportunities and hence higher reservation utilities.[10] Also, the marginal contribution of ability to agent's utility is likely to be the highest in the chosen employment relative to all other alternative options because otherwise the agent would have picked some other job where the improvement in some particular skill would have the highest beneficial effect.

The timing of the game is as follows: (1) regulator proposes the tournament truncation policy; (2) principal designs a new contract which satisfies the new proposed regulation; (3) agents decide whether or not to accept the new contract; (4) if agents agree to sign the new contract, they exert optimal level of effort; (5) all shocks are realized and outcomes (production) and payoffs are determined. Because the form of contract is restricted to a cardinal tournament, the principal's problem is simplified into finding a pair of contract parameters, b and β. The solution to this problem is characterized by the subgame perfect Nash equilibrium of the above game which can be obtained using backward induction. In the first step, we solve for agents' optimal effort choices for any values of contract parameters. In the second step, the principal optimally chooses a pair of contract parameters which maximize his objective function subject to agents' incentive compatibility and individual rationality constraints.

2.2.1 A special case: homogeneous abilities

To build some intuition let's look at a simpler case of homogeneous ability players first. Assuming linear additive performance function $q_i = e_i + u + w_i$, equilibrium optimal efforts are the same and ex ante expected compensations are the same and equal to the base payment b for all players. Since all individual outputs are normalized to one, settlement cost C_i equals the negative of agent's performance with expected value equal to the negative effort, $\mathbb{E}(C_i) = -\mathbb{E}(q_i) = -e_i$. Therefore, the principal's total expected profit is simply the expected profit per representative agent times the number of agents under contract.

Each agent maximizes her expected utility from one contract production cycle by choosing the optimal level of effort. The fact that agents' efforts are unobservable by the principal, the ensuing moral hazard problem needs to be solved. Using first order approach proposed by Harris and Raviv (1979) and Holmstrom (1979), we can

9 This assumption is somewhat restrictive because the change in incentives, in addition to influencing effort, could also alter the pool of agents who accept the contract through sorting. This effect was first documented empirically by Lazear (2000) and subsequently in experimental setting, among others, by Dohmen and Falk (2011) who found that change in the compensation schemes has multidimensional sorting effect with respect to ability, risk aversion, relative self-assessment and even gender. The relationship between incentives and sorting in the context of broiler tournaments is investigated by Wang and Vukina (2016).

10 This idea is empirically verified in Dubois and Vukina (2009).

use the first order condition of the agent's maximization problem as the incentive compatibility (I.C.) constraint in the principal's problem.[11] In addition, the contract must be designed such that agent's expected utility from contracting must be at least as high as the utility of the next best outside option $\underline{\mathrm{U}}$, that is, the optimal contract must satisfy the agent's individual rationality (I.R.) constraint. Therefore, the optimal contract under the regular tournament compensation scheme is obtained as the solution to the following problem:

$$\max_{[e_i^u, b^u, \beta^u]} \quad \mathbb{E}\Pi^u = p + e_i^u - b^u$$
$$s.t. \quad \frac{n-1}{n}\beta^u - c'(e_i^u) = 0 \tag{15}$$
$$b^u - c(e_i^u) \geq \underline{\mathrm{U}}.$$

The Lagrangian function for the problem in (15), $\mathcal{L}(e_i^u, b^u, \beta^u) = p + e_i^u - b^u + \lambda[\frac{n-1}{n}\beta^u - c'(e_i^u)] + \eta[b^u - c(e_i^u) - \underline{\mathrm{U}}]$, needs to be differentiated with respect to effort, both contract parameters b and β, λ (Lagrange multiplier for the I.C. constraint) and η (Lagrange multiplier for the I.R. constraint) to obtain the set of first order Kuhn–Tucker conditions. The closed form solution of the principal's problem given in (15) has the following form:

$$e_i^u = c'^{-1}(1) \tag{16}$$
$$b^u = c(e_i^u) + \underline{\mathrm{U}} = c[c'^{-1}(1)] + \underline{\mathrm{U}} \tag{17}$$
$$\beta^u = \frac{n}{n-1}. \tag{18}$$

The above results show that the individual rationality constraint is binding, which means that the base payment is determined such that agents earn zero rents. This result makes sense because if agents could earn positive rents, the principal could always reduce the base payment to extract those rents without changing the incentives to exert effort.[12] The result also shows that the optimal effort required by the principal occurs

[11] A potential problem of the first-order approach of solving for the optimal contract is that the solution to the first-order condition is not always the solution to the agent's maximization problem. The reason is that it is only the necessary condition. In general, there are more efforts that satisfy the first-order condition than those that satisfy the maximization problem since the objective function need not be concave, see Grossman and Hart (1983). However, this is not an issue in this problem since the first-order condition has only one solution which satisfies the second-order condition automatically when we assume a quadratic cost of effort; see also Mirrlees (1976), Shavell (1979), Rogerson (1985) and Macho-Stadler and Perez-Castrillo (2001).

[12] The principal's ability to extract agents' rents is the consequence of (i) the modeling assumption that all growers' bird weights are the same which changed piece rate into fixed salary b and, (ii) the fact that b is not bounded from below. To the extent that the data supports the equal weight assumption, its consequence on the result is trivial. However, imposing an additional constraint, $b \geq 0$, on the system (15) could fundamentally change the results. The intuition is straightforward: imagine a situation where the optimal contract requires $b < 0$ in order to reach the first-best solution. Whereas having a contractually negative piece-rate is absurd, having a negative base payment is not. In this case $b < 0$ would mean that instead of being paid a salary, an agent would be required to place a bond or pay something like a franchising fee. In this case, the non-negativity constraint makes it no longer possible to reach this solution. In order to induce

where marginal cost of effort equals the marginal benefit of effort to the principal, which equals to one. To motivate agents to exert the desired level of effort, the principal also needs to set the marginal cost of effort equal to marginal benefit of effort to the growers, i.e. $c'(e_i^u) = \frac{n-1}{n}\beta$. Hence, $\beta = \frac{n}{n-1}$, which converges to unity as the number of growers in a tournament increases.[13]

Under the truncated tournament compensation scheme, it can be easily shown that the optimal level of effort in the truncated tournament will be lower than in the regular tournament for all players and the principal's optimal contract design problem with modified I.C. and I.R. constraints is represented by the maximization of the expected profit function:

$$\max_{[e_i^t, b^t, \beta^t]} \quad \mathbb{E}\Pi = p + e_i^t - b^t - \frac{n-1}{n}\beta^t \int_{-\infty}^{+\infty} \int_{\bar{w}_{-i}}^{+\infty} (w_i - \bar{w}_{-i})$$
$$f_w(w_i) f_{\bar{w}}(\bar{w}_{-i}) \mathrm{d}w_i \mathrm{d}\bar{w}_{-i}$$
$$s.t. \ \frac{n-1}{n}\beta^t \int_{-\infty}^{+\infty} \int_{\bar{w}_{-i}}^{+\infty} f_w(w_i) f_{\bar{w}}(\bar{w}_{-i}) \mathrm{d}w_i \mathrm{d}\bar{w}_{-i} - c'(e_i^t) = 0$$
$$b^t + \frac{n-1}{n}\beta^t \int_{-\infty}^{+\infty} \int_{\bar{w}_{-i}}^{+\infty} (w_i - \bar{w}_{-i}) f_w(w_i) f_{\bar{w}}(\bar{w}_{-i}) \mathrm{d}w_i \mathrm{d}\bar{w}_{-i} - c(e_i^t) - \underline{\mathrm{U}} \geq 0 \tag{19}$$

and the solution is given by:

$$e_i^t = c'^{-1}(1) \tag{20}$$
$$b^t = c[c'^{-1}(1)] - \frac{\int_{-\infty}^{+\infty} \int_{\bar{w}_{-i}}^{+\infty} (w_i - \bar{w}_{-i}) f_w(w_i) f_{\bar{w}}(\bar{w}_{-i}) \mathrm{d}w_i \mathrm{d}\bar{w}_{-i}}{\int_{-\infty}^{+\infty} \int_{\bar{w}_{-i}}^{+\infty} f_w(w_i) f_{\bar{w}}(\bar{w}_{-i}) \mathrm{d}w_i \mathrm{d}\bar{w}_{-i}} + \underline{\mathrm{U}} \tag{21}$$
$$\beta^t = \frac{n}{n-1} \cdot \frac{1}{\int_{-\infty}^{+\infty} \int_{\bar{w}_{-i}}^{+\infty} f_w(w_i) f_{\bar{w}}(\bar{w}_{-i}) \mathrm{d}w_i \mathrm{d}\bar{w}_{-i}}. \tag{22}$$

The comparison of the results for the regulated (truncated) and the unregulated (standard) tournament payment schemes shows that with risk neutral, homogenous abilities agents and risk neutral, profit maximizing principal, (i) agents earn zero rents in both standard and truncated tournaments; (2) agents' optimal efforts are the same, $e_i^u = e_i^t, \forall i$; (3) the slope of the truncated tournament is bigger than the slope of the standard tournament, $\beta^t > \beta^u$; (4) the base payment in the truncated tournament is smaller than the base payment in the standard tournament, $b^t < b^u$; (5) principal's profits are the same.

The proof of the above statements is constructed by observing that: (1) Same as in the regular case, each agent's individual rationality constraint binds under truncation

the agent to accept the contract and to exert high effort, the principal could be forced to leave the agents with some rents.

[13] This result is consistent with the actual contracts that generated our empirical data where the slope of all available contracts is given by $\beta = 1$.

because the principal could always lower the base payment without changing the incentives to exert effort. (2) Agents' optimal efforts are the same under both scenarios by way of comparing (16) with (20). (3) The slope of the truncated tournament β^t is greater than the slope of the standard tournament β^u by way of comparing (18) with (22) since the denominator in expression (22) is between 0 and 1. (4) The base payment in the truncated tournament b_t is smaller than in the standard tournament b_u by way of comparing (17) with (21) because both the numerator and the denominator in expression (21) are positive. (5) If agents' equilibrium efforts are the same and their payments are the same, the principal's profits are automatically the same by construction.

The obtained results make perfect sense: with risk-neutral agents, moral hazard is inoffensive because the principal does not face a trade-off between incentives provision and risk-sharing, since the agent can bear all the risk at no cost, i.e. the first-best solution obtains. This means that the truncation of the bonus part of the payment scheme at zero does not destroy the standard result. The reason why the principal can completely undo the proposed regulation is due to the fact that the only regulatory requirement is that the bonus part does not go negative, whereas the piece rate is not regulated.[14] So, the requirement that the bonus must be non-negative is offset by the reduction in piece rate b. Because the truncation causes lowering of equilibrium effort, the principal needs to motivate growers to work harder, that is, increase the incentives via a steeper slope of the new tournament contract. At the same time, the optimal base payment can be lowered because growers' individual rationality constraints are easier to satisfy when growers are no longer punished for lower than average performance.

2.2.2 Heterogenous abilities

Back to the original case. Let's start with the regular tournament scenario first. The principal's problem can be formulated as:

$$\begin{aligned} &\max_{[e^u, b^u, \beta^u]} \quad \mathbb{E}\Pi = pn + e^u n + \sum_{i=1}^{n} a_i - b^u n \\ &s.t. \ \frac{n-1}{n}\beta^u - c'(e^u) = 0 \\ &b^u + \frac{n-1}{n}\beta^u(a_1 - \bar{a}_{-1}) - c(e^u) - \underline{\mathrm{U}}_1 \geq 0. \end{aligned} \tag{23}$$

Several points are worth explaining. First, because agents are heterogenous in abilities, the objective is to maximize the expected profit per entire tournament. Second, based on the formula for optimal agent effort from (6) which appears as the I.C. constraint in the principal's problem, agents' abilities play no role in deciding how much effort to exert, i.e., all players regardless of their ability exert the same level of effort. For this reason, subscript i can be dropped to avoid notational clutter. Third, since all agents are expected to exert the same level of effort, their compensation only depends on

[14] This is what makes this regulatory proposal different from the limited liability (liquidity constraint) of the agents as in Bhattacharya and Guasch (1988) or Marinakis and Tsoulouhas (2012).

their individual abilities relative to average ability of other players in the tournament and agent's I.R. constraint can be written as

$$\mathbb{E}U_i^u = b^u + \frac{n-1}{n}\beta^u(a_i - \bar{a}_{-i}) - c(e^u) \geq \underline{\mathrm{U}}_i, \quad \forall i = 1, 2, \ldots, n \tag{24}$$

Since agent's expected utility on the left hand side of (24) is increasing in ability, applying assumption (e), the number of individual rationality constraints can be reduced from one per agent to only one. This is because agent's expected net utility after subtracting out her reservation utility is monotonically increasing in ability a_i. A direct consequence of assumption (e) is the fact that if the individual rationality constraint is satisfied for the lowest ability agent, it will be automatically satisfied for all higher ability agents. Denoting a_1 as the lowest ability agent, we arrive at the simplified I.R. constraint as it appears in (23).

The first order conditions for the principal's problem in (23) become:

$$c'(e^u) - (a_1 - \bar{a}_{-1})c''(e^u) = 1 \tag{25}$$

$$\beta^u = \frac{n}{n-1}c'(e^u) \tag{26}$$

$$b^u = -\frac{n-1}{n}\beta^u(a_1 - \bar{a}_{-1}) + c(e^u) + \underline{\mathrm{U}}_1, \tag{27}$$

and can be implicitly solved for β^u, b^u and optimal effort.

We now turn to the case of truncated tournaments. In the formulation of the principal's problem, several issues need to be addressed. First, the first-order condition of the agent's maximization problem with respect to effort (which will be subsequently used as agents' I.C. constraints) shows that agents' optimal effort under truncated tournament compensation scheme depends on abilities such that higher ability types exert higher efforts, see expression (8) and Proposition 1.

Second, in order for agents to accept and sign the proposed contract, their individual rationality constraints have to be satisfied. To deal with the I.R. constraints we need an additional result contained in the following lemma.

Lemma 1 *Agents' expected gross utility (without subtracting out the reservation utility) is a strictly increasing function of ability.*

Proof When agents are risk-neutral with heterogeneous abilities, an agent's expected utility under truncated tournament compensation scheme is:

$$\mathbb{E}U_i^t = b^t + \frac{n-1}{n}\beta^t \int_{-\infty}^{+\infty}\int_{\bar{e}^t_{-i}+\bar{a}_{-i}+\bar{w}_{-i}-e_i^t-a_i}^{+\infty} (e_i^t + a_i + w_i - \bar{e}^t_{-i} - \bar{a}_{-i} - \bar{w}_{-i}) \\ \times f_w(w_i) f_{\bar{w}}(\bar{w}_{-i}) \mathrm{d}w_i \mathrm{d}\bar{w}_{-i} - c(e_i^t) \geq 0 \tag{28}$$

where optimal effort is a function of own ability $e_i = e(a_i)$ determined by the first order condition in (8). To see the relationship between expected utility and ability, we take derivative of utility function with respect to ability bearing in mind that effort is also a function of ability to obtain:

$$\begin{aligned}\frac{\mathrm{d}\mathbb{E}U_i^t}{\mathrm{d}a_i} &= \frac{n-1}{n}\beta^t \int_{-\infty}^{+\infty}\int_{\bar{e}_{-i}^t+\bar{a}_{-i}+\bar{w}_{-i}-e_i^t-a_i}^{+\infty}\left(\frac{\mathrm{d}e_i^t}{\mathrm{d}a_i}+1\right) \\ &\quad\times f_w(w_i)f_{\bar{w}}(\bar{w}_{-i})\mathrm{d}w_i\mathrm{d}\bar{w}_{-i} - c'(e_i^t)\frac{\mathrm{d}e_i^t}{\mathrm{d}a_i} \\ &= \left(\frac{\mathrm{d}e_i^t}{\mathrm{d}a_i}+1\right)c'(e_i^t) - c'(e_i^t)\frac{\mathrm{d}e_i^t}{\mathrm{d}a_i} \\ &= c'(e_i^t). \end{aligned} \tag{29}$$

Since cost of effort function is convex, $c'(e_i^t)$ is strictly positive. Hence, $\frac{\mathrm{d}\mathbb{E}U_i^t}{\mathrm{d}a_i}$ is also strictly positive. □

Using Lemma 1 and the results that $\frac{\partial \mathrm{U}_i}{\partial a_i} \leq \frac{\partial \mathbb{E}U_i}{\partial a_i}, \forall a_i$ which are contained in assumption (e), the I.R. constraints for all more capable growers are redundant. Same as before, the only I.R. constraint the principal needs to be concerned with is that of the least capable agent with ability a_1.

Third, yet another complication for the design of the new optimal truncated tournament scheme arises from the possibility that some agents who used to sign the tournament contract before the regulation may choose not to sign the newly offered truncated tournament contract and some other ones, who did not sign before, may now decide to sign, i.e., the new contract may end up attracting a different pool of players. Considering sorting effect directly in the principal's problem could be extremely complicated, hence we rely on the assumption (d) and assume that the pool of players remains the same before and after regulation.

Incorporating I.C. and I.R. constraints, the principal's problem can be stated as:

$$\begin{aligned}\max_{[\{e_i^t\}_{i=1}^n, b^t, \beta^t]} \quad \mathbb{E}\Pi &= pn + \sum_{i=1}^n (e_i^t + a_i) - b^t n - \sum_{i=1}^n \frac{n-1}{n}\beta^t \\ &\quad \int_{-\infty}^{+\infty}\int_{\bar{e}_{-i}^t+\bar{a}_{-i}+\bar{w}_{-i}-e_i^t-a_i}^{+\infty} (e_i^t + a_i + w_i - \bar{e}_{-i}^t - \bar{a}_{-i} - \bar{w}_{-i}) \\ &\quad \times f_w(w_i)f_{\bar{w}}(\bar{w}_{-i})\mathrm{d}w_i\mathrm{d}\bar{w}_{-i} \\ s.t. \quad & \frac{n-1}{n}\beta^t \int_{-\infty}^{+\infty}\int_{\bar{e}_{-i}^t+\bar{a}_{-i}+\bar{w}_{-i}-e_i^t-a_i}^{+\infty} \\ &\quad \times f_w(w_i)f_{\bar{w}}(\bar{w}_{-i})\mathrm{d}w_i\mathrm{d}\bar{w}_{-i} - c'(e_i^t) = 0 \quad \forall i = 1, 2, \cdots, n \\ & b^t + \frac{n-1}{n}\beta^t \int_{-\infty}^{+\infty}\int_{\bar{e}_{-1}^t+\bar{a}_{-1}+\bar{w}_{-1}-e_1^t-a_1}^{+\infty} \end{aligned}$$

$$(e_1^t + a_1 + w_1 - \bar{e}_{-1}^t - \bar{a}_{-1} - \bar{w}_{-1}) \\ \times f_w(w_1) f_{\bar{w}}(\bar{w}_{-1}) \mathrm{d}w_1 \mathrm{d}\bar{w}_{-1} - c(e_1^t) - \underline{\mathrm{U}}_1 \geq 0 \tag{30}$$

Notice that instead of having only one I.C. constraint as in the situations where the optimal effort was constant, here, because the optimal effort depends on the ability, the principal needs to consider a system of I.C. constraints, one for each agent. The full set of first order conditions is rather messy but reasonably straightforward and can be skipped for brevity. Here, we only need to refer to the first order condition with respect to contract parameter b, i.e., $\frac{\partial \mathcal{L}}{\partial b^t} = -n + \eta = 0$, which can be used to show that $\eta = n > 0$, implying that the I.R. constraint for the least capable agent is binding, whereas all other agents would earn some equilibrium rents which the principal cannot extract by using a uniform base payment b^t. The extraction of all rents for higher ability agents would require individualized contracts with base payments indexed by abilities.

Unlike in a simpler case with homogeneous agents, the system of first order conditions for (30) does not have a closed form solution and hence we cannot derive any theoretical predictions regarding the comparison of unregulated and regulated (truncated) tournaments schemes. Instead, the optimal contract parameters b^t and β^t as well as optimal efforts for all agents under truncation need to be obtained numerically and welfare results need to be simulated.[15] This is what comes next after we introduce our data.

3 Welfare comparisons

3.1 Data

We use contract settlement data from one of the large broiler companies in the United States. The contract data set contains contract settlements information for five different broiler production contracts offered between July 1995 and July 1997.[16] There are total of 7421 observations and each observation provides the contract settlement information for one flock of birds. Each observation includes starting and settling date, head started and sold, weight sold, and total amounts and values of various production inputs provided by the integrator. These five contracts are differentiated by the size of the birds produced (target weight). As seen from Table 1, the dispersion of individual producers' bird weights around the average target weight is quite narrow. The coefficients of variation for all five contracts are between 3 and 6% indicating that the modeling assumption about constant weights across all growers is not overly

[15] Similarly, in a different model with homogeneous ability agents and normally distributed aggregated production shock (common and idiosyncratic), Marinakis and Tsoulouhas (2012), after imposing truncation (liquidity constraints), could not obtain either a closed form or a numerical solution to the optimal cardinal tournament parameters. Instead, they were able to obtain significant insight using numerical analysis assuming that idiosyncratic and common shocks follow independent uniform distributions in which case the aggregate shock follows a triangular distribution.

[16] The data set is somewhat old but modern broiler contracts are remarkably similar to what they looked like 20 years ago. In fact, the only change to the tournament payment scheme was an increase in base payment to reflect the overall price inflation in the economy.

Table 1 Production performance summary statistics

Contract	Days		Target weight (lbs.)		Feed conversion		Mortality rate	
	Mean	St. dev.	Mean	St. dev.	Mean	St. dev.	Mean (%)	St. dev. (%)
A	48.54	1.48	4.95	0.25	2.08	0.06	5.24	2.58
B	50.26	1.62	4.81	0.29	2.03	0.08	2.91	3.31
C	56.32	1.99	5.86	0.25	2.19	0.12	4.67	2.99
D	57.06	1.55	6.01	0.20	2.17	0.06	4.45	1.80
E	56.55	1.81	6.21	0.26	2.19	0.11	5.39	2.98

Table 2 Tournaments characteristics summary statistics

Contract	K	T	N	n in each T		Weight (lbs.)		Cost ($)	
				Mean	St. dev.	Mean	St. dev.	Mean	St. dev.
A	908	48	196	18.9	3.11	232,520	120,510	75,691	39,495
B	3234	104	344	31.1	5.42	240,260	131,040	75,316	41,955
C	1361	104	280	13.1	3.19	332,330	138,430	106,270	45,287
D	958	76	184	12.6	2.60	302,880	169,180	100,890	56,288
E	959	103	240	9.3	2.39	364,810	153,960	117,560	51,789

restrictive. The data also shows that it usually takes 48–57 days (6–8 weeks) for 1-day old baby chicks to reach the target weight (5–6 pounds). For all five contracts, the feed conversion ratios are close to 2, which means that two pounds of feed are required for a bird to gain one pound of weight. The mortality rate fluctuates around 5% per flock per growing cycle.

All growers whose birds were harvested during the same calendar week will settle their contracts at the end of that week and will form one tournament. Table 2 contains entries on the total number of observations (flocks) K, numbers of tournaments T and numbers of growers N in each contract. Average number of growers in each tournament n varies between different contracts in the range between 10 and 31 growers. Table 2 also shows the averages and standard deviations of total pounds of output produced by each grower and their corresponding total settlement costs. Obviously, the settlement costs are directly related to weight: the heavier the birds, the large the costs of producing them. Notice that unlike in Table 1 where the standard deviations around the target individual bird's weight are fairly tight, the standard deviations of the total output (weight) are large which is mainly the consequence of different scales of production (number of chicken houses that different growers operate). Within the constraints of our model, different scales of operations would translate into different salaries: growers with larger facilities would receive larger salaries (multiples of b).

To illustrate how the piece rate tournament compensation scheme influences grower's payment, we calculate the number and percentage of growers who received a negative bonus (malus) and compare the average payments of tournament winners and tournament losers to the overall average payment in a contract. The results are presented in Table 3. One can see that average payments vary substantially among

Table 3 Grower Payments per flock summary statistics

Contract	Base	Payments ($)		Penalized growers		Payment with penalty		Payment with bonus	
		Mean	St. dev.	Count	Percentage	Mean	% less	Mean	% more
A	0.0355	8387	4777	418	46.0	6869	−18.1	9683	15.5
B	0.0384	9422	5794	1487	46.0	7462	−20.8	11,090	17.7
C	0.0453	15,438	7317	628	46.1	13,369	−13.4	17,211	11.5
D	0.0453	13,950	8262	450	47.0	12,289	−11.9	15,421	10.6
E	0.0448	16,811	7964	449	46.8	13,849	−17.6	19,418	15.5

contracts. The difference is explained by the size of birds grown, where contract for heavier birds pay on average more because it takes more days to grow heavier birds. More interestingly, payments earned by growers within the same contract can be significantly different. It is not unusual to see that a winner of a tournament receives several times larger payment compared to a loser. This is clearly indicated by large standard deviations of growers' payments. The percentages of growers with variable piece rates below the base payment (those that earned a negative bonus) is quite consistent in all five contracts and hovers around 46%. Table 3 also reports the average payments for growers in the penalty and bonus subgroups and how they compare with the overall average payments. It can be seen that negative bonuses erode between 10 and 20% of growers' overall payments.

For the purpose of simulating integrator's profit, we used broiler meat prices in the period from July, 1995 to July, 1997. These prices are weekly composite 12 cities market average prices.[17] The average price of smaller live birds is 43.75 cents per pound and for the larger birds 45.32 cents per live pound.

3.2 Estimation and simulation

For each of the five contracts, the estimation process involves four steps. First, we obtain the estimates of growers abilities. Second, we simulate growers' optimal efforts under various values of tournament contract slopes to see how the change in incentives influences equilibrium efforts for growers with different abilities. Third, we obtain the optimal contract parameters under tournament truncation by searching for the combination of base payment and slope which gives the principal the highest possible profit and, at the same time, satisfies incentive compatibility and individual rationality constraints. Finally, we calculate the expected profit of the integrator and the expected

[17] The market price is a composite price including US Grade A (branded included) and plant grade ice-packed, whole carcass chill-pack product and whole birds without giblets. The twelve cities are: Boston, Chicago, Cincinnati, Cleveland, Denver, Detroit, Los Angeles, New York, Philadelphia, Pittsburgh, St. Louis and San Francisco. During the two year period covered by the data, chicken prices were reasonably stable with an average of 61 cents per pound. Because these prices are based on dressed (processed) weight, they need to be converted into live weights using industry average processing yields. Processing yields are positively related to size such that for smaller two categories/contracts we used 72.3% yield and for the remaining three categories/contracts we used 74.9% yield, see Vukina (2005).

payments of the growers under the new (truncated) optimal contract parameters and compare the results with those generated by the observed original (unregulated) tournament scheme as well as those generated by the unadjusted parameters truncated scheme.

First, to estimate growers' abilities, we need to compute growers' optimal efforts under regular tournament contracts e_{it}^{u} using first order condition for growers' utility maximization problem in the unregulated case (no truncation) in (6). We specify a quadratic cost of effort function, $c(e_{it}) = \frac{c}{2}{e_{it}}^2$, with a constant disutility parameter c, which gives a closed form solution for optimal efforts, $e_{it}^{u} = \frac{n_t-1}{cn_t}\beta$, with n_t being the number of growers in tournament t. The cost parameter c has an arbitrarily assigned value of $c = 100$. We experimented with different values of c but changing c only changes the absolute values of the simulated effort (the larger the cost parameter, the smaller the optimal efforts) but not the relationships among them. An unbalanced two-way fixed effect model is then estimated to obtain growers' time-invariant abilities, together with the variances of idiosyncratic shocks σ_w^2 and common shocks σ_u^2. The two-way fixed effect model is derived from the grower's additive performance function:

$$q_{it} - e_{it}^{u} = a_N + \sum_{j=1}^{N-1}(a_j - a_N)d_{it}^{j} + \sum_{k=1}^{T-1} u_k g_{it}^{k} + w_{it} \tag{31}$$

where $q_{it} = -C_{it}/Q_{it}$ is the performance measure equal to the negative of adjusted prime cost (APC) for grower i in tournament t.

We assume that ability a_j is a tournament-invariant variable specific to grower j and common production shock u_k is a grower-invariant variable specific to tournament k. d_{it}^{j} and g_{it}^{k} are grower and tournament dummy variables with $d_{it}^{j} = 1$ if $j = i$ and 0 otherwise and $g_{it}^{k} = 1$ if $k = t$ and 0 otherwise. To avoid singularity, only $N-1$ grower dummies and $T-1$ tournament dummies are included in the regression. That way, a_N is the ability of grower N and it is estimated as the constant term of the regression. Growers' fixed effects estimated through the model are the differences between each grower's ability and grower N's ability. Assuming the common shock in tournament T is zero, common shocks for all other tournaments are estimated as tournament specific fixed effects. Idiosyncratic shock w_{it} is estimated as the error term in the regression.

With all the parameters in Eq. (31) estimated, the sample variance of common production shocks $\hat{\sigma_u^2}$ can be computed as $\hat{\sigma_u^2} = \frac{1}{T-1}\sum_{t=1}^{T}(u_t - \bar{u})^2$ where $\bar{u} = \frac{1}{T}\sum_{t=1}^{T} u_t$. Similarly, we can obtain the sample variance of idiosyncratic shocks as $\hat{\sigma_w^2} = \frac{1}{K-1}\sum_{t=1}^{T}\sum_{i=1}^{n_t}(w_{it} - \bar{w})^2$ where $\bar{w} = \frac{1}{K}\sum_{t=1}^{T}\sum_{i=1}^{n_t} w_{it}$ and $K = \sum_{t=1}^{T} n_t$.

Secondly, we need to simulate growers' efforts with truncation. As discussed before, each grower in a truncated tournament decides how much effort to exert based on the first order condition or incentive compatibility constraint (8) assuming all other growers in the same tournament following the same strategy. Notice that unlike in the unregulated case where the actual grower performances play no role in calculating optimal efforts, in the truncated case the realized performances play a role since they impacted estimated abilities. However, besides their abilities, growers' effort choices depend only on the slope of the compensation scheme β whereas the base payment b

plays no role in determining growers optimal efforts. Base payment is only used as a tool for adjusting average payments in response to individual rationality constraints.

The Nash equilibrium of this game is calculated by numerically solving the system of non-linear incentive compatibility constraints, one for each agent in a given tournament. The second-order conditions need to be checked at the final solution for all growers to make sure the calculated optimal efforts are indeed utility maximizing efforts. To investigate how heterogeneous ability growers react to changes in slope parameter under truncated tournament, we vary the slope parameter in the interval [0.5,1.5].

Finding optimal contract parameters involves a choice of two contract parameters: base b and slope β. The problem of finding the solution of optimal contract with truncation is complicated by the fact that growers' reservation utilities are unobservable and one can only estimate their upper bounds relying on the identifying assumption that growers individual rationality constraints had to be satisfied under the observed regular tournament contracts. Otherwise, these growers would not have accepted those contracts and hence they would have not appeared in our data. Based on this insight, we calculate each grower's reservation utility as the smallest of the expected utilities of all tournaments she participated in:

$$\begin{aligned}\underline{\mathrm{U}}_i &= \min(\mathbb{E}U_{it}^u) \\ &= \min\left(b^u + \frac{n_t - 1}{n_t}\beta^u(a_i - \bar{a}_{-it}) - c(e_{it}^u)\right), \quad \forall i = 1, 2, \ldots, n. \end{aligned} \tag{32}$$

The sequential algorithm to calculate the optimal contract parameters involves four steps:

1. Propose a β^t and calculate growers' optimal efforts under β^t by solving the system of incentive-compatibility constraints.
2. Calculate the minimum required base payment b_t which satisfies individual rationality constraint for all growers and all tournaments using

$$\begin{aligned} b^t &= \max(\underline{\mathrm{U}}_i + c(e_i^t) \\ &\quad - \frac{n-1}{n}\beta^t \int_{-\infty}^{+\infty} \int_{\bar{e}_{-i}^t + \bar{a}_{-i} + \bar{w}_{-i} - e_i^t - a_i}^{+\infty} (e_i^t + a_i + w_i - \bar{e}_{-i}^t - \bar{a}_{-i} - \bar{w}_{-i}) \\ &\quad \times f_w(w_i) f_{\bar{w}}(\bar{w}_{-i}) \mathrm{d}w_i \mathrm{d}\bar{w}_{-i}) \end{aligned} \tag{33}$$

3. Calculate expected profit of the principal under proposed β^t and its corresponding base payment b_t by summing up expected profits from all grower and all tournaments.
4. Update β^t until principal's expected profit is maximized. The last set of contract parameters β^{t*} and b^{t*} are the optimal contract parameters.

Note that the calculated reservation utilities are upper bounds of growers' actual reservation utilities which results in overestimation of b^t and underestimation of principal's expected profit.

Table 4 Estimation of two way fixed effect model

Contract	Adjusted R^2	$\hat{\sigma_u}^2$	$\hat{\sigma_w}^2$	F-test 1	F-test 2
A	0.9055	3.4398e−04	3.8810e−05	3.83	119.71
B	0.9279	9.2815e−04	7.5404e−05	6.56	326.22
C	0.8985	9.4536e−04	1.1692e−04	5.31	69.62
D	0.9613	6.7550e−04	2.9442e−05	8.82	210.16
E	0.9487	9.9061e−04	5.6225e−05	10.96	86.27

Estimates of the intercepts, fixed effects of growers and tournaments have been suppressed for brevity
F test 1: $H_0 : a_1 = a_2 = \cdots = a_N$, F test 2: $H_0 : u_1 = u_2 = \cdots = u_T = 0$
All hypothesis tests of equal abilities and zero common production shocks are rejected at 0.01% significant level

3.3 Numerical results and welfare measures

The estimation results for Eq. (31) are given in Table 4. For all five contracts, the Adjusted R^2 is around 0.9, which indicates that growers' heterogeneous abilities and tournament common shocks capture most of the variations in growers' performances. We can also see strong evidence of growers' heterogeneity and statistical significance of common shocks. The null hypotheses of equal abilities across growers (F-test 1) and zero common production shocks (F-test 2) are strongly rejected for all five contracts.

The obtained results provide a good explanation for why the risk-neutral agents model is adequate and why introducing risk aversion would not substantially change the results on the relative performance of the two contracts. A closer inspection reveals that the magnitudes of both risks—common risk which the tournaments eliminate and idiosyncratic risk which stays—are very small (although statistically significant) relative to the total variation in the performance index (adjusted prime cost rating). This means that the individual abilities are critical determinants of performance (because effort is the same for all growers) and payments of individual growers are not going to fluctuate significantly from one tournament realization to the next. Therefore, using continuity of the Bernoulli utility function, linear approximation (risk-neutrality) at any given average payment is a good representation of the actual risk-preferences (at least for low risk-aversion).

We start the presentation of the empirical results with Table 5 which shows the influence of the tournament slope (the power of incentives) on the exertion of optimal growers' efforts in the regular (unregulated) and truncated (regulated) tournament. To highlight certain results, we rank all growers within each contract according to their estimated abilities from the lowest to the highest and divide them into quartiles of ability distribution, with Q1 representing the lowest ability group and Q4 representing the highest ability group. The regular tournament (RT) column gives the average effort for all tournaments for each quartile under the observed (unregulated) tournament with the tournament slope $\beta = 1$ (the slope we observe for all five contracts that generated the data). We can see that the optimal efforts are almost identical for heterogeneous ability growers with the slight differences resulting from the different number of growers in various tournaments, see expression (6). The middle column

Table 5 Grower's Effort Choices under Various Slope Parameters—all tournaments

Contract	Growers quartile [b]	RT (10^{-4})[a]	TT (10^{-4})				
		$\beta = 1$	$\beta = 0.5$	$\beta = 0.8$	$\beta = 1$	$\beta = 1.2$	$\beta = 1.5$
A	Q1	94.65	4.09	4.51	4.21	3.64	2.61
	Q2	94.73	15.94	23.02	26.30	28.30	29.21
	Q3	94.66	30.31	50.77	65.69	81.71	107.65
	Q4	94.79	43.30	71.32	90.61	110.17	139.67
B	Q1	96.79	9.07	12.17	13.18	13.37	12.35
	Q2	96.80	20.35	31.36	37.92	43.60	49.88
	Q3	96.76	28.97	47.65	60.94	75.11	98.61
	Q4	96.78	39.12	64.92	83.17	102.25	132.19
C	Q1	92.24	10.82	15.83	18.45	20.47	22.28
	Q2	92.20	20.19	31.72	39.07	46.08	55.78
	Q3	92.36	26.50	43.05	54.45	66.21	84.69
	Q4	92.60	34.79	57.20	72.87	89.17	114.86
D	Q1	92.25	6.02	6.62	6.03	4.97	7.08
	Q2	92.01	17.53	25.84	30.16	33.51	45.48
	Q3	91.95	28.96	48.40	62.55	77.71	92.13
	Q4	92.02	40.54	67.70	86.67	106.00	132.95
E	Q1	89.01	6.80	9.07	9.84	10.07	9.57
	Q2	89.25	18.29	28.15	34.09	39.41	46.13
	Q3	89.26	27.01	44.31	56.45	69.15	89.39
	Q4	89.49	38.04	62.76	80.02	97.85	125.44

[a] RT represents regular tournament compensation scheme where β is observed to be 1 for all five contracts. TT represents truncated tournament compensation schemes
[b] Q1 contains growers whose abilities are between 0–25% percentile in one contract. Q2 contains growers whose abilities are between 25–50% percentile. Q3 contains growers whose abilities are between 50–75% percentiles. Q4 contains growers whose abilities are between 75–100% percentile

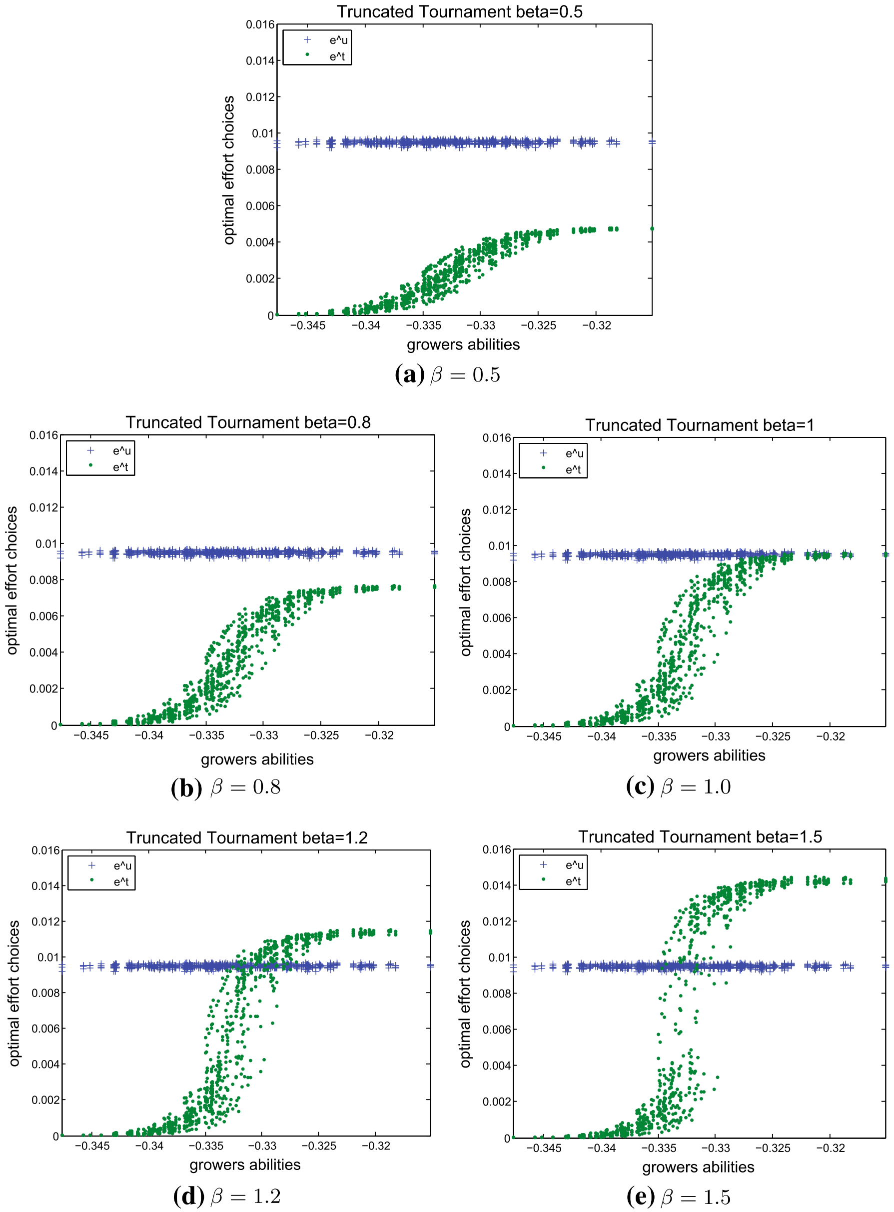
under the truncated tournament (TT) reveals the results of the scenario where the contract parameters did not adjust in response to truncation regulation, i.e., $\beta = 1$, as it was in the original contracts prior to regulation. The results show that tournament truncation causes all growers to decrease their optimal effort choices in comparison to the regular case and that the magnitude of this effort reduction is substantially smaller for high ability growers (Q4) than for low ability growers (Q1).

After the integrator had a chance to adjust the contract parameters in response to regulation, the reduction in optimal effort is muted and can be even reversed. By varying the value of the slope parameter in the interval [0.5, 1.5] we show that the average expected effort is positively correlated with the tournament slope for growers with higher abilities (Q2, Q3 and Q4) in all five production contracts. For slopes greater than 1, the highest ability growers choose to provide even higher efforts in truncated tournament than in the regular tournament. However, this regularity is destroyed for the lowest abilities growers. Only Q1 growers in contract C always positively respond to the change in slope by increasing their optimal efforts. Q1 growers in other four contracts first increase their efforts with the increase in slope and then decrease their efforts as the slope further increases.

The above results patterns can be explained by taking a closer look at the grower incentive compatibility constraint under truncation (8). The impact of β on a grower's optimal effort can be decomposed into two components: pure incentives effect and competition effect. The pure incentives effect captures the impact of β on a single grower's effort when efforts of all other growers remain the same and it is always positive. This is because the marginal utility of effort represented by the left hand side of Eq. (8) under the larger slope parameter lies above the marginal utility of effort under the smaller slope and intersects the marginal cost of effort at a larger effort. The competition effect reflects optimal reactions of all other growers and negatively influences grower's effort since higher efforts by other growers under larger slope would increase the difficulty of winning the tournament which consequently diminishes the marginal utility of working hard. These two effects have opposite impacts and whether an individual grower increases or decreases her effort depends on the relative magnitude of the two effects. For high ability growers, the incentive effect dominates because these growers are still in a good position to win the tournament even if others work harder than they used to do. The negative impact of the competition effect is much more pronounced for low ability growers because their chances of winning become considerably smaller when other growers work harder and they are likely to exert low effort just enough to earn the base payment. Therefore, increasing the slope parameter is an effective tool to motivate high ability growers but it comes at the expense of discouraging the least capable growers from providing high efforts.

The results from Table 5 are also illustrated in Fig. 2 for contract A. In all five panels, the horizontal line represents the optimal efforts under regular tournament e^u with $\beta = 1$. The S-shaped curve shows growers optimal efforts under truncated tournaments with different values of β. As we can see, the larger the slope β, the steeper the S curve. Increasing the slope of the tournament contract is an effective instrument for the principal to motivate average and high ability growers to work hard. However, the motivation effect of an increase in the slope is fairly negligible, or even negative for low ability growers. The effort plots for other four contracts, not included here, follow similar patterns.

Table 6 presents the numerically solved optimal contract parameters which maximize expected profit of the principal under the assumption that the composition of growers remained the same. It is shown that the estimated optimal slopes under truncated tournament are always greater than their original levels which are always 1 in all five contracts. On the other hand, the optimal base payments under truncation are all positive and lower than their empirically observed unregulated counterparts. As mentioned before, these results can be easily explained. Because growers are expected to lower their optimal efforts when the compensation scheme is switched from a regular to a truncated tournament, the principal who optimally adjust his contract to new regulation, will raise the slope parameter to provide growers with higher incentives to work hard. On the other hand, the base payment can be lowered under truncation because growers individual rationality constraints are easier to satisfy with no penalties for substandard performance. The fact that all estimated salary coefficients are positive



(a) $\beta = 0.5$

(b) $\beta = 0.8$ **(c)** $\beta = 1.0$

(d) $\beta = 1.2$ **(e)** $\beta = 1.5$

Fig. 2 Grower's optimal effort choice-contract A

without explicitly imposing $b \geq 0$ constraint validates the use of a simpler theoretical model that allows for rent extraction for the purposes of simulating empirical problems where rent extraction does not seem to be feasible.

The last column in Table 6 shows average optimal levels of effort for four groups of growers with heterogeneous abilities under the optimally designed truncated contract.

Table 6 Optimal contract parameters and effort levels under truncation

Contracts	Original contract		Optimal contract		Growers quartile [a]	Optimal efforts
	b	β	b	β		
A	0.0355	1	0.0305	1.1285	Q1	3.86
					Q2	27.73
					Q3	75.86
					Q4	103.15
B	0.0384	1	0.0321	1.2521	Q1	13.29
					Q2	44.90
					Q3	78.98
					Q4	107.34
C	0.0453	1	0.0383	1.4210	Q1	21.94
					Q2	53.34
					Q3	79.71
					Q4	107.95
D	0.0453	1	0.0409	1.0480	Q1	5.80
					Q2	31.04
					Q3	66.09
					Q4	91.29
E	0.0448	1	0.0399	1.2733	Q1	10.03
					Q2	41.20
					Q3	73.97
					Q4	104.51

[a] Q1 contains growers whose abilities are between 0 and 25 percentiles; Q2 contains growers with abilities in 25–50 percentiles range; Q3 contains growers with abilities in 50–75 percentiles range; and Q4 contains growers with abilities in 75–100 percentiles range

The absolute values of this variable are not meaningful because they depend on the chosen value of the cost of effort parameter c but their comparison makes sense. We observe substantially higher effort levels under the optimally designed contracts compared to the unadjusted contract parameters (see TT $\beta = 1$ column in Table 5). However, only the optimal efforts exerted by the highest ability growers (Q4) are even larger than their effort levels under the regular tournament (RT column in Table 5). For all other ability groups the optimal efforts under truncation are always lower than in the regular (unregulated) case. This pattern is consistent across all five contracts. For the group with the lowest ability (Q1), the relationship between equilibrium efforts in the unadjusted contract and in the optimal contract is not uniform across all five contract but both of those effort levels are always, on average, significantly smaller than under the regular tournament. These results clearly indicate that the proposed regulation is likely to exacerbate the moral hazard problem among most (except for the highest ability) growers and that even after optimal adjustment of contract parameters, the principal cannot completely undo the negative impact of the proposed regulation.

Table 7 Average welfare effects of tournament truncation regulation

	Growers payments (cents) [a]				Integrator profit (cents)				Total
Contracts	RT [b]	TT	TT*	TT*-RT	RT	TT	TT*	TT*-RT	TT*-RT
A	3.550	3.979	3.594	0.044	8.386	7.477	7.922	−0.464	−0.421
B	3.840	4.253	3.862	0.022	7.185	6.293	6.830	−0.355	−0.333
C	4.530	4.988	4.649	0.119	8.117	7.198	7.732	−0.385	−0.266
D	4.530	4.901	4.628	0.098	8.398	7.570	7.994	−0.404	−0.306
E	4.480	4.888	4.623	0.143	8.749	7.899	8.288	−0.461	−0.318

[a] Growers' payments are expected received payments from growing one pound of chickens and integrator's expected profit is profit per grower

[b] RT represents regular tournament with $\beta = 1$ for all five contracts. TT represents truncated unadjusted tournament and TT* represent truncated tournament with optimally adjusted contract parameters. TT*-RT is the difference between the optimally adjusted truncated contract and the unregulated contract

Finally, the average welfare effects of payment truncation regulation on both growers and the integrator are shown in Table 7. For contract growers, the numbers present the average expected compensation from growing one pound of chicken and for the integrator the numbers present the expected profit from harvesting one pound of chicken from grower's farm under the regular tournament (RT), truncated (unadjusted) tournament (TT) and truncated tournament with fully adjusted (optimal) contract parameters (TT*).[18] The numbers show that growers' compensations would increase by about 10% if the principal continues to use the same contracts as prior to regulation (TT) but decrease after the integrator had a chance to respond to regulation (TT*). The final TT* compensations are still slightly greater than what growers could earn in the regular tournament. Considering actual quantities produced in a production cycle, such small welfare gains could be transferred into $70–$400 payment increase from each flock. On the integrator's side, the consequences are completely reversed. The integrator is expected to experience a decrease in profit under the TT scenario but should be able to partially neutralize the negative impact of regulation by changing the tournament contract parameters. At the end of the day, integrator will still lose $1000–$1500 per grower as a result of higher payments to growers and lower efforts. Taking the welfare impacts on both sides into consideration, payment truncation regulation would ultimately (after contract renegotiation) result in the total welfare loss in the amount of $600–$1100 per grower per cycle.

Despite the welfare gain to growers presented in Table 7, not all growers will benefit from the truncated tournament policy. As shown in Table 8, only growers with the lowest and the highest abilities (Q1 and Q4) will benefit from the regulation. However, the sources of their welfare gains are different. Lowest ability growers can earn more money with payment truncation because they are no longer being punished for lower than average performance and now earn the base payment which is higher

[18] Another way of comparing the welfare impacts of regulation would be to compare the payoffs under optimal contract with truncation against the optimal contract without truncation. Since the simulated optimal contract parameters without truncation are fairly close to the actual contract parameters observed in the data, the results would not be appreciably different.

Table 8 Welfare effects of tournament truncation by abilities

Contract	Ability quartile[c]	Growers payments (cents)[a]				Integrator profit (cents)				Total
		RT[b]	TT	TT*	TT*-RT	RT	TT	TT*	TT*-RT	TT*-RT
A	Q1	2.833	3.560	3.065	0.232	8.367	6.735	7.227	−1.140	−0.908
	Q2	3.351	3.653	3.180	−0.172	8.368	7.382	7.870	−0.498	−0.670
	Q3	3.717	4.004	3.649	−0.067	8.420	7.844	8.300	−0.121	−0.188
	Q4	4.299	4.702	4.482	0.182	8.389	7.945	8.290	−0.099	0.084
B	Q1	3.158	3.888	3.274	0.116	7.144	5.578	6.193	−0.951	−0.835
	Q2	3.705	4.041	3.501	−0.204	7.160	6.235	6.845	−0.315	−0.519
	Q3	4.013	4.289	3.917	−0.096	7.206	6.571	7.124	−0.082	−0.178
	Q4	4.484	4.794	4.661	0.177	7.231	6.784	7.160	−0.072	0.106
C	Q1	3.782	4.625	3.979	0.197	7.899	6.318	6.999	−0.900	−0.703
	Q2	4.393	4.802	4.303	−0.090	8.096	7.156	7.797	−0.299	−0.389
	Q3	4.700	5.005	4.707	0.007	8.106	7.422	7.973	−0.134	−0.126
	Q4	5.243	5.519	5.605	0.362	8.368	7.895	8.159	−0.209	0.154
D	Q1	4.000	4.545	4.108	0.108	8.319	6.912	7.347	−0.972	−0.864
	Q2	4.414	4.665	4.240	−0.174	8.353	7.483	7.917	−0.436	−0.610
	Q3	4.666	4.951	4.561	−0.106	8.430	7.850	8.277	−0.153	−0.259
	Q4	5.037	5.441	5.088	0.051	8.490	8.033	8.432	−0.058	−0.007
E	Q1	3.742	4.514	4.039	0.298	8.619	7.055	7.532	−1.087	−0.790
	Q2	4.347	4.652	4.256	−0.091	8.488	7.632	8.099	−0.389	−0.480
	Q3	4.643	4.900	4.671	0.027	8.797	8.212	8.617	−0.180	−0.153
	Q4	5.185	5.485	5.525	0.340	9.089	8.694	8.899	−0.190	0.150

[a] Growers' payments are expected received payments from growing one pound of chickens and integrator's expected profit is profit per grower

[b] RT represents regular tournament with $\beta = 1$ for all 5 contracts. TT represents truncated unadjusted tournament and TT* represent truncated tournament with optimally adjusted contract parameters. TT*-RT is the difference between the optimally adjusted truncated contract and the unregulated contract

[c] Q1 contains growers whose abilities are between 0 and 25 percentiles; Q2 contains growers with abilities in 25–50 percentiles range; Q3 contains growers with abilities in 50–75 percentiles range; and Q4 contains growers with abilities in 75–100 percentiles range

than the amount they can make under the old (regular tournament) system which includes penalties for sub-par performance. On the other hand, highest ability growers can earn more because the large bonus for better than average performance offsets the lower base payment under the new policy. The results also show a welfare loss for growers with relatively low abilities (Q2) and mixed results for growers with relatively high abilities (Q3). Finally, Table 8 also tracks the source of welfare loss of the integrator by looking at his expected profit from each group of growers. Generally, the results show that the lower the growers abilities, the larger the loss of profit for the integrator.

4 Conclusion

The initial impetus for this study came from the regulation that would ban the use of standard tournaments to settle broiler production contracts between poultry integrators and contract growers proposed by USDA-GIPSA in 2010. According to the proposal, the regular tournaments would have been replaced by a truncated scheme that would guarantee the minimum of the base payment for all growers regardless of their performance, meaning that the potential penalties for sub-par performances would have been eliminated. As it turned out, the proposed regulation did not pass the legislative process but GIPSA continues to actively consider reintroducing some type of regulation of the livestock production tournaments in the future. The analytical approach and the results presented in this study have wider appeal to payroll economics researchers and companies' human resources managers.

The objective of this paper was to evaluate the welfare implications of the proposed regulation from both the agents' and the principal's perspectives. In an illustrative simple model, risk neutral and homogeneous ability agents will decrease their optimal effort levels in response to the new truncated tournament regime. Agents' overall welfare would increase due to higher expected payments and lower disutility of effort. Lower levels of effort would cause overall productivity to decline and together with increases in agents' compensation would result in smaller company's profits. In order to minimize the adverse effect of regulation, the principal could offer a new contract that would satisfy the regulatory constraint and would still be accepted by the same agents. As expected, because of agents' risk-neutrality, the moral hazard is inoffensive and the principal could completely neutralize the potential negative effects of proposed regulation by strategically adjusting tournament parameters.

In an empirically relevant case of risk-neutral, heterogeneous abilities agents, the expected compensation in the truncated (regulated) tournament would be strictly higher than in the standard (unregulated) tournament for both high ability and low ability types. Optimal efforts and abilities are positively correlated under truncation such that higher ability players exert higher than average effort and receive higher payments than low ability players. The analytical solution to the problem of optimal contract design under truncated tournament payment scheme is impossible to obtain and the welfare effects needed to be simulated. An empirical estimation is conducted using actual contract settlement data. In this more complicated case, we show that the principal can only partially neutralize the expected welfare loss through change in contract parameters. The distributional effects in equilibrium are such that lower and higher ability workers are more likely to benefit from regulation while average ability workers are expected to lose. Overall, the proposed truncation policy would not significantly increase agents' incomes, as surely must have been wished for by the policy makers who proposed this regulation and, in fact, some producers could end up being worse off than before the regulation.

There are a couple of possible extensions of this analysis for future research. First, our empirical analysis is based on the assumption that the pool of agents that the principal contracts with stays the same. However, the results show that the loss due to regulation incurred by the principal is the largest with the lowest abilities agents. Consequently, it is possible that the principal may seek to terminate the contracts with the lowest ability types and try to attract higher ability agents. This could create additional welfare losses for low ability types who could permanently lose their contracts and consequently incur large losses resulting from investments in relationship specific assets. Broiler production contracts are the prime example of such a possibility where chicken growers whose contracts may end up being terminated could be saddled with enormous losses resulting from heavily leveraged but now vacant chicken houses.

Another interesting line of inquiry would be to investigate whether bonus truncation causes a moral hazard type of behavior on the principal's side. Cardinal tournaments commit the integrator to a fixed average payment per unit of output because bonuses and penalties cancel each other out precisely by construction. Hence, under regular tournament, the integrator has no incentive to misrepresent the productivity of any individual agents or all agents collectively. However, this useful feature of tournaments is destroyed by the truncation because now the average payment per unit of output is no longer fixed *ex ante* by the contract but rather depend on agents' productivity.

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