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Governance Issues in the Principal-Agent Framework: Producing Cellulosic Ethanol in Michigan

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Governance Issues in the Principal-Agent Framework: Producing Cellulosic Ethanol in Michigan

(Vivek Pandey, Aleksan Shanoyan, Brent Ross)

This article analyzes the incentives and compensation problems faced by cellulosic ethanol producer and logging firms and the consequent impact on the organization of the wood based cellulosic ethanol industry in the US. The success of this relationship is central to setting up the biofuel industry in Michigan and in the US at large. The theoretical results indicate that specification contract under the principal-agent framework is of limited utility due to 'metering' problem when the principal contracts with multiple agents for the supply of feedstock.. Alternative arrangements including JVs have the potential to provide close to first best solutions.

1) Introduction

Biofuels are being extensively promoted for their potential to contribute to energy security, stable energy prices, and climate change mitigation in the United States (Khanna, 2008). Within the category of biofuels, corn based ethanol production has long been supported in the United States. Over 7.5 billion gallons of ethanol was produced in 2008 from the corn grown over 90 million acres of farm land (Donner & Kucharik, 2008). However there has been a recent policy shift mandating the increase in production of cellulosic ethanol from being currently insignificant to 21 billion gallons a year in 2022 (EISA, 2007). This article analyzes the incentives and compensation problems faced by wood based cellulosic ethanol producer and the logging firms (they supply feedstock) and the consequent impact on the organization of the wood based cellulosic ethanol industry in the US. We propose to study this problem under the principal-agent

framework. This would allow us to introduce asymmetric information and its impact on the vertical coordination strategy (Macho-Stadler, 2001).

The US biofuel policy is comprised of tax credits for biofuel blenders and production mandates (a renewable fuel standard) authorized in the Energy Policy Act of 2005 and the Energy Independence and Security Act of 2007 (EISA, 2007). The new Renewable Fuel Standard requires the use of at least 36 billion gallons of biofuels per year in 2022. The law seeks to limit the impact of corn based ethanol (defined as conventional biofuels or first generation biofuels) in the RFS by limiting its production to 15 billion gallons a year after 2015 and encouraging the use of cellulosic ethanol which are defined as advanced or second generation biofuels. The advanced biofuels on a life cycle analysis basis must encompass 50 per cent less green house gas emissions (GHG) than the gasoline or diesel fuel it will replace. The second generation biofuels include fuel made from cellulosic materials, hemi cellulose, lignin, sugar, starch (excluding corn), and waste, as well as biomass-based biodiesel, biogas, and other fuels from cellulosic biomass (Velasco, 2008)

First generation biofuels processes are useful but limited. There is a threshold beyond which additional production cannot take place without jeopardizing food supplies (example: corn and sugarcane) and biodiversity (Kish, 2007). They are not cost competitive with fossil fuels and green house gas emission savings are small. There has been a recent growing interest in second generation cellulosic biofuels due to their enhanced potential to contribute to energy security and reduce greenhouse gas emissions by 85% while mitigating the food vs. fuel competition for land as compared to corn ethanol (Khanna, 2009).

Cellulosic ethanol (CE) production has the advantage of abundant and diverse raw material compared to sources like corn and sugar cane. Major sources for CE include switch grass, miscanthus and wood (example: aspen, poplar and willow). Cellulose is present in almost every natural free-growing plant, tree, and bush all over the world without agricultural effort or cost needed to make it grow.

Problem Statement

The cellulosic content contained in the log of woods is the major source of cellulosic ethanol. Once the tree has been uprooted, the cellulosic content goes down with time. Therefore the ethanol producer would be willing that the landing operations (defined as carrying of logs of wood from the logging site to storage site) are completed by the loggers as soon as the tree has been cut. The problem arises in winters when snow affects the logging operations. Landing becomes difficult because the same task requires more resources to be spent by the logging firm (more men and better machines for transporting the wood to the landing area). This gives rise to conflict between the principal (CE producer) and the agent (logging firm). It has been estimated that an uprooted tree loses 60% of the cellulosic content if the wood is left unprocessed for 10 days (Maser et. al., 1988). This will adversely affect the ethanol production and also the principal's revenue. In short, moral hazard and adverse selection problems are anticipated in the contractual relationship between the CE producer and the logging firm.

The moral-hazard problem usually is formulated in terms of a contract between a principal and an agent who "works" for him. The principal and the agent can be people or institutions. With regards to agricultural sharecropping, the principal is the landowner and the agent is the tenant.

In the moral-hazard problem, the agent works on a project for the principal. The amount of work the agent performs affects the probability distribution of the project's return. The problem is that the principal cannot monitor the agent's work, so the agent's effort is private information; that is, it is observed only by the agent himself (Prescott, 1997). In some models, the agent's amount of effort is not observed. In other models, precisely how the task is performed is not observed. Adverse selection is present when the agent has informational advantage concerning his own personal characteristics and will only be revealed if it is in the interest of the agent to do so.

The wood based cellulosic industry has to yet take off on commercial scale. In that respect, we would consider our study to be futuristic. We strongly anticipate that the findings of the study would be particularly useful for the firms and organizations planning to invest in the cellulosic ethanol production facilities. The theoretical results indicate that specification contract under the principal-agent framework is of limited utility due to 'metering' problem when the principal contracts with multiple agents for the supply of feedstock.. Alternative arrangements including JVs have the potential to provide close to first best solutions.

The article is organized as follows. Section 2 presents the methodology used in our research. We develop the conceptual framework in section 3 for analyzing the behavior of agents under symmetric and asymmetric information cases. In section 4 we discuss the optimal contracting schemes under asymmetric information where some options are proposed and analyzed. We conclude our discussion in section 5.

2) Methodology

We make use of the case study methodology in analyzing the governance issues arising from the principal-agent relationship between the ethanol producer and the feedstock provider. The case uses the example of Michigan. The state of Michigan has the 5th largest timberland in the US and it grows 2.5 times more wood fiber annually than it harvests (Pedersen, 2005). Michigan has enough resources to support 6 commercial facilities each producing 50 million gallons of ethanol per year.

The Mascoma Corporation is planning to build the first CE production facility in Michigan. The plant will be located in the Chippewa province, Upper Peninsula (Egan, 2009). The ethanol facility will require 375 thousand cords of wood every year to manufacture 40 million gallons of biofuel. Wood will come mainly from within a radius of 150 miles from the plant's site. This largely rural area includes both state and federal forests, Interstate 75 and access to the Mackinac Bridge, which puts forests in the northern Lower Peninsula within reach. So too are the forests of northern Ontario, via Sault Ste. Marie's international crossing with Canada.

Michigan has about 800 logging firms. Most loggers are independent contractors and run their family businesses. Loggers are supposed to possess many skills which include logging, maintaining their equipments, forestry know-how, accounting, and be able to work with the private forest owners. It is a hard job with many risks. While there are many combinations of equipments, a common set-up includes a feller-buncher and skidder. A feller-buncher is a large machine that has big cutter on the end of a mechanical arm. The cutter holds the trees at once and

places it in small piles, where they are cut into logs by people with chainsaws. Skidder is used to pull whole trees to a collecting point called landings.

2.1) Actors

There are primarily two actors in the production of ethanol- the ethanol producer and the logging firm. The ethanol producer processes the wood logs into ethanol by using an enzymatic process. The producer designs a contract for procuring the wood from the logging firms in Upper Peninsula. The contract would typically carry quality and compensation details. The loggers generally don't own the timberland and the trees. They buy the trees from the forest land owners by paying the stumpage (price of the standing timber, before trees are harvested).

The prices paid for a specific stand of timber will vary considerably due to such factors as size, species, quality, logging conditions, distance to the mill, end product, demand and competition. Timber markets often change rapidly. The timberland owners generally obtain assistance from professional foresters and use the competitive bidding process as the ultimate determinant of fair market value for any specific tract of timber (Michigan DNRE, 2010). In the case of procuring wood for ethanol, logging conditions and distance to the processing facility would be the key factor for stumpage price determination.

The next task of the loggers is to ship the wood to a landing area. A landing area is a small clearing where loggers gather the logs. The landing area is owned and operated by the logging companies. At the landings, the truckers hired by the ethanol producer, pick up the logs.

Operators can load an entire truck with about 15 to 20 cords (cord is a pile of eight-foot logs (or

100" pulpsticks) that is four feet tall and four feet wide) in less than 60 minutes. Logs are then chained into place so that they don't shift during transport to the processing facility.

The prices paid for a specific stand of timber will vary considerably due to such factors as size, species, and quality, logging conditions, distance to the mill, end product, demand and competition. Timber markets often change rapidly. The timberland owners generally obtain assistance from professional foresters and use the competitive bidding process as the ultimate determinant of fair market value for any specific tract of timber (Michigan DNRE, 2010). In the case of procuring wood for ethanol, logging conditions and distance to the processing facility would be the key factor for stumpage price determination.

2.2) Potential Problems

2.2.1) Moral Hazard Problem

Delay in landing operations is very common in the winter season when the snowfall makes it operations difficult and costly. The additional equipments include snow removers to clear the road for transportation (very few logging firms have their own snow removal vehicles) and hire more number of loggers to perform the same task. The total fuel and labor cost is high during winters. Hence higher effort implies higher disutility for the logger. However the effort of the agent is not verifiable. A number of factors contribute to non-verifiability of the effort of the logging firm. This includes the spatial nature of operations, the complex procedure involved in the logging and landing operations and humungous monitoring cost.

Effort is not observed hence it cannot be included in the contract. The observed variable is output, in cases where the ethanol producer is contracting with a single logging firm. Hence contract can be set based on output realized, i.e., output stands as proxy for effort with a good amount of consistency. The problem becomes more complex when multiple agents are involved. The principal can only observe the group output due to the lumpy nature of the production process. However, for purpose of compensation and to incentivize the agents to provide high effort marginal output is necessary information but it is not known.

2.2.2) Adverse Selection Problem

Ethanol producer is expected to contract with multiple loggers. This gives rise to adverse selection problem due to inability of the principal to observe the agent type. On a day when snowfall is heavy, the agents are required to exert very high levels of effort to perform the landing operations instantly, in order to avoid the fall of cellulosic content. This means greater disutility for the agent.

Agents are aware of the fact that is not possible for the principal to make an approximation of the agent's effort by visualizing the logs of wood supplied by them because principal observes only total output. Hence they have incentives to delay the landing operations and instead supply the fresher logs to nearby factories for example-paper and pulp industry, furniture firms etc. because in these industries, the agent's effort can be ascertained by visualizing and touching the wood (Green & Ross, 1997). In the background of this information, the low ability loggers (defined as those with lower logging skills and lesser equipments and employees) would self-

select themselves in the ethanol industry. We would formally show that how this would adversely affect the principal's utility function.

3) The Conceptual Framework

This section presents the analysis of various contractual schemes between the ethanol producer and the logging firm(s) in the principal-agent framework. We begin by explaining the source of tension between the principal and agent followed by a discussion of the model under symmetric information. Then we examine the case of asymmetric information, the incentive mechanism under the first best solution, and the optimal contract design in the presence of moral hazard and adverse selection problems.

3.1) Elements of the Problem

The cellulosic ethanol producer is the principal who contracts the agent to supply wood. The prime objective of the principal and the agent is to maximize their respective utility functions. Their utility function can be expressed as follows:

(1) Principal's utility function: $B[R(c(t)) - w]$

(2) Agent's utility function: $U(w, e) = u(w) - v(e)$

$R(c(t))$: denotes the revenue from the sale of ethanol is function of the cellulosic content in the wood which in turn is dependent on time taken t taken in landing operations after the tree has been cut.

w: compensation received by the agent.

e: agent's effort exerted during logging and landing.

v (.): disutility from a particular level of effort.

For the sake of simplicity, we assume a single-shot game and just two effort levels: high effort and low effort. Hence $e \in (e^H, e^L)$ and that disutility from higher effort is more than disutility from lower effort level, i.e. $v(e^H) > v(e^L)$

The agent is interested in w, which is cost to the principal, whereas the principal is interested in higher levels of e, because high e implies higher cellulose content and hence higher R, but high e translates into higher disutility for the agent. This explains the source of conflict in the relationship.

Outcome does not only depend entirely on logger's effort but also on random factors which are beyond the control of the logger. A partial list of such factors includes forestry practices of the landowner, specie harvested, weather, technological constraints, ethanol demand etc. Hence, we can attach probability values to each type of effort that can result into various levels of revenue for the principal. This is formally expressed as:

$$Pr[R=R_i | e] = p_i(e) \text{ for } i \in (1, 2, 3, \dots, n).$$

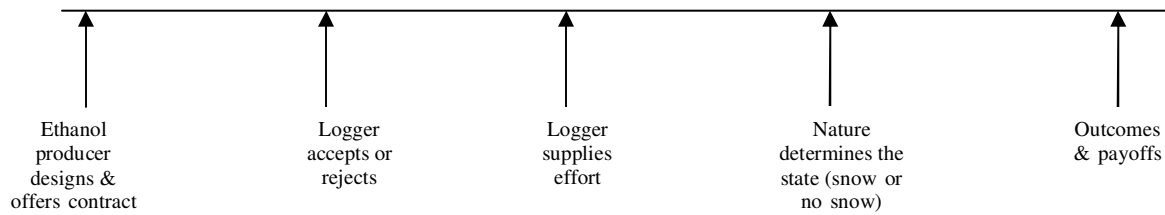
3.2) Base Model

The base model is the perfect or symmetric information model. The principal and the agent share the same level of information with respect to the variables and functions determining the

relationship (such as production function, or the distribution of the random variable) and with respect to identities (both know the utility function of the other) and behavior relevant to the relationship. It implies that the principal can observe the effort exerted by the agent without any positive monitoring cost. Whatever informational asymmetries may exist, they are common for both the players.

The bargaining relationship between the ethanol producer and the logging firm is presented graphically in the figure 3.1

Figure 3.1 The Order of Moves under Symmetric Information



When the logging and landing effort is verifiable and the output is observable, the ethanol producer's decision process can be modeled as the following maximization problem:

$$\text{Max } P_H^H B[R_H - w(R_H)] + P_L^H B[R_L - w(R_L)]$$

$$[e, \{w(R_i)\}_{i=1,2,\dots,n}]$$

s.t.

$$\text{PC: } P_H^H u(w_H) + P_L^H u(w_L) - v(e_H) \geq \bar{U}$$

\bar{U} is the logger's reservation utility and equals the utility from the compensation he receives in the other wood based industry like paper and pulp producing firms or the furniture industry.

The optimal contract under the symmetric information would be fixed payments depending on the effort level observed by the ethanol producer. We derive the following solution after having set up the lagrangian function of the above maximization problems and then finding the first order conditions with respect to effort e and compensation w :

$$w^H = u^{-1}[\bar{U} + v(e_H)]$$

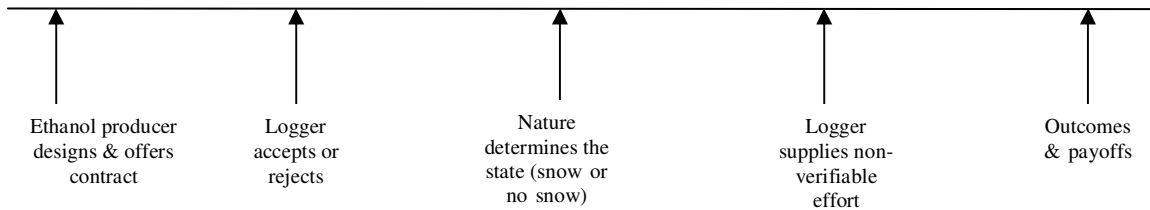
The producer would offer w^H for high effort and $w^L = 0$ for low effort in order to incentivize the logger to provide higher effort.

3.3) Model under Asymmetric Information (Contracting with only One Agent)

One can think of the situations that deviate from the symmetric information case. Informational asymmetries can arise due to agent's behavior during the relationship. We have already discussed such a scenario in section 4 where the ethanol producer cannot observe the effort of the logging firm to ensure timely logging and landing operations. As a result the principal cannot distinguish between suboptimal outputs caused due to factors beyond the control of the agent or due to agent's opportunistic behavior i.e. lower effort is exerted on a snowy day in order to bring down operations cost.

We have graphically represented the relationship between the logging firm and the ethanol producer under asymmetric information graphically in the figure 3.2

Figure 3.2 The Order of Moves under Asymmetric Information (Contracting with One Agent)



The extent to which the agent deviates from the principal's desired level of effort can be captured by the variable L , which is defined as the portion of cellulose lost due to delay in landings. If agent puts high effort then $L=0$ with probability $P(R_H | e_H)$, and if agent exerts low effort, then $0 < L < 1$.

Under the present scenario if the principal gives fixed wage \bar{w} , to the agent, the payoff functions for the agent:

$$EU^H = u(\bar{w}) - v(e^H)$$

$$EU^L = u(\bar{w}) - v(e^L)$$

Since $v(e^H) > v(e^L)$, the agent will choose the lower level of effort. In that case, the utility of the principal is $B[R(c) * (1 - L) - \bar{w}]$. Hence, we have the moral hazard problem if we impose the first best solution to the asymmetric case of non-verifiable agent's effort.

3.4) Model under Asymmetric Information (Contracting with Multiple Agents)

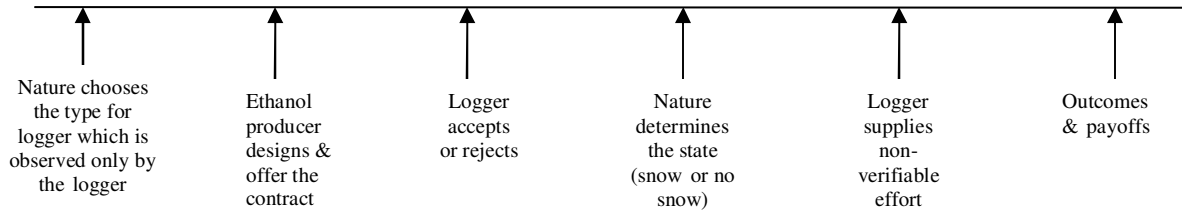
While contracting with multiple loggers, there are three sources of information asymmetry (i) the non-verifiable agents' effort and (ii) the type of agent and (iii) the marginal output. In addition to moral hazard, the principal faces adverse selection problem when principal deals with multiple agents.

Vast quantities of wood are logged by foresters to provide fibers (for pulp, paper products, and boards), and saw timber (for house building and furniture). The processors of these wood based products are concerned with the tensile strength of the wood that is, lignin content. Lignin is a glue-like polymer in the cell wall of plants that surrounds cellulose to provide strength to fibers and to resist microbial decay. The hardness of the wood can be approximately ascertained through visual observation. The monitoring cost in such industries is hence not very high. As a result, the low type firms would find it difficult to have contractual arrangements with the fiber and timber processors.

The ethanol producer is concerned with the cellulosic content in the wood. They don't need strong trees because lignin is difficult to break down for cellulose extraction and requires chemical pretreatment (Chiang et. al., 2010). Chemical pretreatment raises the cost for using the wood as the source of cellulose. It is not possible to examine the cellulose content outside the laboratory. Therefore the agent's output is not observed. Moreover compensation to the logger must be equal or greater than the existing levels. Hence, the low type agent has the incentive to self select himself in the contractual relationship with the ethanol producer.

The general scheme of the game that we will be analyzing is shown in figure 3.3.

Figure 3.3 The order of moves under Asymmetric Information (Contracting with Multiple Agents)



The application of first best or Pareto efficient solution in this case will lead to twin problems of moral hazard and adverse selection. The payoff functions of the ethanol producer and the logger under the status quo are summarized in Figure 3.4. EU and EB denote the expected utilities of the logging firm and the producer respectively with subscripts denoting the type of the agent (High, Low) and the superscripts denoting the effort level (High, Low).

From the figure 3.4, it is evident that the ethanol producer will prefer to contract with high type agent because if both types exerts high effort then $EB_H^H > EB_L^H$. This holds true because $v(e_H^H) < v(e_L^H)$, i.e. the disutility of exerting high effort to high type is less than to the low type. Moreover the low type has incentive to self-select into ethanol market under status quo because $EU_L^L > \bar{U} = u(\bar{w}) - v(e^L)$. This illustrates the presence of moral hazard (high type chooses low effort) and adverse selection (low type self-selects) under the first best case.

Figure 3.4 Payoff Functions of Ethanol Producer and the Logging firm under Status Quo

		Agent's effort level	
		High	Low
Agent's type	High	$EU_H^H = \sum_{i=1}^n P_i^H(e) u(\bar{w}) - v(e_H^H)$ $EB_H^H = \sum_{i=1}^n P_i^H(e) B(R - \bar{w})$	$EU_H^L = \sum_{i=1}^n P_i^L(e) u(\bar{w}) - v(e_H^L)$ $EB_H^L = \sum_{i=1}^n P_i^L(e) B[(R(1-L) - \bar{w})]$
	Low	$EU_L^H = \sum_{i=1}^n P_i^H(e) u(\bar{w}) - v(e_L^H)$ $EB_L^H = \sum_{i=1}^n P_i^H(e) B(R - \bar{w})$	$EU_L^L = \sum_{i=1}^n P_i^L(e) u(\bar{w}) - v(e_L^L)$ $EB_L^L = \sum_{i=1}^n P_i^L(e) B[(R(1-L) - \bar{w})]$

4) Optimal Contract under Asymmetric Information

4.1) Contracting with One Agent

The agent's effort is not verifiable but the output is observable. Hence, the wage is not fixed, but is some function of output R. The principal would solve following maximization problem:

$$\text{Max } \sum_{i=1}^n P_i^H B(R_i) - w(R_i)$$

$$[e, \{w(R_i)\}_{i=1,2,\dots,n}]$$

s.t.

$$\text{PC: } \sum_{i=1}^n P_i^H u[w(R_i)] - v(e^H) \geq \bar{U}$$

$$\text{IC: } \sum_{i=1}^n P_i^H u[w(R_i)] - v(e^H) \geq \sum_{i=1}^n P_i^L u[w(R_i)] - v(e^L)$$

PC is the participation constraint, through which the principal ensures that the agent accepts the contract by paying him at least the reservation wage. IC is the incentive compatibility constraint through which the principal incentivizes the agent to choose the high effort over low effort. Here we have assumed that monitoring cost to be zero.

In the repeated game, the principal can induce the agent not to defect from the high effort strategy by paying efficiency wages w^* (Moretti and Preloff, 2002). Efficiency wages are the wages above the market-clearing wage which is paid in order to provide incentives to the agent to provide higher level of efforts. The efficiency wage would increase the cost of defection for the agent and hence he would comply with the decision of the principal.

4.2) Contracting with multiple agents

Total output is observed but not the marginal output. This is not team production but the complexity of the production process gives rise to metering problem (Alchian and Demsetz, 1972). In the principal agent setup, the final output produced by individual agent is essential to

determine the compensation that should be made to individual agent. Since, effort cannot be linked to output, the optimal contract design is not possible. Prohibitive monitoring cost renders the payment of efficiency wages ineffective and it only adds to the cost of the principal. The probability of getting caught is very low hence the agents find it profitable to defect from the cooperation strategy.

The argument presented here is that moving away from specification contract towards vertical integration, for instance, joint venture, helps in solving the problem efficiently by correcting the incentives mechanism. If few of the big logging firms were to form a cooperative to supply wood and also have equity in the ethanol refinery, it is easier to ensure that the interest of both the parties is become aligned.

McAfee and McMillan (1991) work on optimal contracts for teams suggest that a team subject to both adverse selection and moral hazard, optimal contracts are linear in output under certain conditions. They conclude that the outcome is same whether the principal observes just the total output or each individual's contribution. Thus monitoring is not needed to prevent shirking by team members; instead the role of monitoring is to discipline the monitor.

Holmstrom (1982) showed that in team production under moral hazard, the principal can ensure a full information outcome by offering a contract that punishes each team member arbitrarily severely whenever team output falls below some target. However, this seems an impractical method of solving moral hazard. Moreover, for our purpose the principal cannot disentangle an agent's effort from his ability.

In the special case where agents' type is common knowledge, the moral hazard problem can be completely solved. The principal is needed to adjust the incentive constraint such that any increase in the marginal product is distributed among all the agents. This will give each agent enough incentive to exert desired effort. However principal's variable costs will increase. This can be easily counteracted in the linear form of the contract. The fixed part of the payments is negative in order to account for increase in the principal's cost.

The changed relationship would greatly reduce the monitoring costs and each member would get the share in the group compensation and not individual compensation and they would pay a fixed amount to the ethanol producer which will indicate t . The problem is hence again reduced to when principal contracts with one agent- the Loggers' Cooperative. Interestingly, Mascoma Corporation has already entered into a joint venture with JM Longyear, a forest management and logging company. JML has 25% interest in the joint venture.

5) Possibility of Further Work

There is immense literature on optimal contracting when more than one agent is hired by the principal to perform task(s). The implicit assumption is: the marginal productivity is observed by the principal. The investigation of the scenarios in which metering of individual output is not possible, would be an important addition to the literature and would also find relevant application in fields where group production is an important element in the relationship. Apart from conducting case studies analyzing the possible outcomes of such a relationship, there would

be enormous addition to our understanding if data were to become available for the purpose of econometric exercise.

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