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Do Incentives for Quality Matter?

Corinne Alexander, Rachael E. Goodhue, and Gordon C. Rausser

We use an unusual dataset involving 14 tomato growers over 4 years to analyze the effect of incentive contracts on behavior in a fixed effects econometric model. We find that growers respond to incentive contracts by improving tomato quality, as predicted by economic theory. The comparison is not confounded by the usual contract endogeneity and simultaneity problems because of characteristics of the processing tomato industry and our dataset. We discuss the implications of our findings for the design of agricultural contracts.

Key Words: contracts, panel data, processing tomato industry

JEL Classifications: D86, C23, Q13

People respond to financial incentives in contracts—or so economists believe. Although such a response is obvious theoretically, it is difficult to obtain conclusive support empirically. Contract provisions and agent performance under contracts are often proprietary information, so obtaining data is difficult. Furthermore, observed data are often subject to simultaneity problems between contract determination and performance under the contract (i.e. because agents' contract choices are endogenous relative to incentives in the

contracts, any data solely on performance under a contract are incomplete). In most cases, agents select only one contract so that it is impossible from selected contracts to eliminate the possibility that a hidden factor influences both contract choice and ensuing performance.

To analyze the effect of incentive contracts on behavior, we compare the quality of tomatoes delivered under an incentive contract that specifies premium schedules for multiple tomato attributes (denoted contract tomatoes) to the quality of tomatoes delivered under a fixed price per ton contract (denoted no-contract tomatoes). We also compare the quality of contract tomatoes delivered during the regular season to the quality of contract tomatoes delivered late in the season when an extra premium is paid. We use an unusual dataset of 14 tomato growers who deliver processing tomatoes under both the incentive contract and the fixed price per ton contract, over a 4-year period. The sample is multidimensional: processors value a number of tomato attributes, some of which are less costly than others for growers to deliver. We examine two direct measures of quality and two financial measures of quality to assess growers' responses to price incentives, rather

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Richard Sexton and Jeffrey Williams and three anonymous reviewers provided many useful comments on this paper. Mark Evans, Jerry Gilbert, Gene Myao, and Woody Yerna provided helpful information regarding processing tomato production and the industry. The authors gratefully acknowledge the assistance of the industry members who provided the analyzed data and the financial support received from the Giannini Foundation of Agricultural Economics. Goodhue and Rausser are members of the Giannini Foundation of Agricultural Economics.

than using a single measure. All quality attributes are graded by an independent third party, the state of California, so that neither party to a contract can deliberately misstate or mismeasure quality.

With a fixed effects model, we test whether the quality of the no-contract tomatoes is lower than the quality of the contract tomatoes and whether the quality of contract tomatoes delivered in the late season, when there is a base price premium, is lower than the quality of the contract tomatoes during the regular season. Our comparison supports the fundamental economic hypothesis that people respond to financial incentives in contracts; our analysis shows that growers do respond to incentive contracts by improving tomato quality.

Although a well-developed theoretical literature predicts how performance measures such as quality and output respond to contract incentives, the empirical literature is much less developed (Prendergast; Salani ). Our analysis contributes to the empirical literature regarding agents' responses to contract incentives.¹ Existing empirical studies primarily address nonagricultural examples of incentive contracts, such as managerial compensation (e.g., Lemmon, Schallheim, and Zender; Murphy), worker compensation (Lazear), and franchising (e.g., LaFontaine; LaFontaine and Shaw). In part, this emphasis is due to the difficulties of obtaining data on contract terms and outcomes. In the case of managerial compensation, the reporting requirements for publicly held companies provide a data source. Similarly, franchising studies compile information from a number of published sources.

Broadly speaking, the empirical literature on agricultural contracts is concerned with two questions: what are the determinants of contract choice and how does contract design affect agents' responses and the principal's profit or utility. Examples of the empirical literature regarding the determinants of con-

tract choice include Allen and Lueck and Goodhue et al. Our study addresses the second question. It is distinguished from other empirical studies that address this question in that the structure of the processing tomato industry, combined with the nature of our dataset, insulates our data from three common incentive endogeneity problems: the continuous evolution of contract terms, the simultaneity of contract choice and contract terms, and endogenous matching between heterogeneous principals and agents. With the exception of Akerberg and Botticini, the few existing studies that address the effect of financial incentives on real behavior under agricultural contracts use originally proprietary data on the basis only of outcomes under a contract. They do not observe outcomes in the absence of the contract, so their conclusions are subject to concerns regarding sample selection (Goodhue, Rausser, and Simon; Knoeber and Thurman; Leegomochai and Vukina). Hueth and Ligon, and Wu, who like us use data from the processing tomato industry, suffer from another selection problem; their data reports contract outcomes for multiple processors (principals), each contracting with multiple growers. Given their analytical techniques, the endogeneity of the processor-grower pairings might confound any analysis of responsiveness to contractual incentives. Akerberg and Botticini introduce a means of controlling for this endogenous matching problem econometrically. Their analysis does not control for the evolution of contract terms over time; it relies on cross-sectional data.

The nature of our dataset, combined with institutional features of the processing tomato industry, limits the effect of the three common incentive endogeneity problems. If the contracting situation were continuous, we would expect to see the continuous evolution of contract terms and a large variety of contracts. In contrast, our contracts are identical for everyone contracting in a given year, so we examine outcomes under only four contracts: one for each year. (Marginal incentives across contracts have only small differences.) Similarly, the bargaining con-

¹ A growing empirical literature uses experiments to test contract theory (Wu and Roe; Bull, Schotter, and Weigelt).

weight deduction. The quantity of tomatoes eligible for payment after the weight deductions is referred to as the quantity of delivered tomatoes. Below specified quality thresholds, the processor may reject the load.⁴ The marginal price effect of these weight deductions differs for contract and no-contract tomatoes. No-contract tomatoes receive the flat price per pound on postdeduction pounds. Contract tomatoes receive the base price and any price incentives on postdeduction pounds. Thus, the marginal effect of weight deductions on revenues is larger under an incentive contract.

Over two thirds of the state's tomato growers belong to the California Tomato Growers' Association (CTGA), which acts as a collective bargaining agent.⁵ The CTGA negotiates contracts with each processor individually on behalf of its members. The negotiations determine a base price and any quality incentive payments. Many processors use incentive payments. For example, Campbell Soup Co., Morning Star Packing Co., and Stanislaus Food Products all negotiated quality payments for the 1999 season. The relative and absolute magnitudes differ across processors. Another interesting feature of

these contracts is that tomatoes delivered in the last weeks of the season often receive a per ton late-season premium above the base price, regardless of graded quality.

Once the CTGA approves a contract, the processor offers it to growers on a take it or leave it basis. The negotiated contract is effectively a minimum-price contract; although the negotiated contract is not technically binding for producers who are not CTGA members, processors are prohibited from offering a lower priced contract to nonmembers to prevent nonmembers from underbidding members and gaining acreage. (Anecdotally, processors do not choose to offer higher priced contracts, although this would be permitted.) Although the *ex ante* bargaining process might limit the appropriateness of contract theory for evaluating contract design, it does not distort the usefulness of examining contract outcomes to see whether individual growers respond to contract provisions.

Most processing tomatoes are delivered under output contracts. Industry observers estimate that roughly 98% of processed tomatoes are contracted, which is consistent with our sample, which had 97% of loads delivered under contract. The remaining 2%–3%, however, are essential for the smooth functioning of the tomato marketing system. Once a processing plant begins operating for the season, it must maintain the flow of tomatoes. If an inadequate supply forces the plant to shut down, it is very costly to restart because the entire system must be reesterilized. Processors purchase no-contract tomatoes to ensure a smooth flow of inputs. These no-contract tomatoes are purchased by processors according to posted prices. Although processors determine these prices, the market does not function as a true spot market because posted prices remain constant for a number of weeks and do not reflect the marginal value of the tomatoes to the processor.

Model

We develop a simple theoretical model that predicts how growers will respond to quality incentives for specific tomato attributes.⁶

⁴A relatively small sample (100 lbs.) is used to grade the quality of the 20+ ton load. Starbird examines the effects that the combination of a maximum worm percentage threshold and sampling have on growers' pesticide use decisions. He finds that the sampling process induces growers to use more pesticides than they would if every tomato in a load were graded.

⁵Joanne Hancock, CTGA, personal communication, October 21, 1999.

⁶We do not have information regarding the interactions between the production costs of the different quality attributes, so we simply model a single quality variable. From the predictions regarding this variable, we generate reduced form predictions regarding the specific quality attributes. Because we do not have the data necessary to test empirically structural relationships among the quality attributes, the value of modeling theoretically all such possible relationships is limited at best. We abstract from the repeated nature of the grower-processor relationship. In practice, growers want to obtain contracts for the following year. Because the processor values tomato quality, the grower has an incentive to provide all high-quality tomatoes, whether or not they are under contract that year. Even taking this incentive into consideration, there should still be a differential quality effect because of differences in current returns.

vention for the industry during our sample period (discussed in the following section) guarantees that the processor must offer a contract to the growers each year on a take it or leave it basis so that the simultaneity problem is subdued. We can isolate what growers do in response to contract incentives because of the sequencing and bargaining choices in the industry. Finally, unlike the Lemmon, Schallheim, and Zender sample of seven relatively homogeneous principals and unlike the Hueth and Ligon sample, our sample has a single principal. This provides perfect control for unobservable differences across principals that could affect agent behavior under a contract. Unlike Hueth and Ligon, our dataset includes all deliveries by all agents to the processor so that we do not need to worry about unobservable characteristics that determine grower membership in the bargaining association and might also affect performance.

Our analysis contributes to the literature regarding the adoption of contracting in agriculture and the effects of contracts on the distribution of returns to the contracting parties. We find that the processor obtains higher quality tomatoes from contracting than from spot purchases because growers respond to price incentives for quality and the growers receive a higher price per ton. Our results can be interpreted as evidence that growers will respond to price incentives that are sufficiently large to cover the cost of providing the improved quality, which in turn implies that growers might obtain a net benefit from signing a contract with price incentives for quality. However, because of the nature of our data, our results cannot be interpreted as evidence that the price incentives are optimally chosen by the processor. Consequently, we can not conclude that the benefit of higher quality outweighs the cost of providing the price incentives for the processor. Although the offer of these incentives by the processor might appear to be *prima facie* evidence that the processor increases profits by offering price incentives for quality, the results of our analysis do not completely support this inference.

Processing Tomato Market

Most processing tomatoes are made quickly into paste during the harvest season.² The paste is stored for further processing (ketchup, tomato sauce, etc.) throughout the year. Before a load of tomatoes is accepted for delivery at the processing plant, it undergoes a state-mandated grading process at a state inspection station. The state inspection station grades the load on the basis of seven categories: percentage of tomatoes with worm damage, the Agron color score, percentage of tomatoes with mold damage (mold), percentage of green tomatoes (greens), percentage of material other than tomatoes (MOT), percentage of limited use tomatoes that are broken and overripe (LU), and the sugar content or net soluble solids (NTSS). In contrast to government grading systems for other agricultural products such as grains and beef, interviews with tomato processors and tomato growers found that industry members are generally satisfied with the grading system and view the results as reasonably accurate. Thus, for the purposes of this paper, we assume the expected error of the inspection procedure is zero.³ All contract price incentive payments are based on the results of this state grading. Each load is graded independently, and a grower's payment is calculated separately for each load (see Equation (1) for the calculation of the grower's payment).

All tomatoes, both contract and no-contract, are subject to weight deductions. Loads with excessive mold, greens, LU, worms, and MOT are subject to weight deductions; that is, the grower can only receive payment for 1,800 lbs. of a ton of harvested tomatoes if the quality is low enough to result in a 10%

²Information regarding tomato production and marketing was obtained from personal communications with Mark Evans, Jerry Gilbert, Gene Miyao, and Woody Verxa, as well as from Gould and Sims et al.

³Interviews with growers and processors indicate satisfaction with the state-run, third-party inspection procedure. As one grower put it, "About half the time the errors are against you, and the other half they're for you, so I'm satisfied with the procedure."

Our risk-neutral tomato producers maximize profits per acre. Each producer's revenues per acre are a function of the base price, the quality price incentives faced, the weight deductions faced, the tons of tomatoes delivered, and the quality of the delivered tomatoes. The costs per acre are a function of the tons of tomatoes produced and the quality of the delivered tomatoes. The maximization problem over the quantity (Q) and quality (q) of tomatoes delivered can be written as

$$(1) \quad \max_{q,Q} Q[1 - w(q)][B + p(q)] - C(q, Q),$$

where $w(q)$ is the weight deduction schedule, B is the base price per quality-adjusted ton, p is the price premium schedule, and $C(q, Q)$ is the cost function. For the component functions, $w_q < 0$, $w_{qq} < 0$, $p_q > 0$, $p_{qq} > 0$, $C_q > 0$, $C_{qq} > 0$, $C_Q > 0$, $C_{QQ} > 0$, and $C_{qQ} > 0$.⁷

This system is a simplification of the actual tomato price-quality relationship. The actual schedule includes minimum quality levels that must be met for the processor to accept the tomatoes. The minimum quality standards and the schedule of weight deductions are the same for contract and no-contract tomatoes, whereas the posted price could differ from the base price. In practice, loads are almost never rejected because of failure to meet these minimum standards because the penalties are extremely large, so this appears to be a reasonable simplification. In our dataset of approximately 33,000 loads, only 110 loads were rejected. Our research question addresses the ability of price incentives to induce growers to improve quality beyond the level induced by the weight deduction schedule that includes the minimum quality standards that define when loads are rejected.

The first-order conditions determine the equilibrium levels of q and Q for the grower:

$$(2) \quad \begin{aligned} [1 - w(q)](B + p) - C_q &= 0, \\ -Qw_q(B + p) + Qp_q[1 - w(q)] - C_{qQ} &= 0 \end{aligned}$$

Equation (2) shows that the absence of price incentives for quality, $p(q)$, reduces the marginal benefit of producing quality without affecting the marginal cost. Hence, the quality of each tomato attribute (NTSS and Bad [i.e., more MOT, LU, green, and mold tomatoes]) will be lower when tomatoes are delivered for a fixed price. This lower quality load will have lower NTSS and a higher percentage of bad tomatoes.

We obtain the following testable hypotheses regarding the level of each tomato quality attribute delivered under the incentive contract versus the flat price per ton.

TESTABLE HYPOTHESIS 1: *Tomatoes delivered for a flat price per ton have lower NTSS than do tomatoes delivered under a quality incentive contract.*

TESTABLE HYPOTHESIS 2: *Tomatoes delivered for a flat price per ton have a higher share of bad tomatoes than do tomatoes delivered under a quality incentive contract.*

TESTABLE HYPOTHESIS 3: *Tomatoes delivered for a flat price per ton will be of lower quality overall than will tomatoes delivered under a quality incentive contract.*

We next consider the effect of a late-season premium on quality. Like quality price premiums, the late-season premium is paid per ton of delivered tomatoes. The purpose of the premium is to compensate growers for the reduction in expected returns because of the increased probability of rain from mid-September on. In some instances, the tomato crop can be completely destroyed by rain. No-contract tomatoes do not receive the late-season premium, so we are able to distinguish between incentive effects and the effects of rain on quality. Unlike quality price premiums, the late-harvest premium is identical for all delivered tons. Thus, the late-season premium is equivalent to an increase in the base price of contract tomatoes and does not affect price premium schedules. Totally differ-

⁷ The two assumptions $p_{qq} = 0$ and $C_{qq} = 0$ do not change the qualitative nature of the results of our comparative statistics relative to the more general cases $p_{qq} \geq 0$ and $C_{qq} \geq 0$. If instead of $C_{qq} > 0$ we assumed $C_{qq} \leq 0$, our results would only be strengthened.

entiating the first-order conditions, we obtain

$$(3) \quad dQ + \{-w_q[B + p(q)] + p_q[1 - w(q)] - C_{Qq}\}dq + [1 - w(q)]dB = 0, \\ \{p_q[1 - w(q)] - w_q[B + p(q)] - C_{Qq}\}dQ - \{Qw_{qq}[B + p(q)] + 2QP_qw_q + C_{qq}\}dq - Qw_qdB = 0.$$

Applying the implicit function rule, the effect of a change in B on the grower's optimal choice of q and Q is

$$\frac{dq}{dB} = -[1 - w(q)] / \{-w_q[B + p(q)] + p_q[1 - w(q)] - C_{Qq}\} < 0, \\ \frac{dQ}{dB} = \{[w(q) - 1]\{Qw_{qq}[B + p(q)] + 2QP_qw_q + C_{qq}\} / \{-w_q[B + p(q)] + p_q[1 - w(q)] - C_{Qq}\}^2\} + (-Qw_q) / \{-w_q[B + p(q)] + p_q[1 - w(q)] - C_{Qq}\} > 0.$$

Both of these qualitative effects require $-w[B + p(q)] + p_q[1 - w(q)] - C_{Qq} > 0$. This condition implies that a change in the marginal benefit of q because of a change in Q is larger than the change in marginal cost and that a change in the marginal benefit of Q because of a change in q is larger than the change in marginal cost. Provided that the condition is met, an increase in the base price of tomatoes will increase the optimal quantity of tomatoes and reduce the optimal quality. An increase in the base price reduces the optimal quality because the higher base price makes the quality incentive relatively less important and makes delivering quantity relatively more important. Unfortunately, our dataset does not contain any information on acres harvested or yield, so we can not test any quantity response predictions.

We obtain the following testable hypotheses regarding the level of each tomato quality

attribute delivered under the incentive contract during the late season, when these tomatoes receive a late-season premium that in effect increases the base price.

TESTABLE HYPOTHESIS 4: *Under the quality incentive contract, tomatoes that receive a late-season premium have lower NTSS than do other contract tomatoes.*

TESTABLE HYPOTHESIS 5: *Under the quality incentive contract, tomatoes that receive a late-season premium have a higher share of bad tomatoes than do other contract tomatoes.*

TESTABLE HYPOTHESIS 6: *Under the quality incentive contract, tomatoes that receive a late-season premium will be of lower quality than other contract tomatoes.*

Empirical Model

We develop four fixed effects models—two regarding quality production in processing tomatoes and two regarding realized quality incentive payments—to determine whether growers respond to price incentives for quality as predicted by economic theory. Table 1 summarizes major producer decisions and other factors, such as weather, and their effects on tomato quality. To respond to quality incentives, growers must be able to affect tomato quality. Growers' harvest timing and sorting decisions are the primary ways in which they can affect tomato quality attributes, with the exception of NTSS, which is also determined by preharvest decisions.

The processor's scheduling needs influence the time of harvest, but the decision rests primarily with the grower. A highly skilled grower will time the harvest to maximize the share of ripe tomatoes and minimize the share of LU tomatoes: the conventional rule of thumb is to harvest when 95% of the tomatoes are ripe. Harvesting too early can reduce NTSS and increase greens. As the tomatoes ripen, controlling the share of LU tomatoes becomes a material concern. A grower could choose to apply ethephon to speed ripening (subject to processor approval), even though this could reduce the harvest window for optimal quality. Ethephon is most commonly used early in the season and late in the season

Table 1. Stylized Tomato Production and Harvesting Process

Stage	Decision Maker	Quality Affected
Proplanting		
Set planting schedule	Grower and processor	
Choose tomato varieties	Grower and processor	NTSS, LU, greens
Production		
Fertilizer/water regime	Grower	NTSS
Pesticide applications	Grower with processor approval	Worms
Weather		
Rain		Mold
Heat		LU, color
Harvest		
Time of harvest	Grower and processor	NTSS, LU, greens, color
Sorting		
Mechanical	Grower	LU, greens, mold, MOT
Number of workers	Grower	LU, greens, mold, MOT
Speed of harvester	Grower	LU, greens, mold, MOT

when cooler temperatures slow ripening. The harvest window for very high quality tomatoes that would be eligible for price premiums varies greatly across tomato varieties. It can be as long as 2 or 3 days, but the use of ethephon narrows this harvest window. The harvest window for acceptable quality tomatoes that would not be eligible for price premiums and would only face minimal weight deductions is much longer and lasts as long as 10 days for some varieties.

The grower's decisions regarding sorting effort during harvest directly affect the share of LU, mold, greens, and MOT. The purpose of sorting is to remove these "bad" tomatoes from the load, leaving only the high-quality tomatoes. If the grower mistimes the harvest (i.e., harvests too late when there is a large share of LU or too early when there is a large share of greens), the grower can still deliver high quality by increasing sorting effort. The grower makes three decisions that determine the level of sorting effort and sorting costs. First, the grower sets the sensitivity level of the mechanical sorter which is particularly effective at removing greens and MOT. However, it is possible for the mechanical sorter to be too sensitive, so that it will reject too many good tomatoes. Second, the grower chooses how many workers ride the harvester and remove

LU, mold, greens, and MOT. More workers increases sorting effectiveness but increases labor costs. Finally, the farmer chooses the speed of the tomato harvester. The workers can sort more effectively when the harvester is moving slowly, but again, labor costs increase.

Profit-maximizing growers equalize the price received for each quality attribute per delivered ton with the marginal cost of producing tomatoes with attributes of that quality. Different tomato quality attributes are affected by different production decisions, and the attributes vary in their costliness of production. We examine the grower's decision in two ways. First, we model the quality outcome for delivered loads in terms of NTSS and the percentage of bad tomatoes (LU, greens, mold, and MOT). Second, we model the overall quality outcome as measured first by the per ton net incentives (including both weight deductions and quality premiums) received by the grower and second by the per ton quality incentives received by the grower. We do not explicitly model cross-effects among the variables, although such effects certainly exist.

NTSS is determined by the tomato variety, weather, time of season and grower practices. Sugar content varies greatly across tomato varieties so we include tomato variety dummy

variables to control for these effects. The sugar content of tomatoes tends to increase over the course of the season and is affected by average daily temperatures. We include week-year dummies to control for these effects. The contract late-season variable can capture weather effects; however, it will also capture the effect of the late-season premium, which will tend to decrease NTSS (Testable Hypothesis 4), so that the net effect is indeterminate. Because the growers in our sample are located throughout inland central California (a north-south distance of about 325 mi.) we include grower dummy variables and grower-variety interaction variables to account for soil and microclimate effects. The grower dummy will also reflect any differences in grower management ability that affect tomato quality.

Increasing NTSS comes at the expense of yield, making NTSS the most expensive quality to deliver.³ If the contract incentives are sufficiently large, we expect that grower effort will increase NTSS. Thus, we expect a negative coefficient on the dummy variable for no-contract (Testable Hypothesis 1). Accordingly, we specify the following equation,

$$\begin{aligned} NTSS = & \beta_1 + \beta_{NC}NC + \beta_{LATE}LATE \\ & + \sum_{i=1}^I \beta_{V_i}V_i + \sum_{j=1}^J \beta_{WY_j}WY_j \\ & + \sum_{k=1}^K \beta_{g_k}g_k + \sum_{k=1}^K \sum_{m_k=1}^{M_k} \beta_{g_k V_{k,m_k}} g_k V_{k,m_k} + \varepsilon_{NTSS}, \end{aligned}$$

where β_1 is the intercept; NC is the dummy variable for no-contract, with a predicted negative sign; $LATE$ is the dummy variable for a contract load eligible for the late-season premium, with an indeterminate predicted sign; V_i denotes the variety dummy variable for the i th variety; WY_j denotes the dummy variable for the j th week-year period; g_k denotes the dummy variable for the k th grower; and $g_k V_{k,m_k}$ denotes the dummy variable for the interaction between the k th grower and the m_k th variety of the $M_k \leq I$ varieties produced by that grower. ε_{NTSS} is the error term.

³ Unfortunately, because of the lack of yield data, we cannot directly include this consideration.

The percentage of bad tomatoes depends on grower skill and weather but is ultimately determined by grower sorting decisions. Because the percentage of greens, MOT, LU, and mold are all determined by grower sorting decisions, we choose to model the overall percentage of bad tomatoes, rather than separately model each attribute. Greens and MOT are largely determined by grower sorting effort because the mechanical sorter is very effective at removing these tomatoes. Hotter weather at harvest time tends to increase the share of LU tomatoes and rains tend to increase the share of moldy tomatoes. We include week-year dummy variables to account for these weather effects. The late-season variable, $LATE$, might include some of the effects of cooler and rainier September and October harvesting weather, which will decrease the share of LU tomatoes and increase the share of moldy tomatoes. Even with adverse weather that increases the share of LU and moldy tomatoes, the grower can increase sorting effort in response. Because ultimately, the percentage of bad tomatoes is determined by grower sorting effort, $LATE$ will also include the effect of the late-season premium, which we predict will increase the share of bad tomatoes (Testable Hypothesis 5), so that the predicted sign is positive. We include grower, variety, and grower-variety dummy variables for the same reasons as above: microclimate, soil, innate ability, and variety differences. We predict a positive coefficient on the no-contract variable, NC (Testable Hypothesis 2). The estimated equation is

$$\begin{aligned} BAD = & \beta_2 + \beta_{NC}NC + \beta_{LATE}LATE \\ & + \sum_{i=1}^I \beta_{V_i}V_i + \sum_{j=1}^J \beta_{WY_j}WY_j \\ & + \sum_{k=1}^K \beta_{g_k}g_k \\ & + \sum_{k=1}^K \sum_{m_k=1}^{M_k} \beta_{g_k V_{k,m_k}} g_k V_{k,m_k} + \varepsilon_{BAD}, \end{aligned}$$

where β_2 is the intercept and ε_{BAD} is the error term.

Besides examining direct quality outcomes, we also model the overall quality outcome as measured first by per ton net incentives (including both weight deductions and price premiums) for the year in which the load was delivered. The per ton net incentives are equal to the quality incentive payments on the tons remaining, after weight deductions are taken into account, minus the base price multiplied by the weight deducted. Although the no-contract tomatoes are not eligible for price premiums but do face weight deductions, for this regression, we calculate what their price premium would have been to be able to compare the total quality of no-contract tomatoes to contract tomatoes.⁹ High-quality loads will have a positive net incentive because they will receive price premiums and few weight deductions, whereas low-quality loads will have negative net incentives because they will not receive price premiums and face weight deductions.

The net incentives will be determined by the overall quality delivered and the monetary incentives. The overall quality delivered is determined by the tomato variety, weather, time of season, grower practices, and contract terms. Thus, as with the regressions explaining direct quality outcomes, we include tomato variety dummies, week-year dummies, grower dummies, grower-variety dummies, a contract late-season dummy, and a no-contract dummy. We predict a negative coefficient on *NC* (Testable Hypothesis 3) and a negative coefficient on *LATE* (Testable Hypothesis 6). The estimated equation is

$$\begin{aligned} \text{NETINC} = & \beta_3 + \beta_{\text{NC}} \text{NC} + \beta_{\text{LATE}} \text{LATE} \\ & + \sum_{i=2}^I \beta_V V_i + \sum_{j=2}^J \beta_{WY} WY_j \\ & + \sum_{k=2}^K \beta_G G_k \\ & + \sum_{k=1}^K \sum_{m_k=2}^{M_k} \beta_{GV} G_{k,m_k} \\ & + \varepsilon_{\text{NETINC}}. \end{aligned}$$

⁹If we had not done so, then a no-contract load would, by definition, have a lower net incentive value than would an identical contract load.

where β_3 is the intercept and $\varepsilon_{\text{NETINC}}$ is the error term.

Our second measure of overall quality is composed of only the price premiums per postweight deductions ton. Accordingly, in this model, we exclude the no-contract tomato loads, because they are not eligible for price premiums, and focus on testing for any significant quality difference between late-season and regular-season tomatoes. Only those loads with high-quality tomatoes will receive price premiums, whereas loads with low-quality tomatoes will not receive premiums. As with net incentives, the overall quality delivered is determined by the tomato variety, weather, time of season, grower practices, and contract terms. Thus, as with the regressions explaining direct quality outcomes, we include tomato variety dummies, week-year dummies, grower dummies, grower-variety dummies, a contract late-season dummy, and a no-contract dummy. We predict a negative coefficient on *LATE* (Testable Hypothesis 6). The estimated equation is

$$\begin{aligned} \text{PRICEPREM} = & \beta_4 + \beta_{\text{LATE}} \text{LATE} \\ & + \sum_{i=2}^I \beta_V V_i + \sum_{j=2}^J \beta_{WY} WY_j \\ & + \sum_{k=2}^K \beta_G G_k + \sum_{k=1}^K \sum_{m_k=2}^{M_k} \beta_{GV} G_{k,m_k} \\ & + \varepsilon_{\text{PRICEPREM}}, \end{aligned}$$

where β_4 is the intercept and $\varepsilon_{\text{PRICEPREM}}$ is the error term.

Data

Our dataset contains quality information on all the tomatoes delivered to one processing plant by a set of 14 growers. All of the growers in the dataset delivered tomatoes both under an incentive contract, with price rewards and punishments on the basis of quality, and for a fixed price. All tomatoes, both contract and no-contract, are subject to the same weight deductions for low-quality tomatoes. Tomatoes delivered in contractually indicated, year-specific weeks under incentive contracts re-

ceived a late-season bonus. The data covers 4 years of tomato deliveries, from 1994 to 1997, on a load basis, for a total of 32,994 loads in 765 distinct grower-variety-year-week categories. Contract loads accounted for 97% of our observations. Of the contract loads, 83% were delivered during the regular season. For each load of tomatoes, the dataset contains information on the seven state-graded quality attributes,¹⁰ the date and time of harvest, the tomato variety, the grower, and whether the load was delivered under an incentive contract or for a fixed price. All contract tomatoes delivered in a given year were delivered under the same contract. Contract provisions, including the base price, the late-season premium, and the price premium schedule, vary across years.

Table 2 reports mean, median, maximum, and minimum values for the five quality variables separately and the percentage of bad tomatoes in total and the weight deduction schedule $w(q)$ for the five quality variables. Comparing the weight deduction schedule with the values, it is clear that sometimes quality is high enough that no weight is deducted. Notably, the median load of tomatoes contained 0% MOT and 1% LU and would not face weight deductions for these quality attributes.

Another way to compare quality across categories is to consider average weight deductions for all quality attributes per load. No-contract tomatoes are of lower quality than contract tomatoes, and late-season contract tomatoes are of lower quality than regular-season contract tomatoes; the median weight deduction for regular-season contract tomatoes is 2%, compared with 2.5% for late-season contract tomatoes and 3% for no-contract tomatoes.

¹⁰We do not analyze the worm damage category because less than 1% of the loads contained worm damage. We do not analyze the color score because the incentive contracts do not specify marginal incentives for color and there are no weight adjustments for color. Furthermore, industry sources say that tomato loads are never rejected because of color because the processor can mix tomato loads, paste batches, or both to achieve an acceptable color.

Table 3 provides measures of the importance of price incentives for quality as a percentage of the base price per ton. It reports the average, minimum, and maximum price incentive earned at the mean level of each quality attribute as reported in Table 2 and the average, minimum, and maximum price incentive earned for the highest quality reported in Table 2 (this is the maximum value for NTSS and the minimum value for all the other attributes). Clearly, the price incentives are largest for NTSS, followed by LU, MOT, and, lastly, mold. Meanwhile, the incentives for greens are purely second-order through the weight deductions. Although these percentages might appear small in absolute terms, the 3% of price due to incentives for quality could have a substantial effect on grower profits. During our sample period, a 3% increase in price from the specified base price could mean the difference between a profit and a loss for a grower with the statewide average yield and costs represented by the 1997 University of California Extension Service Yolo County processing tomato budget (Miyao, Klonsky, and Livingston). For a load of top-quality tomatoes, price incentives are equal to about 20%–25% of the base price per harvested ton in each year and are extremely profitable.

Late-season premiums are paid to standard contract growers delivering in specified weeks for each delivered ton. Late-season premiums equal approximately 10%–20% of the base price per harvested ton, depending on the year and with higher premiums for later delivery.

Our dataset has several methodological advantages. For each grower, we have information on tomato quality for tomatoes delivered under a quality incentive contract and for tomatoes delivered for a fixed price. Thus, we are able to separate responses to incentives from the choice of a contract and control for grower-specific effects. Our data represent the complete population of all tomatoes delivered to a processor by a group of growers over a 4-year period. In this respect, and in its avoidance of simultaneity and endogeneity problems, it resembles the dataset used by Lemmon, Schallheim, and

Table 2. Summary Statistics on Quality Attributes of Delivered Tomatoes and Weight Deductions

Quality Attribute	Sample Quality				Weight Deduction Schedule
	Mean	Median	Minimum	Maximum	
NTSS	5.1	5.1	3.0	7.4	None
LU	1.7	1.0	0	31.5	1× -5% for 5.5%-8.0% 1.5× -7.5% for 8.5%-11% 2× -10% for 11.5%+
Greens	0.6	1.0	0	4.5	1× for 0%-2%, 2× for 2.5%-4% Reject at 4.5%+
MOT	0.2	0	0	3.0	Year 1: 1× for 0%-1%, 3× for >1% Years 2-4: 1× for 0%-0.5%, 3× for >0.5%
Mold	1.3	0.5	0	8.0	1×
Bad	3.8	3.5	0	35.5	—

Zender to analyze fund manager compensation, which has perhaps the fewest data-based analytical problems among existing studies.

One potential concern is that our findings here might be driven by postcontracting opportunism. That is, within our sample, growers might be responding to incentives by assigning a load of tomatoes to the incentive contract or the fixed price contract after grading because each grower has both types of contracts. Although theoretically legitimate, this possibility is unlikely because of the parameters of the contract. The contract specifies the tomato varieties and requires the grower to arrange for delivery of contract tomatoes the day before harvest. The possibility for postharvest sorting is further limited by our data: only 7.6% of the no-contract tomato loads were of the same variety and delivered by growers on the same day as the contract tomatoes.

Although our theoretical model does not allow for cost differences between regular- and

late-season tomatoes, interviews with industry members suggest that it is riskier to produce tomato quality during the late season because of the possibility of rain. If it rains, then tomatoes are susceptible to mold damage, which could make it costlier to harvest, or, in the worst case, the crop would be a total loss. Because growers are presumed to equate marginal revenue and marginal cost, any such cost differences imply that simply comparing returns will understate the difference between standard and late-season contracts, so that the late-season contract would result in a relatively larger quality decline.

Results

Our dataset is an unbalanced panel; we have repeated observations on 14 growers but each grower delivered a different number of loads. In order to have standard errors that are robust to the unequal variance-covariance matrix that results from an unbalanced panel,

Table 3. Price Incentives as Percentage of Base Price across Annual Contracts

Quality Attribute	N	Price Incentive at Mean Sample Quality (%)			Price Incentive for Maximum Quality (%)		
		Mean	Minimum	Maximum	Mean	Minimum	Maximum
NTSS	4	1.0	-3	7.3	12.5	6.2	18.3
LU	3	1.0	0.8	1.2	2.1	1.7	2.5
Greens	0	—	—	—	—	—	—
MOT	3	0.7	0.5	1.0	0.7	0.5	1.0
Mold	1	0.3	—	—	0.5	—	—

Table 4. Fixed Effects Models: Selected Estimated Coefficients for Each Regression* by Dependent Variable

Variable	Estimated Coefficient (SE)			
	<i>NTSS</i>	<i>BAD</i>	<i>NETINC</i>	<i>PRICEPREM</i>
Intercept	5.0158** (0.5644)	2.8679** (0.2701)	-0.00013 (0.00012)	0.00085** (0.00012)
<i>NC</i>	0.1596** (0.0271)	0.6453** (0.1260)	-0.00007 (0.00007)	—
<i>LATE</i>	0.0833** (0.0304)	0.5817** (0.1259)	-0.00024** (0.00008)	-0.00020* (0.00009)
Overall R^2	0.11	0.13	0.16	0.23
Observations	32,994	32,994	32,988	32,004

* Coefficients for variety dummies, grower-variety dummies, and year-week dummies are not reported for reasons of space. Complete results are available on request from the authors.

*Significant at the 95% level of confidence.

**Significant at the 99% level of confidence.

we used the *xtreg* procedure in Stata 9.0 for a fixed effects model with robust standard errors. Table 4 reports selected coefficients for the four regressions. (Complete results are available from the authors on request.) Overall, our econometric results indicate that growers do respond to quality incentives, although not all coefficients conform to our predictions.

NTSS

For the equation with *NTSS* as the dependent variable, the coefficient on *NC* was positive and significant. This contradicts Testable Hypothesis 1 obtained from our theoretical analysis. Recall that in our development of the empirical model, the predicted sign on *LATE* was indeterminate because of the opposing influence of biological factors: *NTSS* increases later in the season. Given that the price premium for *NTSS* is much larger than any other quality attribute, or even than all the other attributes combined, this result suggests that biological factors dominate contractual incentives; that is, growers' reactions to the *NTSS* incentives have a smaller effect on *NTSS* than the biological effect of delivering during the late season (*LATE*). Although not all no-contract tomatoes were in the official late-season window, they were mostly delivered in the latter two thirds of the harvest season. This explanation is further supported

by the positive and significant coefficients for contract late-season tomatoes.

BAD

The coefficient on the no-contract dummy was positive and significant; no-contract loads statistically have a larger share of bad tomatoes. For *BAD*, we reject the null hypothesis that growers do not respond to contract incentives in favor of Testable Hypothesis 2. The coefficient on the contract late-season dummy was positive and significant. The sign is consistent with the hypothesis that the late-season premium reduces the effects of other contract incentives on grower behavior. Compared with the *NTSS* regression, the coefficients for both no-contract loads and late-season loads in the *BAD* regression are much larger, roughly four and seven times the magnitude, respectively. This suggests that growers are more responsive to the incentives related to *BAD* tomatoes than the incentives related to *NTSS* despite the price incentives for *NTSS* being much larger than the price incentives to reduce *BAD* tomatoes, as shown in Table 3. The best explanation for this apparent inconsistency is that, although it is costly and difficult for growers to increase *NTSS*, the grower can easily deliver a lower percentage of *BAD* tomatoes by increasing sorting effort at harvest; therefore, a smaller premium is sufficient to incentivize

growers to deliver a low percentage of *BAD* tomatoes

NETINC

The coefficient on the no-contract dummy was negative but not significant; therefore, for *NETINC*, we fail to reject the null hypothesis that growers do not respond to contract incentives. The coefficient on the contract, late season dummy was negative and significant. For *NETINC*, we find in favor of Testable Hypothesis 6 that the late-season premium reduces the effects of other contract incentives on grower behavior.

PRICEPREM

The coefficient on the contract late-season dummy was negative and significant. For *PRICEPREM*, we find in favor of Testable Hypothesis 6 that the late-season premium reduces the effects of other contract incentives on grower behavior. Comparing the *NETINC* regression and the *PRICEPREM* regression, the coefficients on the late-season dummy are of roughly the same magnitude, which suggests that the late-season premium primarily reduces the grower's incentive to deliver high enough quality to receive the price premiums but does not reduce the grower's incentive to avoid weight deductions.

Other Explanatory Variables

Coefficients for variety dummies, grower-variety dummies, and year-week dummies are not reported in Table 4 because of space considerations. The primary value of the results regarding the coefficients for the dummy variables is that we are able to compare the share of dummy variables by type that are significant for each dependent variable and see whether the patterns are consistent with characteristics of processing tomato production. The share of the 29 variety dummies that is significant is much higher for *NTSS* (83%) than for *NETINC* (62%), *BAD* (55%), or *PRICEPREM* (43%). This is consistent with variety being a key

determinant of soluble solids, whereas grower sorting effort and weather are more important for other quality attributes. The share of the 51 year-week dummies that is significant is highest for *PRICEPREM* (90%), declines to 80% for *BAD*, declines to 76% for *NETINC*, and declines to 67% for *NTSS*. Because these dummies primarily capture the effects of weather at harvest and the length of the growing season, the results are neither consistent nor inconsistent with characteristics of processing tomato production. The share of the 121 grower-variety dummies that is significant is noticeably higher for *NTSS* (77%), *PRICEPREM* (73%), and *NETINC* (68%) than it is for *BAD* (60%). This is consistent with grower sorting effort, rather than management skill, being a critical determinant of the undesirable quality attribute aggregated in *BAD*.

Conclusion

Overall, given biological processes and the relative magnitude of differences in marginal incentives for no-contract and late-season tomatoes, our findings indicate that incentive contracts do affect production decisions for agricultural growers in the manner predicted by economic theory. Results were slightly more supportive for the late-season premium comparison to the standard contract than for the no-contract comparison to the standard contract. The nature of our dataset allows us to draw this conclusion in a relatively clean analytical environment, without confounding theoretical factors.

Implications for Agricultural Contract Design

Our analysis illustrates both the value and the limitation of econometric investigations of the effects of agricultural contracts on the contracting parties on the basis of contract outcome data. We were able to demonstrate that growers respond to sufficiently large price incentives and infer that they receive a net benefit from doing so because they did not respond to all price incentives. We were able to demonstrate that the processor received higher

quality tomatoes in loads eligible for price incentives. However, because of the nature of our data, we could not conclude from this result that the processor was better off offering price incentives than not contracting, or than offering a contract without price incentives. We can hypothesize that the processor would not offer these incentives unless it increased profits, but the results regarding NTSS suggest that offering this incentive does not improve profits, because it does not improve quality. Hence, there is the possibility that the processor is not acting optimally, as well as the possibility that our analysis was simply unable to identify an incentive effect on the basis of our methodology and data. Given this limitation, our analysis provides three specific lessons regarding agricultural contract design.

First, to maximize returns from a contract with growers, a processor must consider the technical relationships governing the production of the product attributes valued and the cost of producing those attributes. In our case, growers responded to relatively small price incentives for reducing the share of undesirable attributes (*BAD*). For NTSS, the price incentive was insufficient to improve quality. Indeed, having a contract had a statistically significant negative effect on NTSS.

Second, the processor must pay careful attention to the relative importance of price incentives to growers' total price per delivered unit. The level of the base price, as represented by a late-season premium, increased the share of *BAD* tomatoes, and reduced overall quality as measured by both net incentives (*NETINC*) and price premiums (*PRICEPREM*).

The case of NTSS provides a third lesson regarding the design of agricultural contracts: price incentives might not always be the most efficient means of inducing growers to provide desired quality attributes. The statistical significance of the negative effect of having a contract on NTSS is likely due to the majority of noncontract tomatoes being delivered later in the season when NTSS is naturally higher. On the basis of information regarding the processing tomato industry from interviews and other sources, we hypothesize that the yield reduction needed to increase

NTSS significantly reduced revenues, so that contract incentives did not induce growers to increase NTSS. Given that the price incentives are already high relative to those for other attributes, processors might want to consider alternative means of increasing NTSS content, such as including production practice requirements in contracts and monitoring compliance when scouting fields during the season.

[Received September 2004; Accepted July 2006.]

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