CONTRACT CHOICE IN THE LIVESTOCK INDUSTRY

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Introduction

The industrialization process in the food industry is increasing at a very rapid pace. In the USA, more than 95% of the eggs, almost 100% of the broiler production, and 98% of vegetables for processing, is produced under contract or direct vertical ownership (Manchester [1]). In the hog industry the portion of total production produced under contracts is 5% and another 5% is produced by vertically integrated firms. In the grain industry, only a small percentage (less than 2%) is produced under such arrangements, whereas the vast majority of the production is produced by independent farmers (Manchester [1]). Why is it that certain agriculture industries have developed in an industrialized fashion faster than others? What are the economic implications of this form of production system?

The purpose of this paper is to investigate the economic analytics of contracting in agriculture, particularly in the intensive livestock industry, in order to provide some answers to the above questions, in a purely theoretical form. More specifically, in this paper we put forward a game theoretic model which attempts to examine the first question given above, and to provide a tool and some insights into the analysis of the second question. A dynamic game with incomplete information is set up, to model a situation where a feed mill contracts with farmers for the production of an output. Initially there are no alternatives to the producers but to contract, and later this constraint is relaxed and the producers are allowed to produce independently. It can be shown that this may result in adverse selection problems. The game is in the family of signalling games, the signal here is some type of investment that the producer is undertaking in order to "signal" to the contractor whether she is a "good" or a "bad" farmer.

Theory of Organizational Form and Contract Choice

Contracting in agriculture has been a subject of ongoing research since A. Marshall (Marshall [2]; Cheung [3]; Knoeber [4]; Rhodes [5]; Barry [6]). One natural approach has been to view contracting as a form of vertical integration and apply standard industrial organization (I-O) theory to model it. The most recent extensive treatment of this approach is by Wu [7] and to a lesser extend by Royer [8]. The basic premise of the I-O approach is to treat an exclusive contract between a downstream and an upstream firm as an alternative to some type of competition (open market, Cournot, Bertran, Stackelberg, etc.). In a game theoretic framework the outputs of the firms and the welfare implications of each alternative can then be determined. Wu shows that total output decreases as the number of firms tied with contracts increases and as the number of vertically integrated firms decreases (Wu [7], pp. 72-82).

Within this analysis, it is not surprising that a downstream firm finds itself in a worse position when it ties itself to a contract with an upstream input supplier than it would have been if it had relied on the open market. The reason being, that competition between upstream firms will drive the input price down, whereas the firms tied to a contract will not be able to switch to a lower price supplier. This result is somewhat awkward, since it does not let one get to the heart of the problem, namely "why firms enter into contractual arrangements to begin with ?" In fact, Wus' model provides analytical evidence that firms have a disincentive to enter into contracts. This outcome is strengthened by further investigation where Wu searches for the possibility of joint profits for both upstream and downstream firms combined, and the potential for lamp sum transfers between upstream and downstream contracting parties. In no case was it found that joint profits increase under contract. One explanation put forward is the efficiency argument by the transaction cost school.

Consideration of transaction costs has made possible the analysis of organizational forms. Williamson notes: "... if transaction costs are negligible, the organization of economic activity is irrelevant, since any advantages one mode of organization appears to hold over another will simply be eliminated by costless contracting." (Williamson [9], p. 233). Indeed, in the absence of transaction costs, vertical contracting can replicate the advantages of vertical financial ownership (Mahoney [10], p. 560). Several studies have shown that in the absence of transaction costs, vertical contracts can perfectly substitute vertical financial ownership (Blair and Kaserman [11]; Bolton and Bonano, [12]). Coase [13], in his seminal article on "the nature of the firm" in 1937, was concerned with the choice "firm versus market" and he concluded that: "The main reason why it is profitable to establish a firm would seem to be that there is a cost of using the price mechanism" (Coase [13]).

However, contracting is not costless. There are three sources of transaction costs according to Williamson [14]: specificity of assets, bounded rationality, and opportunism. The agency literature has provided an extensive treatment of the transaction cost approach to contracting. In fact Williamson [15] finds very few differences between transaction and agency costs.

One branch of the agency literature is the very extensive principal-agent approach (Jensen [16] distinguishes two agency literatures the "positive agency" and the "principal-agency"). Here the main theme is the incomplete information between principals (contractors) and agents (farmers), as well as the potential for "shirking" behaviour by the agent (Grossman and Hart [17]; Ross

[18]; Milgrom and Roberts [19]; Holmström [20]; Stiglitz and Weiss [20]). Within the principal-agent literature, very important contributions have been made in the area of share tenancy (Cheung [3]; Allen and Lueck [21]; Stiglitz [22]; Hayami and Otsuka [23]). A relatively recent strand within the principle-agent doctrine has been the literature on franchise contracts (Lafontain [24]; Brickley and Dark [25]).

As limitations of space does not allow for an extensive treatment of the vast literature on contracts in agriculture, it is worth mentioning some attempts that have raised the issue and have pointed to important aspects of this subject. The "synthetic" approach of Mahoney [10], had a great influence on this literature where he combines the pure transactions cost approach with the more recent advances in the positive agency theory (Porter [26]; Eisenhardt [27]; Ouchi [28]; Ring and Van de Ven [29], among others). Some of the contributions and significant surveys in the analysis of organization in agriculture have been Barkema [30]; Sauvée[31], Barry [6]; Rhodes [5]. The contribution of Knoeber [4], and Knoeber and Thurman [32], as well as the work of Laura Martin [33], and the on-going research of Grimes and Rhodes [34], [35], are some of the most recent comprehensive analytical contributions in the area of livestock contracting.

Most of the research cited above has dealt extensively with the problem of contract choice and its peculiarities in agriculture and especially in land tenancy as well as in livestock. None of this work has dealt yet with the problem of contract failure and especially adverse selection. There have been cases in history where the contracting experiment has failed dramatically. One such case is cited in Storey and Karantininis [36] in Manitoba, Canada. Also, very little can be found in this literature as to why some industries tend to integrate more than others. Some attempts can be cited (Raimund Martin and Moore [37]; Gillespie, Karantininis, and Storey [38]), however these approaches are rather ad-hoc. Knoeber [4] on the other hand, emphasizes the choice of tournaments in the broiler versus the turkey industry and not necessarily the choice of contracts.

In this paper, an attempt is made to present a more general analytical device that offers an alternative explanation as to why some industries more than others tend to rely on contracts rather than on independent production. A dynamic game with incomplete information and signals is presented in the following Section.

A Signalling Game with Contracts

We consider the following game. There are two types of farmers, bad (B) and good (G). Their type is determined by "nature". By this, one does not have to imagine a purely abstract event, like throwing a dice. "Determined by nature" here can be interpreted as simply being exogenous to the model. Furthermore, "good" and "bad" does not have any ethical or other such connotation. Good and Bad can be interpreted as "full time" and "part time" farmers. Farmers that are willing to devote their whole time and effort on livestock farming are expected to show a better performance, whereas others are expected to be poor performers in the livestock activity. Everybody in the game knows the initial distribution of the farmer types. Let us assume that this is given simply by [α,_1-α], where $0<\alpha<1$ is the percentage of G farmers, and 1-α is the percentage of B farmers.

The farmers can reveal their type only by giving a "signal". In this case, we assume that this signal is some investment that the farmer is willing to undertake. The signal could be chosen to be anything else (education, previous records, etc.), however, it is common practice in hog or chicken contracting, that farmers commit themselves to some type of investment, a new barn, or some other buildings and equipment (specific silos, trucks, etc.). This investment is usually "contract specific". For example, the barn design can be such that the boxes will be sized such as to fit the market weight that the contractor specifies. Due to asset specificity, the farmers that undertake the investment can be expected to remain longer in the contractual relationship, and hence it can be inferred that they are of the G type rather than the B type. However, it is possible, that the B types could make the investment in order to mislead the contractor and be offered a better contract.

It is assumed that there is one contractor who offers two types of contracts. A High-Protection (H) contract, designed for G farmers; and a Low Protection (L) contract, designed for the B types. The contractor makes money on both contracts, provided he offers the right contract to the right farmer. A lot can be said about contract design, and there exists a vast literature on contract theory that discusses the aspects of optimal and incentive contracts (Grossman and Hart, Milgrom and Roberts).
The general rules for the payoffs are as follows:
a. Farmers: Investment costs farmers 1 unit (payoff of -1 unit), the H contract gives a payoff of 3 units and the L contract 1 unit.
b. Contractor: If he matches the right farmer to the right contract, he receives 2 units. He receives an additional unit, if the farmer is G type, irrespective of the contract type.

These payoffs could have be designed to be in a continuum rather than scalars. Also, one could design a game where there are more combinations between the payoffs. However, by keeping the game as simple as possible, we are able to demonstrate some very key features that give us a good insight into the problem.

Perfect Bayesian Equilibria

The extensive form of this game is shown in Figure 1. This game belongs to the general game-type known as "signalling games" (Kreps and Wilson [39]; Spence [40]; Gibbons [41]). The objective is to find the perfect Bayesian equilibria (Kreps and Wilson [39]; Gibbons [41]). The literature cited contains enough details about the conditions of Bayesian equilibria. The key feature of this equilibrium is that incomplete information is available, and the players in this game form beliefs about the strategies the other players follow. These beliefs are elevated to the level of the importance of strategies so they are "reasonable" as much as the strategies must be "credible" (Gibbons [41]; Kreps and Wilson [39]; Harsanyi [42]).

Two types of perfect Bayesian equilibria are investigated in the signalling games, "pooling" and "separating". Pooling equilibrium is one where both types give the same signal and they can not be distinguished in the equilibrium. Separating equilibrium is one where the two types are revealed by their signal (i.e. in this case, by whether they invest or not).

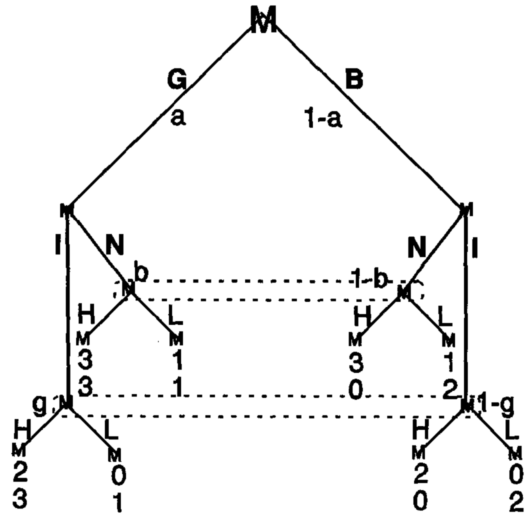

Figure 1. A Game of Contracts and no Open Market Transactions

Let us first examine the pooling equilibrium [(N,N)], i.e. the case where both types of farmers do not invest. Initially we assume that the probability is $\alpha=0.5$. Following Bayes' rule and the farmer's strategy, the contractor assigns a probability $\beta=0.5$ ($\beta=\alpha 1/[\alpha 1+(1-\alpha)1]$) that she is a G type if she chooses N (and hence $1-\beta = 0.5$, that she is B type if she chooses N). Given this, the best response for the contractor is to offer the farmer an H contract which gives a payoff of 3 to both types of farmers. However, if the initial farmer type probability is $\alpha<0.5$, then the best response for the contractor is to offer an L contract. Intuitively, if there are more bad farmers relative to good farmers, it is better for the contractor to offer an L contract, rather than an H contract (given the specific payoffs).

In order for this to be an equilibrium, the farmers must have no incentive to deviate. Let us first check the G farmer's incentive to deviate: In order not to deviate, his reward if he invests must be less than if he does not invest. If the initial probability is $\alpha>0.5$, then, as we sow above, the contractor always offers an H contract which gives a reward of 3 to the G farmer. This strictly dominates any alternative (H, or L) if the farmer invests because if he invests he gets at best 2. But, what if the initial distribution is $\alpha<0.5$ and the contractor chooses L with a payoff of 1 for the G farmer? In this case, in order for these pooling strategies to be in a perfect Bayesian equilibrium we need to check whether there is an incentive for the G farmer to deviate. In order for the G farmer not to deviate by investing, the contractor must offer L if he observes investment, so the payoff for the G farmer is 0, which is less than what he gets if he doesn't invest (payoff of 1). In order for the contractor to chose L, his belief about probability γ, must be $\gamma<0.5$ (solving the inequality: $3\gamma+0[1-\gamma]\geq 1\gamma+2[1-\gamma]$, gives $\gamma<0.5$). For the same reason, the B farmer will not deviate either. Therefore, we find that [(N,N),(H,L)], for ($\alpha>0.5$), or ($\alpha<0.5$ and $\gamma<0.5$) is a pooling perfect Bayesian equilibrium.

This equilibrium may seem paradoxical: the contractor offers an H contract when he observes N and H or L, when he observes I. Let us give an intuitive explanation for this seemingly paradoxical equilibrium. First, let us take the situation where there are more G producers than B ($\alpha>0.5$). Then the contractor, since his payoff depends on "matching the right farmer to the right contract" is offering an H contract because it is more likely that the producer is G. If the payoffs were determined differently, then we could probably have reached a different equilibrium. Therefore, in this case the equilibrium is driven by the initial distribution $[\alpha,1-\alpha]$ of the farmer types and the specific determination of the payoffs.

The second pooling equilibrium is [(I,I), H,L)]. This can be a perfect Bayesian equilibrium, if $\alpha>0.5$ and $\beta<0.5$. In this case, the contractor's strategy is (H,L). None of the farmer types has an incentive to deviate from this equilibrium.

The separating equilibrium [(I,N), (H,L)], is not perfect Bayesian because the B type has an incentive to deviate and invest (pretending he is a G farmer and being offered an H contract with a payoff 2>1). On the other hand, if the contractor follows a strategy [(I,I), (H,H)], it can not result in equilibrium, since there is an incentive for type G to deviate and Not invest for a payoff of 3>2. Similarly, the separating equilibrium (N,I) is not perfect Bayesian.

Hence, the game in Figure 1 can only produce two pooling equilibria, depending on the initial distribution of farmer types and the contractor's beliefs:

1.	(i) $\alpha>0.5$:	[(N,N), (L,H)] $\forall\ 0<\gamma<1$
	(ii) $\alpha>0.5 \wedge 0\leq\beta<0.5$	[(I,I), (H,L)]
2.	$\alpha<0.5 \wedge 0\leq\gamma<0.5$	[(N,N), (L,L)]

The Choice to Remain Independent: Adverse Selection

In the game presented above, the players were assumed to have no choice but to enter into a contract. This, however, does not represent the reality, since a producer always has the choice to remain independent. In Figure 2, we present a game where we suppose that if a G type producer remains independent he receives a payoff of 2 and a B type a payoff of 1, whereas the contractor receives 1 in both cases. It is logical to assume that the contractor being a feed mill can sell compound feed to the farmers for a standard profit determined by the competition. It may seem initially too strong an assumption that the farmer who remains independent will necessarily chose to buy the feed from the specific feed mill. This can be justified by two arguments. First, it can be viewed as a spatial monopoly, where the existing feed manufacturer charges the price of the next alternative feed mill plus transportation cost. Or, alternatively, it can be viewed as that the feed mill has to produce to maximum capacity, and if he can not find a contractee he sells the feed in the open market for the going price, similarly, the farmer can buy feed of the same quality and price on the open market.

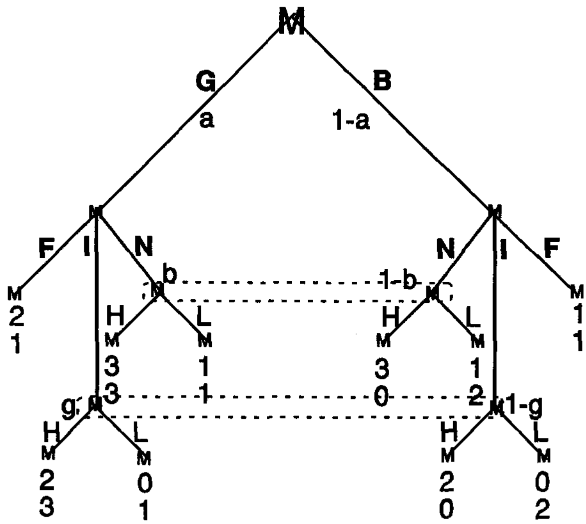

Figure 2. Adverse Selection, Contracts and Open Market Transactions

In this case, the equilibrium 2 described above, fails because the G type has an incentive to deviate by being independent. Both equilibria 1-i, and 1-ii still hold. Now, we have to examine two alternative separating equilibria where one type chooses to be independent and the other to enter into a contract:

First, the separating equilibrium where the G farmer is independent and the B is contracting. There are two possibilities here: [F,N] and [F,I]. Take the latter first. The contractor places a probability γ=0 (based on Bayes' rule and the farmer's strategy). The strategy [F,I], however, is equilibrium dominated by N: the B type farmer should always play N, if the contractor places a belief γ=0, because he (the B type) will always be better off (at least a payoff of 1) if he plays N.

The separating equilibrium [(F,N), (L,L)] is perfectly Bayesian if γ<0.5. The belief that γ<0.5 is actually intuitively satisfied: The observation (I) is off the equilibrium path, and the belief should be determined by Bayes' rule and the players' equilibrium strategies where possible (Gibbons, 1992). Given that the G farmer's strategy is F, then the contractor must place a probability of

$\gamma=0$. This is true for the additional reason that I is dominated by F for farmer G. Hence, if the contractor unexpectedly observes (I) he will believe that this can only be a B type and he offers B, which gives the contractor a payoff of 2 (and the farmer a payoff of 0.). As a result, the B farmer will not play I. Similarly, the G farmer will not play F either, because any outcome of N (at best 3, at worst 1) is at least as good as F (a payoff of 1). Therefore, the following separating equilibrium is perfectly Bayesian.

3. [(F,N), (L,L)] for $\gamma=0$

This equilibrium depicts a case where the G farmers prefer to be independent, whereas the B farmers chose to Not invest and enter into a B contract. This equilibrium leads to an adverse selection situation: The contractor would like to attract the Good farmers into the contracting scheme, however only Bad farmers are attracted and the Good farmers prefer to be independent.

There is, however, an intuitively derived situation where this equilibrium can never be observed: the contractor can always promise that anybody receives an H contract, and under certain conditions this might be believed. This promise is "credible" if the initial distribution is $\alpha>0.5$. This is explained as follows: The payoff the contractor receives if the Good farmers are independent and the Bad farmers enter into a contract is $\alpha 1+(1-\alpha)2=2-\alpha$. If the contractor always offers an A contract, then his payoff is: $\alpha 3+(1-\alpha)0=3\alpha$. Therefore, he will do the latter (offer an H contract) if: $3\alpha>2-\alpha$, or $\alpha>0.5$. Therefore, if the initial distribution is such that Good farmers exceed Bad farmers ($\alpha>0.5$), then the contractor can make the "credible promise" that anyone entering into a contract will receive an H type irrespectively, and this promise will be believed by both types. In this case, the game becomes a "prisoner's dilemma" game.

The second separating equilibria [I,F], and [N,F] where the Bad farmer remains independent and the Good farmer contracts in, does not satisfy the conditions of perfect Bayesian equilibria.

Discussion

We have shown that in the game as presented above, there is a possibility of both pooling and separating equilibria. As the game is constructed it has been shown too that the separating equilibrium leads to adverse selection: the contracts are designed in such a way that they attract the poor perfomers into the contracting scheme, whereas the good producers prefer to remain independent.

What are the conditions that can result in such a situation ? First, as we have seen above, if the initial distribution of the farmer types gives more Good farmers than Bad ones, the situation may result in a prisoner's dilemma. But, what determines the initial distribution of Farmer types ?

a. As discussed earlier, the distribution is not determined, per se, by human nature (i.e. some people are simply more capable than others). In addition, it can be determined by the alternatives these producers have. If, for example, crop farming is profitable, this will tend to increase the percentage of "Bad farmers" since they will be willing to spend less time and effort on their livestock operation than on crops.

b. The profitability of independent livestock production will also determine the distribution as well as the payoffs for independent producers. If the profitability of independent production is such that it guarantees a compatible payoff, then it is likely that more producers will chose this alternative. The profitability of independent production, in turn, depends on various factors: structure and competition in the market for final products, structure and competition in the market for inputs, and economies of scale. The market structure and competition in the final market will determine the margins that are available for independent producers. The market structure in the final market is partially determined, by the structure and economies of scale in processing, marketing and distribution and retail firms in the industry. For example, in the chicken industry, where the product is very standardized, final distribution is done via super market chains, where there are highly oligopolistic structures and the margins are small for producers. Whereas, pork and other types of red meat in some countries are still distributed to a large extent via independent small and medium sized butchers where competition is greater. This can be one of the many reasons why the chicken industry is more integrated with more production produced under contracts.

The structure of the inputs market is also very important. For example, in the chicken industry, due to technology, there has been a complete separation between hatching and chicken production. Conversely, in the pork and beef industry the two processes (piglet and pork production) are still to a great degree integrated. This results in a completely different structure: chicks that are produced by large scale (rather oligopolistic) hatchers are an input to chicken farmers. In pig production, on the other hand, even though there are also certain economies of scale in breeding sows to produce piglets, once a farm reaches a certain size it always pays to finish the hogs to market, instead of simply selling piglets. As a result, piglets are sold mainly by small to medium size producers and hence the market is more competitive, given also that it is always easier to integrate (farrow-to-finish) - something almost impossible for chicken production, unless a very large scale is reached.

c. The design of contracts. This is a very crucial issue in this analysis. As we saw above, the payoffs the producers receive from the various types of contracts determine their equilibrium strategies and beliefs. Two aspects are very important in contract design: Incentives and monitoring.

Incentive contracts. Since people have an incentive to shirk, the contract must provide enough incentives so that they induce people to make a maximum effort. The principal-agent literature provides a good background and alternative solutions to the problem (Hart and Holmström [43]; Hart [44]; Milgrom and Roberts [19]). The analysis presented above points to two important elements for the contract designer (a) extraction of the maximum effort on the part of the farmer, and (b) a contract that selects "good" from "bad" producers, and gives an incentive to good producers to enter into contracting instead of

remaining independent. This later part we believe is the elementary contribution of this analysis in the analysis of contracts in the livestock industry.
Monitoring. Costs of monitoring is very important in relation to the previous discussion on incentive contracts. If monitoring is costly then the contract must be designed so as to induce farmers to put in a maximum effort with no need of monitoring. Furthermore, where maximum effort can not be extracted, due to costly monitoring, a second best outcome may result (Hayami and Otsuka [23]; Williamson [14]; Stiglitz [22])

d. Attitudes towards risk. Depending on the level of risk of independent production versus that under contract, and the risk attitudes of farmers and contractors, different equilibria may result. For example, risk averse producers will tend to prefer the shelter of contract production as opposed to risk-neutral (and risk-loving) producers. Also, if there is enough competition on the final markets, it is very hard for the contractor to provide any more risk coverage than the market already provides. In this case, the contract can not be more attractive than the open market transaction for the producer, from a risk point of view.

In practice, there have been various methods to avoid the problem of adverse selection and to design a more appropriate contract. In the chicken industry, for example, the use of "tournaments" seems to provide an efficient alternative, given its long survival in the US (Knoeber [4] provides an excellent treatment, more theoretical work can be found in Lazear [45]).

Summary and Extensions

The analysis presented in this paper provides a point of departure for the understanding of contracting in the livestock industry, and more generally in agriculture. It provides with a structure that may prove useful for the positive analysis of the organizational structure of agricultural industries. It points to structural characteristics and variables that could be key determinants in the understanding of why certain organizational forms emerge in certain industries. Some of the factors can be identified as industry-specific, whereas others, exogenous to the industry and perhaps more country- specific.

This model can be extended in many directions. First, it could be enriched by specifying a continuum of payoffs instead of the simplified scalar representation in this paper. This can be done by specifying production and utility functions for the various participants. Furthermore, one could introduce some risk elements, which might prove very significant for the analysis. For example, the literature provides an extensive discussion on the attitudes towards risk of contractors and farmer contractees (Allen and Lueck [21]; Hayami and Otsuka [23]).

A very important element that could be incorporated in this model is the situation where the contractor (feed mill) has an incentive to cheat too, say by providing lower quality input (feed). This is a of double-bind morally hazardous situation (Cooper and Ross [46]). In our case it could be combined with the adverse selection problem already analyzed here.

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