# Oligopsony Power, Asset Specificity and Hold-Up: Evidence from the Broiler Industry*

Tomislav Vukina
North Carolina State University
Raleigh, NC 27695-8109

Porametr Leegomonchai
Chaikomol Business Co., Ltd.
Bangkok, Thailand

May 27, 2004

**Abstract**

In this paper we look for empirical evidence of hold-up in the broiler industry by using the cross-sectional national survey of broiler growers. First, we focus on the problem of under-investment and hypothesize that the degree of under-investment is negatively related to the number of processors competing for grower services in a given area. Second, we provide an indirect test of hold-up by looking at the grower contract payoffs as a function of the frequency of the technology upgrade requests and the processor's market power. The results show moderate empirical support for the presence of hold-up in the broiler industry contracts.

*This material was prepared under a cooperative agreement with the Grain Inspection, Packers and Stockyards Administration (GIPSA) - USDA. Any opinions, findings, and conclusions or recommendations expressed in this article are those of the authors and do not necessarily reflect the views of GIPSA or the U.S. Department of Agriculture. We are grateful to Lee Schrader and John Wilson for providing the data used in this study, and to Federico Ciliberto and Barry Goodwin for econometric estimation advice.

**Oligopsony Power, Asset Specificity and Hold-Up: Evidence from the Broiler Industry**

# 1 Introduction

The use of contracts to vertically coordinate the production and marketing of agricultural commodities has become common practice in many agricultural sectors. Commodities such as tomatoes and broilers have been produced almost exclusively under contracts between processors and independent growers for decades. For example, in the broiler industry contracts, processors control almost every aspect of production from the distribution of inputs (chicks and feed) to decisions about when to harvest the mature birds and repopulate the houses with new flocks. Most of the contracts are written such that they cover one flock at the time. In order to receive the first contract, a grower is required to construct housing facilities and to equip them according to a processor's specification. These assets are considered relationship-specific because their value outside the industry is virtually nil, and their value within the industry, but outside the contract is significantly reduced.

There are two important factors affecting the salvage value of the relationship-specific investments in the broiler industry: 1) the physical specificity, and 2) the location specificity. Housing facilities are valuable assets within the contract with the current processor, whereas outside the contract, they need to be modified to satisfy the other processors' specific requirements. Secondly, processors may have monopsony-oligopsony power in a given geographical area in the sense that growers may have limited opportunity to contract with other processors. The fact that live birds cannot be transported over a long distance significantly reduces growers' choice of processors. In this case, location specificity translates into market power.[1]

[1]Among distinctive structural characteristics of agricultural markets discussed by Rogers and Sexton (1994) the following three pertain to broiler production: a) agricultural products are perishable, b) processors' needs for agricultural products are highly specialized, and c) farmers specialize to supply

In both of these situations, the growers' assets are the source of potentially appropriable quasi-rents in the sense that they have low salvage value outside the bilateral contractual relationship.[2] This constitutes a hold-up problem that can manifest itself in two ways. First, according to Williamson (1985), appropriable quasi-rents affect the level of investments. Being aware of the possibility that they may be held-up by processors, growers will cautiously invest in specific assets. These investments are considered sub-optimal compared to the situation where processors and growers vertically integrate. The magnitude of the under-investment problem varies with factors determining the salvage value of the investment, which in turn affects the magnitude of quasi-rents. Second, after housing facilities have been constructed, the processor may exploit his advantageous bargaining position by frequently requesting upgrades and technological improvements as conditions for contract renewal. Lewin-Solomons (2000) showed that growers may be held up since physical specificity could effectively reduce the grower's compensation without causing additional moral hazard problems. When a contract involves physical asset specificity, the fear of contract termination would induce the agent to exert high effort without the need for efficient compensation.

In this paper, we construct two tests of hold-up and empirically verify the derived propositions by using the cross-sectional national survey of broiler growers.[3] First, within the incomplete contracts paradigm, we hypothesize the presence of grower under-investment in housing facilities and predict that the degree of under-investment will be related to the number of processors competing for grower services in a given area. The stronger the competition, the smaller the under-investment problem. Second, we provide an indirect test of hold-up by looking at the grower contract payoffs as a function of the frequency of the technology upgrade requests and the processor's market power.

particular commodities through extensive investment in sunk assets.

[2]Quasi-rents can be measured by the value of the asset in excess of its next best alternative use (see, Klein, Crawford and Alchian (1978)).

[3]The survey was conducted by the Indiana Department of Agricultural Statistics and Purdue University and was funded by a grant from the Fund for Rural America; Cooperative State Research, Education, and Extension Service, USDA. We obtained only a portion of the survey responses which were necessary to test the hold-up hypotheses.

Based on the efficiency wage model with asset specificity, we hypothesize that broiler integrators may force excessively high levels of asset specificity onto growers thereby alleviating the need for high efficiency wages.

The results are mixed. When it comes to testing the under-investment model, the results seem to be, at last partially, supportive of the prediction that growers' investments in the relationship specific capital assets vary systematically with the processors' market power. Indirect test of hold-up, where we predict that the increase in asset specificity would enable a fall in compensation rate was empirically verified as well. However, we found no support for the prediction that the integrator's market power would strengthen the negative relationship between the grower compensation rate and asset specificity.

The paper is organized as follows. In section 2, we briefly review the theoretical literature on contractual opportunism; in particular, the transactions cost and incomplete contract theory. In Section 3 we present the broiler industry stylized facts and introduce two theoretical frameworks where hold-up may naturally arise. In section 4, we discuss the data, econometric techniques, and results. The last section concludes.

# 2 Contracts and Hold-Up: Theory and Evidence

The economic relationships where hold-up may naturally occur are characterized by the existence of rents to continuing an existing relationship (because of turnover costs or asset specificity) that are available to parties to bargain over, significant problems of writing contracts contingent on all important future events, and the fact that all contracts can be renegotiated by mutual consent (Malcomson, 1997, p.1916). The literature on hold-up originated within the *transaction cost theory* and its objectives to explain the organization of firms. More recently however, the more formal *incomplete contracts theory*, also known as the *property rights theory* has received a considerable attention.

The origins of transaction cost literature can be traced back to Coase (1937). Coase focused on the costs of transacting in different organization environments, particularly, the cost of writing, executing, and enforcing contracts. He argued that an organization is designed to minimize the transaction costs of doing business between parties. Expanding and formalizing Coase's ideas, Williamson (1985) argued that economizing with transactions costs is the primary motivation for adopting different structures governing the contractual relationship between parties. For example, if the transactions between the two parties (buyer and supplier) are recurrent and involve high levels of specific investment (i.e., idiosyncratic transaction), the two will have a strong incentive to vertically integrate. Signing the contract to govern this relationship may not adequately prevent the hold-up problem from occurring. The reason for this is that it is impossible to stipulate in advance the exact response to all future contingencies (i.e., the complete contract is costly and most of the time impossible to write). Specifically, the buyer may renege on the contract by threatening not to buy from the supplier at the specified contract price should some unanticipated event occur. The supplier, who incurred the investment, has no choice but to accept the unfair lower price. Without the vertical integration between the buyer and the supplier, the rational supplier will be reluctant to invest in the first place because of the fear of opportunistic behavior of the buyer.

The Coase-Williamson idea has been widely tested. In particular, the theory of relationship-specific investment and the scope of the firm has been extensively tested in the area of industrial procurement. When firms require specialized inputs that have higher value inside the contractual relationship than in an open market, they must decide if they will produce those inputs themselves or purchase them either on the spot market or by entering a long-term contract. The trade-off between production efficiency and the severity of hold-up governs the choice of length and flexibility of the procurement contracts when transactions involve physically specific assets. Joskow(1985; 1987; 1990), Masten (1984), Monteverde and Teece (1982), Levy (1985), John and Weitz (1988), and Maher (1997), all adopt similar research strategies to empirically test the theory. The authors would typically collect the data on contractual forms and measures of physical asset specificity in various contexts. For example, in Joskow's series of papers, the relevant assets are coal mines and power plants. They would then show that simple spot markets are used less frequently relative to other organizational forms, such as long-term contracts or vertical integration, when assets are more relationship-specific.

The empirical testing of the transactions cost theory suggests that the direct evidence of one party being held-up is rather rare. This is because parties are aware of such problems and have already adopted suitable institutional arrangements to address the problem of expropriation in advance. Without those mechanisms, parties would be reluctant to invest, or their investment level would be sub-optimal. For example, coal mines eventually sign long-term contracts or vertically integrate with electricity firms (Joskow, 1987). Similarly, the empirical evidence of hold-up in franchising contracts, which are organizationally very similar to livestock production contracts, appears to be quite rare as well (Beales and Muris (1995)).

At the time when the empirical work was providing the confirmation for the transactions cost theory, 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 incomplete contracts 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.[4] However, incomplete contracts theory's focus on ex ante investments seems mostly a matter of modelling convenience,

[4] As Williamson (2000) puts it: "The most consequential difference between the TCE (transaction cost economics) and GHM (Grossman-Hart-Moore) setups is that the former holds that maladaptation in the contract execution interval is the principal source of inefficiency, whereas GHM vaporize ex post maladaptation by their assumptions of common knowledge and costless bargaining."

since residual rights of control could also affect the efficiency of bargaining. As a matter of fact, the transactions costs theory literature does recognize that ex ante investment distortions are a potential cost of ex post opportunism (Whinston, 2003, p.5).

A way to potentially correct the distortions in ex-ante investments is to introduce the ex-ante optimal renegotiation mechanism (Hart and Moore (1988), Aghion, Dewatripont and Rey (1994), Noldeke and Schmidt (1995)). The under-investment problem may be solved by allocating all bargaining power in the renegotiation process to one party, and by specifying an appropriate default point that obtains if renegotiation breaks down. For example, in Aghion, Dewatripont and Rey (1994), the default point is an exogenous value that induces the optimal level of investment decided by the party who has all the bargaining power in the renegotiation process. The results imply that if the default point is correctly guessed, the under-investment will not occur. The ex-ante optimal renegotiation design result is interesting because it corrects the hold-up problem by simply writing a contract with an optimal renegotiation clause. However, it is unclear whether a renegotiation design can be written ex-ante in the world of incomplete information.

# 3 Stylized Facts and Two Simple Models

Modern broiler industry is a vertically integrated system of production, processing, and distribution. Broiler companies (called integrators) control all stages of production ranging from breeding flocks and hatcheries to broiler grow-out and processing. The finishing stage of production (the final stage of the production process where one-day-old chicks are brought to the farm and grown to market weight) is organized almost entirely through contracts between processors and independent growers. Over the past 40 years, the industry has become increasingly concentrated such that in 2002 the industry's five-firm concentration ratio based on the volume of production was 55.41 The largest five firms in the industry are Tyson Foods, Goldkist, Pilgrim's Pride, ConAgra Poultry and Perdue Farms (WATT PoultryUSA, 2003).

Broiler companies typically run their operations through smaller divisions (profit centers) spread throughout the country. Each division offers a contract to all prospective growers on a take-it-or-leave-it basis. The contracts usually do not include provisions specifying the number of flocks that a grower will receive per year. In fact, many of them are valid for only one flock of birds at a time. Virtually all contracts stipulate the identical division of responsibilities for providing inputs. The integrator's responsibility is to provide baby chicks, feed, medication and services of field personnel. Growers are required to construct and equip broiler houses and supply labor and management. They are also responsible for utilities, repair and maintenance, waste and dead bird disposal.

Investments in broiler houses and equipment constitute about half of all invested capital in the broiler industry (Perry et al., 1999). Modern broiler houses are well-insulated, environmentally controlled units equipped with automatic feeders and watering lines. A two 20,000 square feet house contract broiler production unit with tunnel ventilation, solid walls, cool pads, infrared brooders and furnaces, and nipple drinkers with capacity of 23,000-27,000 birds per house, costs in the range of \$230,000 to \$260,000 (Cunningham, 1998). The functionalities of broiler houses are specific to the broiler production such that retrofitting them for other purposes (for example, growing turkeys) may be prohibitively costly. Thus, each house will have a relatively low salvage value due to its physical specificity.

The nature of broiler production requires geographical concentration of production units. Contract growers are typically located within a short distance from the integrator's processing plant because live birds cannot be hauled long distances. Broiler operations also tend to be concentrated in proximity of feed mills such that integrator's costs of distributing feed to contract producers are minimized. These characteristics are very important because they restrict the grower's choice of integrators. We anticipate that the location specificity of growers' assets, and therefore, their salvage value will be different in different areas. In an area where there are many integrators, grower's assets will have a relatively high salvage value because the same assets can be utilized to produce broilers under contracts offered by another company. On the contrary, grower's assets will have relatively low salvage value in areas where the number of integrators is small.[5]

When contracts are up for renewal, which tacitly happens whenever a new flock of birds is delivered to the farm, the bargaining power of the grower can be substantially diminished, depending on the degree of asset specificity. The integrator may exploit this situation by not changing the nominal payment to the growers for many flocks even if the period has experienced a significant cost inflation. Alternatively, the integrator may require frequent upgrades of facilities and equipment without necessarily making adequate provisions in the contract that will secure the grower's market rate of return on this additional investment.[6]

## 3.1 Under-Investment Model

We model a contractual relationship between the two parties: a broiler processor (integrator) and a contract broiler grower. Both are assumed risk neutral. In order to obtain a short-term production contract with the processor, the grower must construct the broiler house(s). The investment level, expressed in the number (or size) of chicken houses is denoted by $I$. The cost of constructing each broiler house is $c$ and the total grower's investment is given by $cI$. The benefits from the stream of services generated by the grower's investment is the function of the investment, $b(I)$, with $\frac{\partial b(I)}{\partial I} > 0$ and concave. The contract stipulates that the processor compensates the grower for his services, after which she becomes the residual claimant on the realized benefits.

Consider first the efficient level of investment. Because the grower's compensation appears on the revenue side for the grower and on the cost side for the processor, it drops out entirely, and the first-best outcome is obtained by solving $\max_I \Pi = b(I) - cI$,

[5]Take, for example, two different types of ventilation used in today's chicken houses. One integrator may strongly suggest that all growers convert their chicken houses from the standard "curtain" ventilation to the more efficient "tunnel" ventilation. One grower may decide to accept the suggestion and install this technological improvement, whereas another grower may refuse to upgrade the facilities and move to another integrator that does not require tunnel ventilation (if one exists in the area and is willing to sign-up new growers).

[6]Growers' complaints about this type of opportunistic behavior by integrators has been documented in Ilvento and Watson (1998) and FLAG (2001).

which yields $\frac{\partial b(I)}{\partial I} = c$. As usual, the efficient level of investment is obtained by equating the marginal benefit of investment with the marginal cost of investment.

Next, denote by $r(n, \lambda, I)$ the value of the grower's investment outside the contractual relationship (i.e., the asset salvage value). This value depends on the size of investment, $I$, the degree of the asset's physical specificity, $\lambda \in [0, 1]$, and the degree of location specificity determined by the number of processors in the area, $n \geq 1$. The most extreme form of physical specificity (i.e., the investment is useless outside the current contract) is given by $\lambda = 0$, whereas $\lambda = 1$ means that the investment is generic. We assume a differentiable form of the salvage value function

$$r(n, \lambda, I) = \lambda I \left(1 - \frac{1}{n}\right), \tag{1}$$

such that in case of the extreme physical specificity, the salvage value $r(n, 0, I) = 0$ regardless of the number of processors in the area, and in case of the perfect monopsony, the salvage value $r(1, \lambda, I) = 0$, indicating that the asset has no value outside the current contract regardless of its physical specificity. Of course, $r(n, \lambda, 0) = 0$. In addition, $\frac{\partial r}{\partial n} = \frac{\lambda I}{n^2} \geq 0$, meaning that higher concentration of processors translates into higher salvage value of the asset, and $\frac{\partial r}{\partial I} = \lambda \left(1 - \frac{1}{n}\right) \geq 0$, meaning that the higher the investment, the higher the salvage value outside the contractual relationship. Finally, $\frac{\partial^2 r}{\partial I \partial n} = \frac{\lambda}{n^2} > 0$, indicating that the cross partial derivative of the salvage value function is positive and symmetric. The increment in the salvage value increases when the number of processors in the area increases.

For completeness, one also needs to specify the default payoff for the processor when no contracting takes place. Since the processor is assumed to make no investments, the value of her investment outside the contract is naturally zero. Therefore, the total gain from contracting is $b(I) - r(n, \lambda, I)$ because the cost of investment has already been incurred and is thus sunk, and the grower's compensation drops out. The gain from contracting is presumed positive. If it is negative, continued contracting is inefficient and the parties simply go their separate ways.

Now suppose that the parties engage in Nash bargaining (see Hart and Holmstrom, 1985) over the distribution of gains from contracting. In particular, the parties bargain to determine the compensation that the grower will receive for his services $p$. Suppose that bargaining enables the grower to capture a share $\alpha \in [0, 1]$ of this gain. Then, the bargained compensation is

$$p^* = r(n, \lambda, I) + \alpha[b(I) - r(n, \lambda, I)] \tag{2}$$

which clearly increases with the size of investment. The processor thus captures part of the return on the grower's investment, which is exactly Williamson's (1985) hold-up.

Anticipation of hold-up affects the grower's choice of investment as his decision to invest is determined by the solution to $\max_I \pi = p^* - cI$, or more precisely:

$$\max_I \pi = \alpha b(I) + (1 - \alpha) \left[\lambda I \left(1 - \frac{1}{n}\right)\right] - cI \tag{3}$$

For simplicity we can assume that the parties have equal bargaining power such that $\alpha = \frac{1}{2}$ and they split the benefits evenly.[7] The first-order condition now becomes

$$\frac{1}{2}\left[\frac{\partial b(I)}{\partial I} + \lambda\left(1 - \frac{1}{n}\right)\right] - c = 0 \tag{4}$$

and the second order condition for maximization is automatically satisfied since $b(I)$ is a concave function. With decreasing marginal benefits from investing ($\frac{\partial^2 b(I)}{\partial I^2} < 0$), the investment level that satisfies (4) will always be lower than the first-best level of investment given by $\frac{\partial b(I)}{\partial I} = c$. This is because $2c - \lambda\left(1 - \frac{1}{n}\right) > c$ for any meaningful cost value (i.e., for $c > 1$). Therefore, if the processor has any bargaining power at all, the grower will always under-invest.

The comparative statics results based on (4) show that

$$\frac{\partial I^*}{\partial n} = -\frac{\frac{\lambda}{n^2}}{\frac{1}{2}(\frac{\partial^2 b(I)}{\partial I^2})} \geq 0 \tag{5}$$

[7]The comparative statics results derived below continue to have the same signs for any bargaining share $\alpha \in (0, 1)$.

and

$$\frac{\partial I^*}{\partial \lambda} = -\frac{(1-\frac{1}{n})}{\frac{1}{2}(\frac{\partial^2 b(I)}{\partial I^2})} \geq 0 \tag{6}$$

The signs of both comparative statics results are non-negative because the denominator in both expressions is negative since $\frac{\partial^2 b(I)}{\partial I^2} < 0$. The results indicate that the smaller oligopsony power (more processors) and lower physical asset specificity both lead to the larger investment in relationship specific assets.

## 3.2 Efficiency Wage with Asset Specificity

Our second approach to the hold-up problem in broiler contracts is motivated by Lewin-Solomons (2000). Critical of direct tests for hold-up, she argued that the reason for why we rarely observe hold-up is because it only occurs off the equilibrium path but nevertheless influences equilibrium payoffs.[8] The reason for a weak empirical evidence of actual hold-up (excessive opportunism) is because parties will always seek contracts that prevent such opportunism, since opportunism reduces total surplus and hence is good for no one. The crux of the problem is the fact that the potential for opportunism can have a significant influence on contract stipulations even if no actual opportunism occurs. The mere fact that the integrator could act opportunistically helps keeping the growers in check. Therefore, in testing for the presence of hold-up, it is not valid to look only for actual instances (Lewin-Solomons, 2000, p.10).

The above argument is rooted in the standard efficiency wage result (Shapiro and Stiglitz, 1984). Namely, when incentives problems (caused by the grower's limited liability and the moral hazard problems associated with the fact that effort is unobservable) are sufficiently severe, growers earn positive employment rents. If these rents are high enough, the integrators may hire fewer growers, which would result in the involuntary unemployment for some growers who are perfectly willing to sign a contract but are not able to obtain one. The presence of involuntary unemployment creates an additional

[8] Most of the critical remarks target the literature on the regulation of franchising contracts (Beales and Muris, 1995, and Brickley, Dark and Weisbach, 1991), which are in many respects identical to the broiler industry integrator-grower contracts.

incentive for the grower to exert high effort because shirking increases the probability of getting fired. Because the grower utility from shirking (exerting low effort) is now lower than before, the incentive compatibility constraint can be satisfied with the lower wage relative to the situation where the market clears.

Next, let's add the asset specificity. In this case, the compensation has to be high enough that the grower has a sufficient incentive not to shirk and that he earns sufficient quasi-rents to justify the entire investment. Enforcing high effort now becomes cheaper because a grower fears that, if terminated, he may loose part of the investment that is relationship specific. The minimum incentive-compatible wage is therefore lower than without the asset specificity and the need for involuntary unemployment is reduced since termination is costly even with full employment. The threat of having to switch to another integrator may replace the threat of unemployment. In fact, as shown by Lewin-Solomons (2000, p.21) involuntary unemployment may not exist at all, in which case any form of anti-termination regulation could not be justified purely on the efficiency grounds.

However, when markets fail to clear (which happens when minimal incentive-compatible wage with full employment is above the reservation level and demand at that wage is insufficient to employ all growers), distortions will exist because the integrators can reduce the necessary wage by requiring excessively high levels of asset specificity. When an integrator is a monopsonist, this effect is amplified because an increase in the grower's compensation will cause a smaller increase in the grower's incentive to exert high effort than in the competitive case. This is because by increasing her grower's pay the integrator has increased the market wage and therefore the grower's termination payoff. Since an increase in asset specificity strengthens the incentive compatibility constraint as much as before, and the fall in grower compensation weakens the constraint less than before, a rise in asset specificity makes possible a larger fall in grower compensation relative to the competitive case.[9]

[9]This effect on the termination payoff is ignored by the competitive firm but internalized by a

# 4 Empirical Investigation

The data set used in this study contains the results of the survey of contract growers that produced broilers for different integrators in the mid to late 1999 in Alabama, Arkansas, Delaware, Georgia, Maryland, Mississippi, North Carolina, South Carolina, Texas, and Virginia. The data set has 983 partially usable observations containing information on the individual grower's socio-economic characteristics, the investment in broiler operation (number, size, and age of the chicken houses), the performance and overall satisfaction with contracts, and the degree of local competition for grower services among integrators.

The average contract broiler grower is 51 years old, has high school education, and 16 years of experience as a broiler grower. Almost 82% of the contract holders are males. For 86% of growers, broiler enterprize accounts for more than a half of their gross farm income. For 47% of growers, more than a half of the last year's total family income came from chickens. Other source of income for large number of contract broiler growers is off-farm employment. Between the spouses, the average contract broiler farm holds 0.77 off-farm jobs. The indebtedness of contract growers is significant. Only 27% of growers had the total farm debt at the end of 1998 below $50,000. However, about 85% of them had the total farm debt of less than half a million dollars. For nearly 47% of growers, more than three quarters of the total farm debt is tied to the broiler operation. This is not surprising in light of the fact that the construction of chicken houses, necessary to obtain the production contract with an integrator, are typically financed by mortgage type loans.

The average contract farm's investment consists of 3.6 chicken houses with the total floor space of 57,014 square feet. Farms differ quite substantially with respect to the scale of operation, ranging from one up to twelve chicken houses per contract. The chicken houses also vary in terms of the floor space, ranging from 4,000 to 26,000 square feet per

monopsonist. This result is formally proven as Proposition 2 in Lewin-Solomons (2000, pp. 23-24).

house. The variation in size for older houses is more pronounced, while newer facilities tend to be more standardized. The age of housing facilities varies dramatically from farm to farm. Some houses are brand new, whereas others are more than 60 years old. The average house in the data set is 14.6 years old. The number of substantial improvements made to each house varies substantially across houses between zero and 13, with the average number of improvements of 2.5 per house.[10] The variation is of course greater if one makes comparison across farms. The average number of improvements per farm is 5.1, with the standard deviation of 6.8, the minimum of zero, and the maximum of 63.

Many among the surveyed contract growers report bad financial results. Approximately 8% of the growers claim that they lost money in 1998, whereas 32% report the annual net cash flow below $15,000. Given that virtually all broiler contracts use variable piece rates to compensate growers, grower annual income is highly sensitive to the number of flocks grown each year, the total weight of harvested broilers, and the grower's efficacy in utilizing feed and other integrator supplied inputs.[11] During the three year period prior to the survey, each grower had received on average 5.5 flocks per year and the average grow-out weight was 5.1 pounds per bird. The individual grower performance variable indicates that the average grower in the data set ranked above the average of his/her settlement group approximately six out of ten times indicating that the average grower in the data set may be slightly better than the average grower in the population of contract growers. However, given the size of standard deviation (2.72), the difference is not significant.[12]

[10]The survey question asks for substantial improvements made to each house over past five years, whereas "substantial" means improvements costing at least $3,000 each.

[11]The majority of broiler contracts are settled using a two-part piece-rate tournament consisting of a base payment per pound of live meat produced and a bonus payment based on the grower's relative performance. The bonus payment is calculated as a percentage of the difference between group average settlement cost and grower's individual settlement cost. Settlement cost for each grower is the sum of the costs of integrator supplied inputs (chicks, feed, medication, etc.) divided by the total pounds of live broilers produced. The calculation of the group average settlement cost includes growers whose flocks were harvested within the same week. For the below average settlement cost, the grower receives a bonus; for the above average settlement cost, he receives a penalty. For detailed description of broiler tournaments see for example Tsoulouhas and Vukina (2001) and Levy and Vukina (2004).

[12]Tournaments work such that one half of the participants receives the bonus and the other half

Several questions in the survey provide information about the growers' overall satisfaction with the contract. Only 60% of the surveyed growers reported that in the last three years the contract has changed to increase their net pay. Almost 41% responded that their income from broiler operation has been less than they expected based on the information they had received from the company when they were starting out. Among the reasons that explain lower than expected income, in the first place growers mention operating costs that had risen faster than expected, followed by the poor quality of chicks received from the integrator, the company's frequent requests for expensive improvements and upgrades, and higher than expected chick mortality.[13]

Finally, critical for answering the research questions formulated in this project are the survey responses related the industry concentration and local competition for grower services. The results show that the average number of integrators offering contracts in a grower's area at the time of the survey (1999) was 2.48, down from 2.8 in the period when the grower first started growing broilers. Approximately 29% of the growers had only one integrator to contract with when they started contracting. The situation did not change much over time. At the time of the survey, about 28% of growers still had only one integrator offering contracts in their area. The summary statistics of the variables used in estimation of the econometric models are reported in Table 1.

## 4.1 Testing for Under-Investment

From the previously derived theoretical results, it follows that the under-investment varies positively with $n$ and $\lambda$ which determine the salvage value of the asset. Keeping physical specificity ($\lambda$) constant, in equilibrium, growers facing less competition among integrators would tend to under-invest in housing facilities. In other words, for any

receives the penalty. Aggregate bonus and aggregate penalty cancel each other out precisely. Therefore, in the sequence of 10 tournaments, an average ability grower should win 5 and loose 5 tournaments.

[13]The problem of asymmetric distribution of variable quality inputs by integrators to growers of different abilities have been studied by Leegomonchai and Vukina (2004). They tested for the presence of career concerns and ratchet effect type of dynamic incentives in broiler contracts and found little empirical evidence of integrators's discrimination.

given level of physical specificity of the asset, the size of the investment in this asset is explained by its location specificity where the latter is measured by the degree of competition among the integrators offering contracts. This result can be summarized as follows:

***Proposition 1***: *The size of the relationship-specific investment is positively related to the number of processors contracting for grower services in a given area.*

A straightforward approach to test Proposition 1, given the available data, is to relate the size of the grower's initial investment to the number of integrators that were offering contracts at the time period when that grower started out as a broiler grower. For that purpose we specify the following econometric model:

$$I_i^0 = \alpha_0 + \alpha_1 n_i^0 + \alpha_2 Z_i + \sum_{k=2}^{10} \delta_k s_i^k + \sum_{t=2}^{T} \rho_t d_i^t + \epsilon_i \tag{7}$$

where $I_i^0$ represents the size of the initial investment of grower $i$, $n_i^0$ is the number of processors that were offering contracts in the grower's area at the time when he started out, and $Z_i$ is the vector of the grower's socio-economic characteristics. The model also includes two sets of dummy variables, geographical and temporal dummies. We define $\delta_k$ as the investment shock common to all farmers that reside in the same state $k$, $\rho_t$ as the investment shock common to all growers who started out as broiler growers in the same year $t$, $s_i^k = 1$ if $i = k$ and 0 otherwise, and $d_i^t = 1$ if $i = t$ and 0 otherwise. Finally, $\epsilon_i$ is an individual farmer's idiosyncratic investment shock. Proposition 1 will be supported by the empirical evidence if the sign of $\alpha_1$ is positive and statistically significant.

The initial investment variable $I_i^0$ is measured as either the number of chicken houses that the grower started with or the square footage of the chicken houses floor space. Both variables were constructed by combining the responses to the question about the number of years a farmer had been a broiler grower with the responses to the question about the age and the size of each house that a grower operates. There are three cases that we identified in the survey data. The simplest case is characterized by the situation where the number of years that a grower spent as a broiler grower is exactly equal to the age of the oldest chicken house on the farm. In this case, the initial investment is measured by the number of chicken houses on the grower's farm (or their total square footage) that are of the same oldest age.

The second possibility is that the number of years that a grower spent as a broiler grower is less than the age of the oldest house on the farm. This case describes the situation where the grower bought (or perhaps inherited) an already existing broiler farm. The size of the initial investment in this case is determined by the number of houses (total square footage) on the farm whose age is greater or equal to the years of experience that a farmer has as a broiler grower. All houses that satisfy this criterion can be treated as the initial investment because arguably the grower must have bought the operation of the size he thinks appropriate given the market power of the processors in his area.

Finally, the number of years that a farmer had been a broiler grower can be larger than the age of the oldest chicken house on the farm. This case is likely reflective of the the situation where a grower started out long time ago and already decommissioned some of the oldest houses on the farm, or perhaps even sold the old facility and moved to a new location. The task of determining the size of the initial investment in this case is rather formidable. The problem is caused by the fact that the survey responses about the number of companies offering broiler contracts in the grower's area correspond to the time period when the grower started out as a broiler grower. If one measures the size of the initial investment (like in the first case) by the number of houses of the same oldest age, there will surely be a mismatch between the time when the oldest chicken houses were constructed and the time when the number of integrators offering contracts in a given area was recorded. Lacking better solution, this problem will be addressed by dropping the data that fit into this category and re-estimating the model to see whether the results change.

Among growers' socio-economic characteristics we include only purely exogenous variables such as growers' sex, age, and education. Age variable measures grower's age when he started growing broilers and is obtained by subtracting the years of experience as a broiler grower from the grower's age at the time of the survey. Variables such as income, debt, etc., can be interpreted as consequences of investment decisions that farmers previously made and are therefore endogenous. State fixed effects are included in the model because it is reasonable to anticipate that the poultry industry investment climate may have differed across states, even if one accounts for the number of processor operating in a given market. For example, it is easy to imagine that access to loans to construct housing facilities could have been easier in some states than others. Also, states may have differed historically with respect to regulation related to environment or corporate agriculture that could have made the legal climate more or less conducive to investing in the broiler enterprizes. Lastly, the quality of information available to potential contract growers provided by the extension service or Farm Bureau could have been different across states. Finally, time dummies are included in the model to absorb the impact that the business cycle might have had on the growers' investments. Particularly important is the dynamics of the broiler industry costs and returns and its ramifications for the entry and exit of broiler companies.

The estimation results of two different model specifications are presented in Table 2. Both models are estimated by including and excluding the observations where the number of years that a farmer had been a broiler grower is larger than the age of the oldest chicken house on the farm. The results are qualitatively identical. The presented results are those where the said observations had been dropped. The models are different only with respect to the measurement of the initial investment variable. In the model with the number of chicken houses that the grower owned when he started growing broilers as a dependent variable, the coefficient associated with the number of integrators offering contracts in his area at that time is positive and significant at the 7% level. In the model with total square footage of space under contract as a dependent variable, the number of integrators coefficient is insignificant (and has the wrong sign). In both models growers with completed college or higher degree education tend to invest more. Also, states and time dummies are jointly significantly different from zero confirming our conjecture that time and states fixed effects may be significant.

Based on the obtained results it is difficult to give a definitive answer about the model prediction. We tend to trust the results of the model with the number of houses as a dependent variable more than the other specification because the size of the chicken house is typically not something that a grower decides. Chicken houses are built according to companies' specifications regarding size, equipment, etc. The only thing that the grower can decide is how many of those units he wants to built. Therefore, the results seem to be supportive of the prediction that growers' investments in the relationship specific capital assets vary systematically with the processors' market power.

## 4.2 Indirect Tests of Hold-Up

According to the efficiency wage model with added asset specificity, if the market for grower services does not clear, integrators will force excessively high levels of asset specificity onto growers thereby alleviating the need for high efficiency wages. Monopsony power of the integrator on the market for grower services would strengthen this effect. The model also predicts that in such circumstances growers would enjoy limited or no contractual safeguards against the risk of loosing their investment. There is substantial evidence that broiler industry, may fit this description. The testable hypothesis can be summarized as follows:

***Proposition 2****: Let an individual integrator choose grower compensation $\tilde{p}$ and the level of asset specificity $\tilde{\lambda}$, then the increase in asset specificity enables a fall in the compensation rate, i.e. $\frac{\partial \tilde{p}}{\partial \tilde{\lambda}} < 0$. Moreover, if the integrator has a market power, this affect is amplified, i.e. $\frac{\partial^2 \tilde{p}}{\partial \tilde{\lambda} \partial n} < 0$.*

Relying on this theoretical result and the available survey data, the post-contractual opportunism of the broiler processors can be investigated by looking at the relationship between contract payments, the frequency of the housing facilities upgrades requests that integrators place on their contract growers, and the geographical concentration of processors offering contracts to broiler growers. To test Proposition 2, we estimate the following model:

$$p_i = \beta_0 + \beta_1\lambda_i + \beta_2 n_i + \beta_3\lambda_i n_i + \beta_4 x_i + \sum_{k=2}^{10}\delta_k s_i^k + e_i \tag{8}$$

where $p_i$ represents some measure of contract payoff for grower $i$, $\lambda_i$ measures the degree of asset specificity, $n_i$ is the measure of integrator's monopsony power, and $x_i$ is the vector of the grower or farm specific characteristics that can potentially influence contract payoffs. The model also includes states fixed effects. We define $\delta_k$ as payoffs shocks common to all farmers that reside in the same state $k$, with $s_i^k = 1$ if $i = k$ and 0 otherwise. Regression error term $e_i$ is interpreted as an individual farmer's idiosyncratic shock. Proposition 2 will be supported by the empirical evidence if $\frac{\partial p}{\partial\lambda} = \beta_1 + \beta_3 n_i < 0$ and $\frac{\partial^2 p}{\partial\lambda\partial n} = \beta_3 < 0$ and statistically significant.

The results of two different model specifications are presented in Table 3. In the first model, the dependent variable is a discrete choice variable assuming the value of 1 if during the three year period prior to survey the terms of the contract had changed to increase grower's pay, and 0 otherwise. The probit estimates of this model are presented in the left side panel of Table 3. In the second model, contract payoffs are measured as net cash flow from the broiler production in the year prior to survey. According to the questionnaire, *net cash flow* is defined as poultry income left over after paying poultry-related expenses, such as poultry house mortgage payments, insurance, repairs, utilities and disposal of litter. As seen from Table 1, net cash flow variable comes in 6 intervals and the model was therefore estimated using ordered probit (see Wooldridge, 2002, pp. 508-509).[14] The ordered probit results are presented in the right side panel of Table 3.

The right-hand side variables in (8) were measured as follows: the degree of asset specificity was measured by the number of substantial improvements (upgrades) per

[14]The STATA routine that performs this type of estimation with interval-coded data is called *interval regression*.

house, the degree of monopsony power is measured by the number of integrators offering contracts in each grower's area at the time of the survey, and the vector $x$ contains different variables depending on the model specification. In the *pay increase* specification we include the measure of grower performance and the vintage of the capital stock. The grower performance is measured by the number of times (out of 10 flocks) the grower placed better than average in his settlement group, and the vintage of capital stock is measured by the average age of chicken houses currently in operation. The rationale for including some measure of grower performance (ability) is the fact that contract may have changed to increase pay only for growers that perform well, whereas average growers or below-average growers may have gotten no increase, or even worse, their pay could have actually gone down. Similarly, we included the average age of the chicken houses on a given farm to account for the possibility that the contract may have changed to increase pay only for newer houses or for those with superior equipment.

In the *net cash flow* specification, in addition to grower performance and capital vintage variables, we included the average number of flocks that were placed on each grower's farm per year during the three year period prior to survey, the average number of birds placed in each flock, and the average weight of grown birds that were harvested from the grower's farm. Given the nature of the payment formula used to settle broiler production contracts all those variables will critically influence grower revenue and therefore the net cash flow.

The results are mixed. The first part of Proposition 2 postulating that the increase in asset specificity enables a fall in the compensation rate holds in both specifications because $\beta_1 + \beta_3 n_i$ (evaluated at the mean of the number of integrators, $\bar{n} = 2.48$) is negative and significantly different from zero. In the probit model $\chi^2 = 5.62$ and $P > \chi^2 = 0.0178$, whereas in the ordered probit model $\chi^2 = 5.51$ and $P > \chi^2 = 0.0189$. However, the second part of Proposition 2 postulating that the integrator's market power would strengthen the negative relationship between the grower compensation rate and asset specificity is not supported by the data. The coefficient $\beta_3$ is not significant and has the incorrect sign.

# 5 Conclusions

The ideas of hold-up and post-contractual opportunism figure prominently in the theoretical literature, yet the empirical confirmation of these phenomena is hard to produce. In this paper we look for empirical evidence of hold-up in the broiler industry. The main motivation for this endeavor came from the substantial anecdotal and other non-scientific evidence (trade magazines, small farm advocacy groups, etc.) about contract growers complaining about unfair treatment and exploitation by poultry integrators. Given the fact that the existing business between processors and contract growers is governed by the short-term contracts whereas the underlying relationship is inherently long-term due to the specificity of capital assets involved in the production of birds, the claim that growers could be held-up by the processors deserves to be carefully studied.

In the first part of the paper, we consider the problem of hold-up as an under-investment problem. The theoretical rationale for this approach can be found in the transactions cost theory and in the theory of incomplete contracts. In this case we expect to observe parties undertaking precautionary measures in order to prevent the hold-up from occurring. One of such actions will result in a suboptimal level of investment compared to the first best. We empirically tested the under-investment model with the cross-sectional national survey data of contract broiler growers and found the systematic relationship between the number of processors in a given area and the size of the grower investment as measured by the number of chicken houses under contract.

In the second part of the paper, we performed an additional test of hold-up based on Lewin-Solomons (2000). Arguing that direct tests for hold-up are essentially erroneous, she predicts that when the market for grower services does not clear, which may be the case in some regions of the Southeast where not all prospective broiler growers can find contracts, integrators will force excessively high levels of asset specificity onto growers. This may be manifested in the frequent request for upgrades of the existing housing facilities and equipment. We test this proposition by looking at the relationship between contract payoffs received by growers and the number of times a substantial improvement of his facilities was requested by the integrator as a prerequisite for contract renewal and the number of integrators in each grower's feasible region. The results seem to be supporting the hypothesis that the increase in asset specificity enables a fall in the grower compensation rate. However, the hypothesis that the integrator's market power would strengthen the negative relationship between the grower compensation rate and asset specificity is rejected by the data.

Finally, what are the lessons to be learned from this what appears to be a mixed result? Before making any firm conclusions about the gravity of the hold-up problem in the broiler industry, we should humbly admit the limitations of the available data. The survey instrument that generated this data set was primarily designed with sociologically oriented research agenda in mind. The responses used in this study required some creativity to make them usable for the purposes of estimating even the simplest of hold-up models.

# References


[1] Aghion, P., M. Dewatripont, and P. Rey, “Renegotiation Design with Unverifiable Information.” *Econometrica,* 62 (1994):257-282.

[2] Beales, J. and T. Muris, “The Foundations of Franchise Regulation: Issues and Evidence.” *Journal of Corporate Finance,* 2 (1995): 157-197.

[3] Brickley, J.A., F.H. Dark, and M.S. Weisbach, “The Economic Effects of Franchise Termination Laws.” *Journal of Law and Economics* 33 (1991): 101-132.

[4] Coase, R., “The Nature of the Firm.” *Economica,* 4 (1937): 386-405.

[5] Cunningham, D.L., “Broiler Production Systems in Georgia: Cost and Return Analysis.” Department of Poultry Science, The University of Georgia, Athens, 1998.

[6] Farmer’s Legal Action Group Inc. (FLAG), “Assessing the Impact of Integrator Practices on Contract Poultry Growers.” Privately Published, December 2001, URL: www.flaginc.org/pubs/poultry/poultryrpt.pdf.

[7] 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.

[8] Hart, O., *Firms, Contracts and Financial Structure,* Oxford, U.K.: Oxford University Press, 1995.

[9] Hart, O. and B. Holmstrom, “The Theory of Contracts.” in T.F. Bewley, ed., *Advance in Economic Theory, the Fifth World Congress,* Cambridge: Cambridge University Press, 1985: 71-156.

[10] Hart, O. and J. Moore, “Incomplete Contracts and Renegotiation.” *Econometrica,* 56 (1988): 755-785.

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

[12] Ilvento, T. and A. Watson, *Poultry Growers Speak Out: A Survey of Delmarva Poultry Growers,* University of Delaware: College of Agriculture and Natural Resources, 1998.

[13] John, G. and B. Weitz, "Forward Integration into Distribution: An Empirical Test of Transaction Cost Analysis." *Journal of Law, Economics and Organization,* 4 (1988): 337-356.

[14] Joskow, P., "Vertical Integration and Long Term Contracts: The Case of Coal-Burning Electric Generating Plants." *Journal of Law, Economics and Organization,* 1 (1985): 33-79.

[15] Joskow, P., "Contract Duration and Relationship-Specific Investment: Empirical Evidence from Coal Markets." *American Economic Review,* 77 (1987): 168-185.

[16] Joskow, P., "The Performance of Long-Term Contracts: Further Evidence from Coal Markets." *RAND Journal of Economics,* 21 (1990): 251-274.

[17] Klein, B., V. Crawford, and A. Alchian, "Vertical Integration, Appropriable Rents, and the Competitive Contracting Process." *Journal of Law and Economics,* 21 (1978): 297-326.

[18] Leegomonchai, P. and T. Vukina, "Dynamic Incentives and Agent Discrimination in Broiler Production Tournaments." *Journal of Economics and Management Strategy,* 2004: forthcoming.

[19] Levy, D., "The Transactions Cost Approach to Vertical Integration: An Empirical Examination." *Review of Economics and Statistics* 67 (1985): 438-445.

[20] Lewin-Solomons, S.B., "Asset Specificity and Hold-Up in Franchising and Grower Contracts: A Theoretical rationale for Government Regulation." 2000. Working Paper, University of Cambridge and Iowa State University.

[21] Levy A. and T. Vukina, "League Composition Effect in Tournaments with Heterogeneous Players: An Empirical Analysis of Broiler Contracts," *Journal of Labor Economics,* 22 (2004): in press.

[22] Maher, M., "Transaction Cost Economics and Contractual Relations." *Cambridge Journal of Economics,* 21 (1997): 147-170.

[23] Malcomson, J.M., "Contracts, Hols-Up, and Labor Markets." *Journal of Economic Literature* 35 (1997): 1916-1957.

[24] Masten, S., "The Organization of Production: Evidence From the Aerospace Industry." *Journal of Law and Economics,* 27 (1984): 403-417.

[25] Monteverde, K. and D. Teece, "Supplier Switching Costs and Vertical Integration in the Automobile Industry." *Bell Journal of Economics,* 13 (1982): 206-213.

[26] Noldeke, G. and K. Schmidt, "Option Contracts and Renegotiation: A Solution to the Hold-up Problem." *RAND Journal of Economics,* 26 (1995): 163-179.

[27] Perry, J., D. Banker, and R. Green, "Broiler Farms'Organization, Management and Performance." *U.S. Department of Agriculture, Economic Research Service, Agriculture Information Bullitin No.748,* 1999.

[28] Rogers R. and R. Sexton, "Assessing the Importance of Oligopsony Power in Agricultural Markets." *American Journal of Agricultural Economics,* 76 (1994): 1143-1150.

[29] Shapiro, C. and J.E. Siglitz, "Equilibrium Unemployment as a Worker Discipline Device." *American Economic Review* 74 (1984): 433-444.

[30] Tsoulouhas, T. and T. Vukina, "Regulating Broiler Contracts: Tournaments versus Fixed Performance Standards," *American Journal of Agricultural Economics,* 83 (2001): 1062-1073.

[31] WATT PoultryUSA Magazine, January 2003.

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

[33] Williamson, O.E., *The Economic Institutions of Capitalism: Firms, Markets, Relational Contracting,* New York: Free Press, 1985.

[34] Williamson, O.E., "The New Institutional Economics: Taking Stock, Looking Ahead," *Journal of Economic Literature* 38 (2000); 595-613.

[35] Wooldridge, J.M., *Econometric Analysis of Cross Section and Panel Data,* The MIT Press, Cambridge, Massachusetts, 2002.

Table 1: Data Summary Statistics

| Definition | Obs. | Mean | Std.Dev. | Min | Max |
|---|---|---|---|---|---|
| Number of houses each grower operated in 1999 | 983 | 3.6 | 1.89 | 1 | 12 |
| Total size of all houses on a farm (in sq.ft.) | 983 | 57014 | 33000.62 | 6720 | 197000 |
| Number of improvements per farm | 983 | 5.1 | 6.79 | 0 | 63 |
| Size of the individual house (in sq.ft.) | 3564 | 15725 | 3735.78 | 4000 | 26000 |
| Vintage of the individual house | 3563 | 14.6 | 9.94 | 1 | 65 |
| Number of improvements per house | 1984 | 2.5 | 1.82 | 1 | 13 |
| Number of houses each grower had when started | 829 | 2.7 | 1.51 | 1 | 12 |
| Size of all houses each grower had when started (in sq.ft.) | 829 | 41296 | 26062.78 | 4000 | 164600 |
| Number of integrators offering contracts in 1999 | 821 | 2.48 | 1.49 | 1 | 11 |
| Integrators offering contracts when grower started | 828 | 2.81 | 2.25 | 1 | 20 |
| Years of past experience as broiler grower | 971 | 16.1 | 10.18 | 1 | 61 |
| Grower's age in 1999 | 975 | 51 | 10.93 | 17 | 84 |
| Over past 10 flocks ranked better than average | 802 | 5.96 | 2.72 | 0 | 10 |
| Average number of flocks per year in 1996-1999 | 973 | 5.52 | 0.74 | 3 | 8.5 |
| Average number of of birds placed per flock in 1996-1999 | 964 | 71947 | 41549.93 | 12000 | 300000 |
| Average weight per bird (in pounds) in 1996-1999 | 949 | 5.13 | 1.17 | 1.95 | 8.4 |
| | | Percent | - | - | - |
| Contract changed to increase net pay in 1996-1999 | 915 | 59.89 | | | |
| Growers with 1998 net cash flow negative | 983 | 0.08 | | | |
| Growers with 1998 net cash flow $0-$14,999 | 983 | 0.325 | | | |
| Growers with 1998 net cash flow $15,000-$29,999 | 983 | 0.275 | | | |
| Growers with 1998 net cash flow $30,000-$44,999 | 983 | 0.153 | | | |
| Growers with 1998 net cash flow $45,000-$59,999 | 983 | 0.042 | | | |
| Growers with 1998 net cash flow $60,000+ | 983 | 0.036 | | | |

Source: "Broiler Growers' Survey." Indiana Department of Agricultural Statistics and Purdue University, August 1999.

Table 2: Estimation of the Under-Investment Model

| | Number of houses (OLS) | | | Total square footage (OLS) | | |
|---|---|---|---|---|---|---|
| | Coefficient | Stat. | Prob. | Coefficient | Stat. | Prob. |
| Intercept | 7.793 | t=5.37 | 0.000 | 119752.7 | t=5.23 | 0.000 |
| No. of Integrators | 0.05606 | t=1.80 | 0.073 | -40.5207 | t=-0.08 | 0.934 |
| Grower age | 0.00873 | t=1.48 | 0.140 | 244.278 | t=2.63 | 0.009 |
| Male dummy | 0.2481 | t=1.64 | 0.102 | 2793.265 | t=1.17 | 0.242 |
| High school dummy | 0.01936 | t=0.09 | 0.931 | 2919.045 | t=0.83 | 0.405 |
| Trade school dummy | -0.01395 | t=-0.05 | 0.957 | 1746.35 | t=0.43 | 0.668 |
| Some college dummy | -0.03875 | t=-0.16 | 0.875 | 1847.805 | t=0.48 | 0.634 |
| College & higher dummy | 0.53807 | t=2.10 | 0.036 | 10562.71 | t=2.62 | 0.009 |
| States dummies* | . | F(9,630)=5.32 | 0.000 | . | F(9,630)=4.75 | 0.000 |
| Time dummies* | . | F(41,630)=3.98 | 0.000 | . | F(41,630)=6.16 | 0.000 |
| | $\bar{R}^2$=0.2424; F(57,630) =4.86 | | | $\bar{R}^2$=0.3508; F(57,630) =7.51 | | |

* States and time fixed effects estimates have been suppressed for brevity. F-statistics test that they are jointly equal zero.

Table 3: Estimation of the Efficiency Wage with Asset Specificity Model

| | Pay increase (Probit) | | | Net cash flow (Ordered Probit) | | |
|---|---|---|---|---|---|---|
| | Coefficient | Stat. | Prob. | Coefficient | Stat. | Prob. |
| Intercept | 0.77711 | z=2.29 | 0.022 | -17822.25 | z=-1.90 | 0.058 |
| Upgrades | -0.12521 | z=-2.32 | 0.020 | -932.6156 | z=-1.54 | 0.122 |
| Integrators | -0.05328 | z=-1.10 | 0.272 | 248.1487 | z=0.42 | 0.671 |
| Upgrade×Integrator | 0.022137 | z=1.44 | 0.151 | 56.6267 | z=0.31 | 0.759 |
| Performance | 0.05308 | z=2.73 | 0.006 | 1272.73 | z=5.52 | 0.000 |
| Vintage | -0.00616 | z=-0.98 | 0.325 | 231.1833 | z=2.89 | 0.004 |
| States* | . | $\chi^2(9) = 21.33$ | 0.0113 | . | $\chi^2(9) = 10.42$ | 0.3174 |
| Flocks per year | | | | 2892.5 | z=2.62 | 0.009 |
| Birds placed | | | | 0.15442 | z=9.09 | 0.000 |
| Weight of birds | | | | 1926.77 | z=2.86 | 0.004 |
| | $LR\chi^2(14) = 43.89$; $P > \chi^2 = 0.0001$ | | | $LR\chi^2(17) = 151.51$; $P > \chi^2 = 0.0000$ | | |

* States fixed effects estimates have been suppressed for brevity. $\chi^2$-statistics test that they are jointly equal zero.