Mitigating Contractual Hazards: Short-term vs. Long-term Contracting in Animal Agriculture

Pierre Dubois

Toulouse School of Economics

21 Allée de Brienne, F-31000 Toulouse

E-mail: pierre.dubois@toulouse.inra.fr

and

Tomislav Vukina

North Carolina State University

Department of Agricultural and Resource Economics

Raleigh, NC 27695-8109

Phone: 919-515-5864; E-mail: tom_vukina@ncsu.edu

Contributed Paper prepared for presentation at the International Association of Agricultural Economists Conference, Beijing, China, August 16-22, 2009

1. Introduction

The production contracts between integrator firms (principals) and independent farmers (agents) in most agricultural settings (e.g., chickens, hogs, tobacco) are governed by short term clauses, i.e. at the end of one production cycle the contract is tacitly renewed unless explicitly canceled. The most recent innovations in contract form shows that some firms converted their short-term contracts into long-term ones. One example of such conversion comes from the contracts for the production of hatching eggs which constitutes an early stage in the production of broiler chickens.

The objective of this research is to empirically measure the effects of the contract switch on agents' behavior. We hypothesize that changing a production contract from short-term to long-term should alleviate the hold-up problem with a measurable impact on agents' performance across various productivity margins.

Economic relationships where hold-up may occur are characterized by the existence of rents to continuing an existing relationship (because of turnover cost of asset specificity) that are available to parties to bargain over, by the significant problems of writing contracts contingent on all important future events, and by the fact that all contracts can be renegotiable by mutual consent (Malcomson, 1997). The literature on hold-up originated within the transaction costs (rent-seeking) theory and its objectives to explain the organization of firms (Coase, 1937; Williamson, 1985). More recently, a closely related and more formal theory of vertical integration emerged in the works of Grossman and Hart (1986), Hart and Moore (1990), and Hart (1995). Like the transactions cost approach, the so called property rights (incomplete contracting) theory takes the incompleteness of contracts and existence of ex-post quasi rents as critical to understanding hold-up. The incomplete contracts theory then focuses on how ownership of physical assets, which confers residual rights of control over these assets, alters the efficiency of trading relationships (Whinston, 2003, p.2). From the perspective of the hold-up problem, the main point that distinguishes the incomplete contract theory from its predecessor seems to be its explicit focus on distortions in ex-ante investments, in contrast to maladaptation in the contract execution phase emphasized in the transaction cost economics.

Switching from a short-term to a long-term contract would therefore, depending on the useful life of the investment, either completely eliminate or substantially mitigate the under-investment problem. This phenomenon should be reflected in an increased investments in productivity enhancing technologies and practices that would improve agents' productivity and hence payoffs but whose voluntary adoption was hindered by the fear of the principal's opportunistic behavior whenever a short-term contract would be up for renewal. This effect is likely to be welfare enhancing for both parties to the contract.

The obtained results are pretty much in line with the received theory. Using an un-balanced panel of contract settlement data for the production of hatching eggs from one company that contracts the production with 68 growers divided in 2 divisions we show that switching from a short-term to a long-term contract alleviated the hold-up problem and resulted in faster adoption of both observable and unobservable productivity enhancing technologies and practices that improved performance across various performance margins.

2. The Comparison of Contract Forms

The production of broiler chickens involves three stages: raising broiler breeder males (cockerels) and hens (pullets), housing the mature breeding flock for the production of hatching eggs, and the production (grow-out) of commercial broilers. Various stages of broiler production are typically covered by different contracts and farmers generally specialize in one production stage under one contract. Our analysis is based on the individual contract settlements for the production of hatching eggs in two production divisions owned by the same company in the period from 1992 to 2003. There are 68 contract growers in the data set and 498 flocks. Approximately in the middle of that period, the company decided to change the contract duration. The new contract became effective for all flocks delivered on or after January 1, 1997. Compared to the old contract which was a flock-by-flock contract, the new contract is written for the period of 15 years.

The division of responsibilities for providing inputs in the production of hatching eggs between the old and the new contract remained unchanged. In both contracts the principal's responsibility is to supply breeder chickens, feed, litter, medication and technical instruction. Agents' responsibilities are to provide proper care and maintenance of flocks, housing, equipment, and other facilities necessary to gather, grade and maintain hatching eggs.

The payment mechanism in both contracts is some variant of the variable piece rates. The payment mechanism in the old contract consists of the finishing fee, piece rates for the hatching eggs and commercial eggs, the hatchability bonus and the feed conversion bonus. Over the years (see Table 1) the payment mechanism has been amended multiple times, such that the last version of the old contract prior to the introduction of the new contract has the same payment mechanism as the one used in the new long-term contract.

The payment mechanism in the new contract has the identical finishing fee (2.5 cents per chicken per week until the birds are 25 weeks of age) and the identical piece rate for commercial eggs (9 cents per dozen) as the old contract. These two elements of the payment scheme have not changed during the analyzed 12-year interval. However, the piece rate for hatching eggs has been changed multiple times from as low as 27 cents per dozen hatching eggs at the end of 1991 to 32 cents base rate in January of 2000 when the last correction to the payment scheme took place. In addition, the contract has two types of equipment bonuses: 2 cents per dozen of hatching eggs (introduced in January 1993) if a grower installs male feeders and high profile grills and 2 cents per dozen of hatching eggs (introduced in April 1995, subsequently raised to 3 cents in March 1998) if a grower installs cool cells. Starting in July 1996, the contract begins to officially distinguish the "in-season" and the "out-of-season" flocks in the sense that the out-of-season flocks receive an additional 1 cent per dozen hatching eggs premium. The out-of-season flocks are flocks that were placed on a pullet farm during the months of November, December, January or February. Adding the equipment and out-of-season premiums, the composite piece rate for hatching eggs in 2000 for growers with installed male feeders and cool cells was 37 cents per dozen hatching eggs (32+2+3) for in-season flocks and 38 cents (32+1+2+3) for the out-of-season flocks.

Both contracts have the hatchability and feed conversion bonuses but their specifications also changed multiple times over the years. In the early versions of the old contract the hatchability bonus was symmetric around 85% hatchability, with the bonus/penalty in the amount of 0.5 cents per dozen hatching eggs for each percent deviation from 85%. This formula remained intact for the in-season flocks until January 2000 when the benchmark was lowered to 84% and the rate was increased to 1 cent per dozen hatching eggs. However, beginning with pullets started on November 1, 1992, the formula for the out-of-season flocks changed such that each percent hatchability above 85% carried a bonus of 0.5 cents per dozen hatching eggs, whereas the penalty in the same amount was imposed only for each percent hatchability below 83%. In January 2000, the 83-85% range benchmark hatchability was lowered to 82-84% and the rate was raised from 0.5 cent to 1 cent per dozen hatching eggs.

Prior to July 1996, the feed conversion bonus was symmetric around 7.5 pounds of feed per dozen hatching eggs, with the bonus/penalty in the amount of 4 cents per dozen hatching eggs for each pound deviation from 7.5 pounds. Since then, the feed conversion bonus remained symmetric around 7.5 pounds for the in-season flocks and around 7.75 pounds for the out-of-season flocks. In 2000, the benchmark feed conversion ratios were raised to 7.75 for in-season flocks and 8.00 for out-of-season flocks. For the purposes of calculating bonuses, the individual grower feed conversion ratios and hatchability are always calculated for flocks to 65 weeks of age. If the integrator decides to keep the flocks beyond the 65 weeks of age, the feed conversion and hatchability beyond 65 weeks of age are ignored. In both old and new contracts the aggregate bonus, i.e., the sum of the hatchability and feed conversion bonuses, cannot be negative. If the sum turns out to be negative, there is always a truncation at zero.

Finally, according to the new contract, the decisions about the number of flocks the grower will receive, the number of pullets and cockerels included in each flock, the time of removing each flock, and the date, time and interval of placement for any future flocks remained under the sole discretion of the company. In this regard, from the grower's perspective, the immediate material consequence of the contract switch also appears to be minimal. In fact, based on the available 12-year records (1992-2003), the behavior of the integrator regarding the frequency of the delivery of flocks to growers is the same before and after the switch. Each grower received approximately one flock per year and those growers for which the time-out period was unusually long were awarded an extra payment to compensate them for the loss of income.

3. Hypothesis Testing

Based on the received theory we formulate and empirically test our main hypothesis that switching from a short-term to a long-term contract causes productivity gains resulting from an apparent solution to the hold-up problem. In particular, switching from a flock-by-flock contract to a 15-year contract increases the investments in both observable and hence contractible and unobservable and hence non-contractible investments that improve grower performance across various productivity margins.

3.1. Technology Adoption

There are two technological improvements that growers could have adopted to earn equipment and performance bonuses. These are male feeders and cool cells, both of which would automatically earn equipment bonuses and improve the feed conversion ratios and the hatchability of eggs thereby improving chances to earn performance bonuses. The adoption rates exhibit stark differences. Prior to the introduction of the new contract in January 1997, 88.5% of the flocks were already grown with male feeders, whereas only 9.6% of the flocks were grown with cool cells. Two factors can explain the difference. First, the equipment bonus for male feeders and high profile grills was introduced 2 years earlier (January 1993) than the equipment bonus for cools cells (April 1995), so it is reasonable to expect earlier adoption of male feeders than cool cells. Secondly, installing cool cells represents substantially larger investment, so it is not surprising that the more rapid adoption of cool cells followed the introduction of the new long-term contract which gave contract growers some security against abrupt termination.

A formal way of capturing the effect of the contract switch on the technology adoption is to run simple probit regressions. The results, summarized in Table 2, clearly show that the indicator variable for the contract switch labeled *long_term*, specified to be equal 1 if the year is greater or equal 1997 and 0 otherwise, is positive and significant in both regressions. Changing the contract from short-term to long-term increased the probability of technology adoption for both cool cells and male feeders. This is true even after we include the individual yearly dummies that are picking up other unspecified changes in the incentive structure of the contract, technology, quality of inputs, etc.

The other two explanatory variables of interest are the division indicator and the size of the facility. The results show that the probability of technology adoption is larger in division *M* then in division *H*. This is in line with other results showing consistently superior performance of growers in division M. The expected sign of the size variable is positive as we were expecting to see higher probability of adoption with larger housing facilities. As it turned out, *square footage* has the correct positive sign, however, the parameter is not significantly different from zero.

3.2.Pure Effort Effect

The fact that the last version of the old contract has the same payment mechanism as the new long-term contract enables us to identify the effects of the contract length on growers' performance. This is accomplished by specifying another indicator variable labeled *period* which equals 1 for the period during which none of the contract parameters have changed (7/1/1996 - 3/1/1998) and 0 elsewhere and then multiplying that variable with previously defined variable *long_term*. The product of the two indicator variables gives new indicator variable, labeled *period_long_term*, which captures the effect of the change in contract length net of influences caused by changing other contract parameters.

The empirical strategy that we implemented consists of two steps. In the first step we estimate the performance equations without the technology adoption variables. In the second step we include the technology adoption variable (cool cells) to evaluate its impact on the magnitude and the statistical significance of the *period_long_term* coefficient. The idea is that if switching the contract from short-term to long-term impacted the grower performance only via the investment in the observable productivity enhancing technology, then we should see the magnitude and/or statistical significance of the *period_long_term* coefficient deteriorate. If this does not happened, then we would conclude that in addition to expediting the observable investments, the contract switch also solved the hold-up problem by stimulating the unobservable and hence non-contractible investments.

The analysis is carried out using three groups of performance measures: the number of eggs produced (hatching eggs and total eggs), the hatchability of eggs, and the feed conversion ratios. In the first group we look at 4 indicators: the number (in dozens) of hatching eggs per hen (*ratio*), the number of hatching eggs per square foot (*ratio1*), the total number of eggs (hatching plus commercial) per hen (*ratio2*), and the total number of eggs per square foot (*ratio3*). The second group of performance indicators deals with the hatchability of eggs. Here we use three performance indicators: the number of hatching eggs that actually hatched (*hateg*), the number of hatching eggs that hatched per hen (*ht*), and the number of hatching eggs that hatched per square foot of the chicken house (*htsqft*). Finally, we look at feed conversion ratios. In this group we use two performance indicators: total feed conversion (*fc_total*) and feed conversion for hatching eggs (*fc_hatching*). Feed conversion is defined as pounds of feed used to produce one dozen eggs.

The OLS results are presented in the first four columns of Table 3. The results are virtually identical across different performance measures. The most important point to make is that the *period_long_term* coefficient is positive and significant, which means that the clean impact of switching from a flock-by-flock to a 15-year contract on grower productivity is positive. At the same time the *long_term* coefficient is also positive and significant for two performance variables measuring total eggs production (*ratio1* and *ratio3*) but negative for the remaining two performance variables measuring hatching eggs production. This result is likely due to the change in the breed of chickens. Starting in 1998, the company started changing the dominant breed from a Peterson male and Arbor Acre female to a Ross male and a Ross female. The change has been made to improve the feed conversion and processing yield of broilers, but the egg production and hatchability suffered especially if the hen house environment was not properly controlled, as the Ross males and females are more susceptible to heat stress than the old breeds. It appears that the introduction of the new breed that began in 1998 could have reversed the productivity gains achieved by the contract switch.

The next set of results deal with the hatchability of hatching eggs. In addition to the explanatory variables used before, we included two dummy variables capturing the announced changes in hatchability bonuses. Referring to Table 1, one can see that the hatchability bonus has been changed twice during the period covered by the data. The variable *hd1* assumes the value of 1 for all dates larger than or equal to the date of the first change and 0 elsewhere, and *hd2* is defined similarly for the second change in the hatchability bonus. The first change is impossible to evaluate since we don't know what this bonus was prior to this change because it occurred outside our data range. The second change is characterized by an increase in the rate from half a cent to 1 cent and the hatchability target was lowered, so this change should generate positive incentives to exert effort. However, the change was most likely made to offset the negative impact on hatchability associated with the switch to a new breed of birds. The main results are pretty much in line with the previous findings. The *period_long_term* variable is positive and significant in all three cases confirming the positive impact of the contract switch on productivity. However, the *long_term* variable is now always negative and significant in 2 out of 3 models, indicating that the breed change most definitely had negative impact on the hatchability of eggs.

The last two models in columns (8) and (9) of Table 3 deal with the feed conversion ratios. Again, the main results are identical to the ones obtained before. The coefficients on *period_long_term* are this time negative and significant because lower feed utilization per dozen eggs means better performance. The *long_term* coefficients are not significant meaning that, most likely, the positive effects of the contract switch and negative consequences of the breed change approximately cancel each other out. The first change in the feed conversion bonus is captured by dummy variable *fcd1* and the second change with *fcd2*. The definition of these variables mimics the definition of the hatchability bonus variables (see Table 1 for exact dates). The impact of the first change on grower incentives to work hard cannot be evaluated because we don't know what that bonus was before the change. The impact of the second change is most likely negative because the rate stayed the same (plus or minus 4 cents per dozen eggs per each percent outside the target feed conversion rate) but the target feed conversion was increased so it now became easier to earn the bonus (or avoid the penalty) than under the old rules. The first bonus change dummies are insignificant in both models, but the second are positive and statistically significant. Therefore, the result is in line with our expectations, indicating that increasing the feed conversion ratio target dulled the incentives to exert effort and in fact feed conversion deteriorated (increased).

3.3.Non-contractible Investments

The second step in the estimation procedure is based on the working hypothesis that all improvements in grower productivity come from the adoption of observable technological improvements such as male feeders or cool cells. The decisions to adopt these new technologies are clearly endogenous. Different growers, depending on their idiosyncracies, will have different incentives towards technology adoption. To deal with the endogeneity of technology adoption, we exploit the panel nature of the data set and estimate our models with grower fixed effects. The specification of all models stayed essentially the same as before, the only difference being the inclusion of the indicator variable *cool* which assumes the value of 1 if the flock was grown under the cool cells environment and 0 if not. The dummy variable for male feeders was not used, because at the time of the contract change virtually all growers have already adopted this inexpensive technology. The only other difference relative to the previous specification is the omission of the division indicator (*M*), which becomes redundant with grower fixed effects. The results are presented in Table 4.

The obtained results are surprisingly consistent across all 9 models. Several interesting findings are worth pointing out. First, we see that *period_long_term* is always positive and most of the time significant at 1% which convincingly shows that switching the contract duration from a short-term to long-term contract had positive impact on productivity. Secondly, the technology adoption variable *cool* is positive and significant in 7 out of 9 models indicating a positive impact of technology adoption on productivity. In the remaining two cases, which are both feed conversion models, *cool* is insignificant (and also has the wrong sign). It looks like cool cells do not significantly improve feed conversion over and above what male feeders do. Thirdly, in contrast to our original belief that the entire gain in productivity came about via the cool cells adoption, this result seems to be indicating that switching the contract from short-term to long-term also solved the hold-up (under-investment) problem by stimulating growers to carry out some other unobservable and hence non-contractible investments which turn out to be complementary with the cool cells technology. This conclusion is supported by the results showing that in all 9 specifications, the magnitude of the *period_long_term* coefficient after the inclusion of the cool variable is larger (Table 4) than before (Table 3).

Finally, notice that the *long_term* variable is now almost always negative and statistically significant. The exceptions to this general result are the two feed conversion equations. This result seems to be proving our earlier conjecture that the positive productivity impacts of the contract change were subsequently wiped out by the introduction of Ross breed birds which perform worse when it comes to egg production and hatchability (especially in hot weather) but hatched chicks would subsequently become superior broilers.

4. Conclusions

In this paper we present the results of a natural experiment where a poultry company that contract the production of hatching eggs with independent growers converted their short-term contract into a long-term contract. The nature of the change in contract parameters enabled us to isolate the effect of the change in contract length from other changes in contract parameters on agents' incentives to perform. Using contract settlement data we showed that switching from a short-term to a long-term contract alleviated the hold-up problem and resulted in increased investments in productivity enhancing technologies and practices which improved performance across all productivity margins.

References:

Coase, R., “The Nature of the Firm." Economica, 4 (1937): 386-405.

Grossman, S. and O. Hart, The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration." Journal of Political Economy, 94 (1986): 691-719.

Hart, O., “Firms, Contracts and Financial Structure.” Oxford, U.K.: Oxford University Press, 1995.

Hart O. and J. Moore, “Property Rights and the Nature of the Firm." Journal of Political Economy, 98 (1990): 1119-1158.

Malcomson, J.M., “Contracts, Hold-Up, and Labor Markets.” Journal of Economic Literature, 35 (1997): 1916-1957.

Whinston, M.D., “On the Transaction Cost Determinants of Vertical Integration." The Journal of Law, Economics and Organization, 19 (2003): 1-23.

Williamson, O.E., “The Economic Institutions of Capitalism: Firms, Markets, Relational Contracting.” New York: Free Press, 1985.

Table 1: Payment Schedule Changes

Date	Base Price Hatching Eggs		Approved Male Feeders	Cool Cell	Total Hatching Egg Pay		Commercial Egg Pay	Hatchability Bonus Benchmark		Hatchability Bonus Rate	Feed Conversion Bonus		Feed Conversion Rate
	In	Out			In	Out		In	Out		In	Out	
12/31/1991	0.27				0.27		0.09						
11/1/1992	for pullets started on							85%	83-85%	0.005			
1/30/1993	0.28		0.02		0.30		0.09						
2/19/1994	0.29		0.02		0.31		0.09						
4/29/1995	0.30		0.02	0.02	0.34		0.09						
7/1/1996	0.30	0.31	0.02	0.02	0.34	0.35	0.09				7.5	7.75	0.04
2/1/1997	New long-term (15 years) contract introduced.												
3/1/1998	0.30	0.31	0.02	0.03	0.35	0.36	0.09						
5/25/1998	0.31	0.32	0.02	0.03	0.36	0.37	0.09						
1/1/2000	0.32	0.33	0.02	0.03	0.37	0.38	0.09	84%	82-84%	0.01	7.75	8.00	0.04

Table 2: Technology Adoption Results (Probit Regression)

Cool Cells

Number of observations = 427
LR chi2(10) = 177.91 Prob > chi2 = 0.0000
Log likelihood = -199.28809 Pseudo R2 = 0.3086

	Coef.	Std. Error	z	P>|z|	95% Conf. Interval	
long_term	6.991878	0.4759001	14.69	0.000	6.059131	7.924625
M	0.6837308	0.1500295	4.56	0.000	0.389678	0.9777833
square_foot	7.21E-06	9.18E-06	0.79	0.432	-1.08E-05	0.0000252
_Iyear_1995	4.321457	.	.	.	.	.
_Iyear_1996	5.065826	0.5022111	10.09	0.000	4.08151	6.050141
_Iyear_1997	-1.700029	0.2961899	-5.74	0.000	-2.28055	-1.119507
_Iyear_1998	-1.049649	0.2648746	-3.96	0.000	-1.568794	-0.530505
_Iyear_1999	-0.462092	0.25683	-1.8	0.072	-0.965469	0.0412859
_Iyear_2000	-0.020377	0.2548659	-0.08	0.936	-0.519905	0.4791508
_Iyear_2002	0.1817008	0.2633776	0.69	0.490	-0.33451	0.6979115
_cons	-7.066497	0.5328992	-13.26	0.000	-8.110961	-6.022034

Male Feeders

Number of obs = 277
LR chi2(8) = 30.18 Prob > chi2 = 0.0002
Log likelihood = -97.483984 Pseudo R2 = 0.1340

	Coef.	Std. Error	z	P>|z|	95% Conf. Interval	
long_term	1.809001	0.7096581	2.55	0.011	0.418097	3.199905
m	0.6275569	0.2127911	2.95	0.003	0.210494	1.04462
square_foot	0.0000252	0.0000256	0.98	0.326	-0.000025	0.0000753
_Iyear_1993	0.4414272	0.6776929	0.65	0.515	-0.886826	1.769681
_Iyear_1994	0.8062322	0.6682783	1.21	0.228	-0.503569	2.116034
_Iyear_1995	1.140799	0.6714812	1.7	0.089	-0.17528	2.456878
_Iyear_1996	1.264637	0.6757938	1.87	0.061	-0.059894	2.589169
_Iyear_1997	-0.334171	0.4193151	-0.8	0.425	-1.156014	0.487671
_cons	-1.158838	1.071201	-1.08	0.279	-3.258354	0.9406768

Table 3: Performance Measures: OLS Results

	ratio	**ratio1**	**ratio2**	**ratio3**	**hateg**	**ht**	**htsqft**	**fc_total**	**fc_hatching**
m	**0.424**	**0.186**	**0.426**	**0.186**	**9,621.981**	**0.523**	**0.239**	**-0.182**	**-0.194**
	(0.081)**	(0.048)**	(0.082)**	(0.048)**	(1,394.187)**	(0.074)**	(0.043)**	(0.033)**	(0.034)**
long_term	**-0.212**	**0.208**	**-0.046**	**0.297**	**-8,580.872**	**-0.467**	**-0.019**	**-0.064**	**0.009**
	(0.097)*	(0.057)**	(0.098)	(0.058)**	(1,981.278)**	(0.105)**	(0.060)	(0.082)	(0.084)
period_long_term	**0.849**	**0.193**	**0.784**	**0.156**	**16,988.606**	**0.978**	**0.343**	**-0.218**	**-0.267**
	(0.134)**	(0.079)*	(0.135)**	(0.080)	(2,499.907)**	(0.134)**	(0.077)**	(0.061)**	(0.062)**
seas	**-0.152**	**-0.095**	**-0.263**	**-0.150**	**961.918**	**-0.029**	**-0.032**	**0.087**	**0.037**
	(0.087)	(0.052)	(0.088)**	(0.052)**	(1,494.500)	(0.080)	(0.046)	(0.035)*	(0.036)
days_prod	**0.044**	**0.020**	**0.046**	**0.021**	**606.445**	**0.033**	**0.015**		
	(0.004)**	(0.002)**	(0.004)**	(0.002)**	(68.548)**	(0.004)**	(0.002)**		
hens					**11.833**				
					(0.184)**				
fcd1								**-0.076**	**-0.064**
								(0.079)	(0.081)
fcd2								**0.100**	**0.097**
								(0.047)*	(0.048)*
constant	**1.151**	**0.842**	**0.973**	**0.766**	**-178,925.559**	**2.315**	**1.345**	**6.789**	**6.945**
	(1.138)	(0.674)	(1.154)	(0.681)	(20,506.584)**	(1.103)*	(0.633)*	(0.042)**	(0.043)**
hd1					**585.350**	**-0.034**	**0.025**		
					(4,623.385)	(0.249)	(0.143)		
hd2					**8,098.489**	**0.431**	**0.312**		
					(1,885.115)**	(0.101)**	(0.058)**		
Observations	498	498	498	498	498	498	498	498	498
R-squared	0.37	0.20	0.36	0.22	0.91	0.34	0.21	0.14	0.13

Standard errors in parentheses
* significant at 5%; ** significant at 1%

Table 4: Performance Mesures with Technology Adoption: Grower Fixed Effects

	ratio	ratio1	ratio2	ratio3	hateg	ht	htsqft	fc_total	fc_hatching
long_term	**-0.581**	**-0.048**	**-0.403**	**0.044**	**-11,908.713**	**-0.698**	**-0.164**	**-0.072**	**0.003**
	(0.117)**	(0.070)	(0.119)**	(0.071)	(2,109.090)**	(0.110)**	(0.065)*	(0.074)	(0.076)
period_long_term	**1.122**	**0.393**	**1.048**	**0.353**	**19,386.487**	**1.128**	**0.439**	**-0.181**	**-0.236**
	(0.140)**	(0.084)**	(0.141)**	(0.084)**	(2,430.109)**	(0.130)**	(0.077)**	(0.055)**	(0.057)**
seas	**-0.244**	**-0.110**	**-0.289**	**-0.132**	**-2,049.824**	**-0.146**	**-0.053**	**0.068**	**0.047**
	(0.199)	(0.119)	(0.201)	(0.120)	(3,364.563)	(0.180)	(0.106)	(0.077)	(0.079)
days_prod	**0.036**	**0.018**	**0.038**	**0.018**	**462.992**	**0.024**	**0.012**		
	(0.004)**	(0.002)**	(0.004)**	(0.002)**	(70.020)**	(0.004)**	(0.002)**		
cool	**0.408**	**0.394**	**0.380**	**0.386**	**5,728.117**	**0.316**	**0.293**	**0.038**	**0.018**
	(0.133)**	(0.080)**	(0.134)**	(0.080)**	(2,355.762)*	(0.126)*	(0.075)**	(0.054)	(0.055)
hens					**11.428**				
					(0.252)**				
fcd1								**-0.065**	**-0.043**
								(0.071)	(0.073)
fcd2								**0.104**	**0.103**
								(0.044)*	(0.046)*
constant	**3.741**	**1.718**	**3.589**	**1.652**	**-120,618.015**	**5.334**	**2.356**	**6.691**	**6.820**
	(1.174)**	(0.705)*	(1.189)**	(0.711)*	(21,668.396)**	(1.131)**	(0.670)**	(0.056)**	(0.058)**
hd1					**-3,889.759**	**-0.300**	**-0.062**		
					(4,579.222)	(0.245)	(0.145)		
hd2					**6,017.905**	**0.303**	**0.220**		
					(1,890.847)**	(0.101)**	(0.060)**		
Observations	498	498	498	498	498	498	498	498	498
Number of id	68	68	68	68	68	68	68	68	68
R-squared	0.36	0.20	0.34	0.21	0.85	0.32	0.19	0.10	0.10

Standard errors in parentheses
* significant at 5%; ** significant at 1%