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Centralization Versus Decentralization of Decision Making Authority:  
Effects on Information Acquisition and Economic Efficiency

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Choices regarding the degree of centralization or decentralization of decision making are important for agribusiness firms and, in particular, for agricultural cooperatives. The agricultural cooperative sector is characterized by two alternative forms of organization structure. The federated system of cooperatives, which predominates in the Midwest, is an example of decentralization. Farmers belong to local cooperatives which are, in turn, members of regional cooperatives. Centralization of decision making characterizes the centralized system of cooperatives, which can be found in the Northeast and Southeast. In this case farmers are members of the centralized cooperative, which compares in size and function to the regionals in the federated system. The centralized cooperative operates service outlets that farmers encounter on a day-to-day basis.

As noted by van Ravenswaay, centralization of decision making authority is an issue common in the organization design literature. This issue has, however, received little attention in the economics literature. A recent article by Sah and Stiglitz is one exception. They present a model which considers how the structure of an organization affects errors in decision making and, therefore, the quality of decision making. In particular questions regarding the probability that new projects will be undertaken and overall profitability with different organization structures are considered. In this paper we modify and extend the model of Sah and Stiglitz to evaluate different aspects of economic efficiency for alternative industry structures.

In the sections which follow we first describe the model we use to consider the effects of centralization versus decentralization of investment decisions. We then use the model to derive optimization conditions that yield

information on the probability that a project will be adopted, the expected profit for the firm and for the industry as a whole, and firms' expenditure on information. Comparative static analysis is performed to consider how firms adjust their expenditure on information as a result of structural and environmental changes. A numerical example is then presented, followed by conclusions and suggestions for further study.

### The Model

This model is developed from the perspective of firms evaluating and ultimately adopting or rejecting investment projects. The profit maximizing decision for a firm is to accept all projects with a positive net return and reject all projects with a negative net return, since the net return includes opportunity costs. A key aspect of this analysis is the fact that firms evaluate projects without perfect information and, as a result, reject some good projects and accept some bad projects. As firms acquire more information, the proportion of good projects rejected and the proportion of bad projects accepted is reduced.

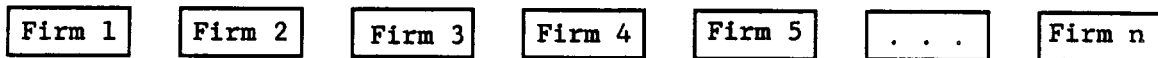
This model assumes that firms choose a level of expenditure on information, evaluate a set of projects and, according to a decision rule, adopt some proportion of this set. The initial portfolio of projects, from which firms are assumed to receive a random draw, is specified by a probability distribution,  $f(X)$ . Projects which are adopted by the industry make up the final portfolio of projects which depends upon the distribution of the initial portfolio of projects, the structure of the industry, the decision rule employed and the level of expenditure on information.

The alternative industry structures considered in this study are shown in Figure 1. In the Pure Polyarchy, a number of firms independently evaluate and

Figure 1: Industry Structures

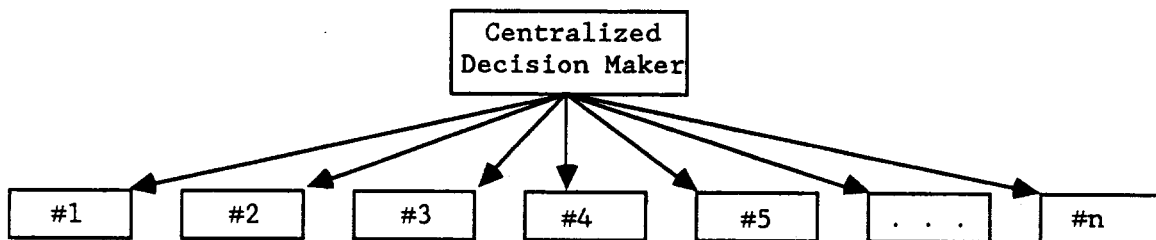
## Pure Polyarchy

Each project is independently evaluated by each of the  $n$  firms with a decision to accept or reject.



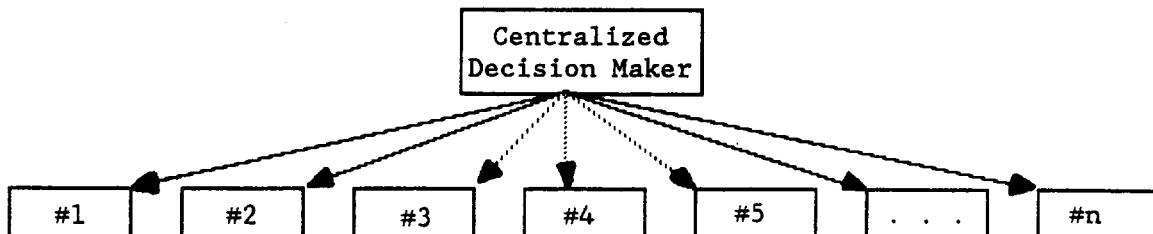
## Pure Hierarchy

The centralized decision maker evaluates projects and, for those projects accepted, implements them in all  $n$  production units.



## Mixed-Decentralized Decision

Projects that are accepted by the centralized decision maker are then evaluated by the decentralized units, which independently decide to accept or reject projects.



undertake projects. All projects are available for adoption by all firms. This case resembles the decisions of local cooperatives in the federated system. The industry consists of one firm with a number of production units in the Pure Hierarchy. Projects are evaluated centrally and, if accepted, are implemented in all production units. The centralized cooperative system is best described by this structure. In the final structure, Mixed-Decentralized Decision, decision makers at both the decentralized and the centralized level evaluate projects. All projects are first reviewed centrally and, if accepted, are forwarded to the decentralized firms which independently evaluate and accept or reject projects. This resembles the federated cooperative system when an investment project is first identified by the regional cooperative. Local cooperatives are then free to adopt or reject projects that are recommended by the regional.

To allow for comparisons among the industry structures, it is assumed that the decentralized firms in the Pure Polyarchy and the Mixed-Decentralized Decision are equal in size and number to the production units in the Pure Hierarchy. It is further assumed that the net benefit any one firm or production unit experiences is independent of whether or not others develop the project. This assumption will hold if the nature of the projects is such that its net benefit is not influenced by the number adopting the project or if the industry is small relative to the rest of the world.

As noted earlier, the decision rule influences the final portfolio of projects. In evaluating a project, decision makers observe a net return equal to some value  $Y$ . Decision makers accept projects when  $Y > 0$  and reject projects when  $Y < 0$ . Since decision makers have incomplete information regarding projects, the observed net return for a project will differ from

its true net return. Defining the true net return as  $X$ , it follows that  $Y = X + \theta$ . In this analysis, it will be assumed that  $\theta$  is a normally distributed random variable with mean zero and variance  $\sigma_\theta^2$ . The probability that a decision maker accepts a given project with net return  $X_1$  is:

$$P(Y_1) > 0 = P(X_1 + \theta > 0) = \Phi(X_1/\sigma_\theta),$$

where  $\Phi(X_1/\sigma_\theta)$  is the standard normal distribution evaluated at  $(X_1/\sigma_\theta)$ .

Although this analysis considers the critical value for accepting or rejecting a project to be zero, the analysis could easily be adjusted for some alternative critical value. Sah and Stiglitz identify how the reservation level or critical value that decision makers select changes with the industry structure.

The focus of this study is on how the firm's expenditure on information varies with industry structure. Acquisition of information reduces uncertainty by reducing  $\sigma_\theta$  according to a cost of information function,  $c(\sigma_\theta)$ , with  $\partial c/\partial \sigma_\theta < 0$ . In this analysis, the cost function is assumed to have the form  $\gamma/\sigma_\theta$ . Each firm is, thus, faced with the problem of adjusting  $\sigma_\theta$  to maximize expected return minus expenditure on information. All firms face the same cost of information function and know its form with certainty.

For a firm in the polyarchy, the probability of accepting a particular project is  $\Phi(X/\sigma_\theta)$ . With  $n$  firms in the industry, the probability that a particular project is adopted by at least one firm is one minus the probability that none of the firms adopt the project or  $1 - (1 - \Phi(X/\sigma_\theta))^n$ . For any one firm in the Pure Polyarchy, evaluating  $m$  projects the objective is to:

$$(1) \text{Max}_{\sigma_\theta} \int_0^m [X f(X) \Phi(X/\sigma_\theta)] dX - (\gamma/\sigma_\theta)$$

The first order condition for this maximization problem is:

$$(2) \int [X^2 f(X)\phi(X/\sigma_g)]dX = (\gamma/m)$$

where  $\phi(X/\sigma_g)$  is the standard normal density evaluated at  $(X/\sigma_g)$ .

A sufficient condition for the existence of a local maximum in this and the next two cases is that the second derivative of the objective function with respect to  $\sigma_g$  be less than zero. With  $f(X)$  assuming a normal distribution this second order condition holds if  $\alpha^2 > 2$ , where  $\alpha$  is the mean of the distribution.

From equation two one can see that, irrespective of the initial portfolio, as the number of projects,  $m$ , increases, the firm will spend more on information, decreasing  $\sigma_g$ . To maintain the equality in equation two, the decrease in the right-hand side of the equation must be matched by a decrease in the left-hand side of the equation.  $\phi(X/\sigma_g)$  is the only left-hand side term which the firm has any control over and will decrease as  $\sigma_g$  decreases. Similarly as  $\gamma$ , the parameter of the cost function, increases, the firm will spend less on information and thus increase  $\sigma_g$ .

The probability that the pure hierarchy will accept a given project is  $\Phi(X/\sigma_g)$ . Since the acceptance or rejection of a project is determined solely by the decision of the hierarchy, the probability that a given project is adopted is also  $\Phi(X/\sigma_g)$ . Since a project has  $n$  chances of being accepted in the pure polyarchy and only one chance in the pure hierarchy, the probability that it will be accepted is greater in the former case. This intuitive result follows analytically because

$$1 - (1 - \Phi(X/\sigma_g))^n > \Phi(X/\sigma_g).$$



The objective for the firm in the hierarchy is to:

$$(3) \text{ Max}_{\sigma_{\theta}} \text{ mn} \int [ X f(X) \Phi(X/\sigma_{\theta}) ] dX - (\gamma/\sigma_{\theta})$$

The first order condition for this maximization problem is:

$$(4) \int [ X^2 f(X) \Phi(X/\sigma_{\theta}) ] dX - (\gamma/(n m))$$

The same comparative static results hold for the hierarchy as for the polyarchy with respect to changes in the number of projects and the parameter of the cost function. It also follows that as the number of production units,  $n$ , increases, the hierarchy will spend more on information, thereby reducing the level of  $\sigma_{\theta}$ .

In the Mixed-Decentralized Decision structure decision makers at both the centralized and the decentralized level are acquiring information to reduce  $\sigma_{\theta}$ . For this structure the subscript  $c$  on  $\sigma_{\theta}$  will refer to the centralized firm while the subscript  $d$  to the decentralized firm. The probability that a given project is accepted by a given decentralized firm is  $[\Phi(X/\sigma_{\theta c}) \cdot \Phi(X/\sigma_{\theta d})]$ , since it must first be accepted by the centralized firm with a probability of  $\Phi(X/\sigma_{\theta c})$  and then accepted by the decentralized firm with a probability of  $\Phi(X/\sigma_{\theta d})$ . The probability that a given project is adopted by at least one of the decentralized firms is  $1 - [1 - (\Phi(X/\sigma_{\theta c}) \cdot \Phi(X/\sigma_{\theta d}))]^n$ . It can be shown analytically, under fairly unrestrictive assumptions, that

$$(1 - [1 - (\Phi(X/\sigma_{\theta c}) \cdot \Phi(X/\sigma_{\theta d}))]^n) < \Phi(X/\sigma_{\theta}),$$

and, therefore, that a project has the smallest probability of being accepted in this third system. The intuitive explanation is that a project must pass through two evaluation processes in this latter structure, making it

more difficult for acceptance than in either the Pure Polyarchy or the Pure Hierarchy.

Since a project has the greatest chance of being adopted in the Pure Polyarchy and the least chance in the Mixed-Decentralized Decision structure, for any given portfolio of projects, the greatest percentage of projects will be adopted in the Pure Polyarchy, followed by the Pure Hierarchy and the Mixed-Decentralized Decision structure. One would expect, therefore system-wide profits to be greatest in the Pure Polyarchy when the initial portfolio contains mostly good projects. Alternatively, if the initial portfolio contains a majority of bad projects the Mixed-Decentralized Decision structure will yield the highest expected profit.

Defining the share of net return received by the decentralized firm as  $s$  and the share received by the centralized firm as  $(1-s)$ , the objective for the centralized firm in Case 3 is to:

$$(5) \text{ Max}_{\sigma_{\theta_c}} (1-s)mn \int [ X f(X) \Phi(X/\sigma_{\theta_c}) \Phi(X/\sigma_{\theta_d}) ] dX - (\gamma/\sigma_{\theta_c})$$

The first order condition for this maximization problem is:

$$(6) \int [ X^2 f(X) \phi(X/\sigma_{\theta_c}) \Phi(X/\sigma_{\theta_d}) ] dX = (\gamma/((1-s) n m))$$

The same comparative static results hold for this centralized firm as for the Pure Hierarchy with respect to the parameter of the cost function, the number of projects and the number of decentralized units. If the share of the net return that the centralized unit receives,  $(1-s)$ , increases the firm will spend more on information, thus reducing the level of  $\sigma_{\theta}$ . If the centralized firm receives all of the net return ( $s=0$ ), and the decentralized firms do not always accept all projects,  $\Phi(X/\sigma_{\theta_d}) < 1$ , the centralized firm will spend less

on information than the Pure Hierarchy. Since it is more realistic to consider the case where  $s > 0$ , there is even more reason to believe that the centralized unit will spend less on information than the Pure Hierarchy. The objective for the decentralized firm in Case 3 is to:

$$(7) \text{ Max}_{\sigma_{gd}} \quad s m \int [ X f(X) \Phi(X/\sigma_{gc}) \Phi(X/\sigma_{gd}) ] dX - (Y/\sigma_{gd})$$

The first order condition for this maximization problem is:

$$(8) \quad \int [ X^2 f(X) \phi(X/\sigma_{gd}) \Phi(X/\sigma_{gc}) ] dX - (Y/(s m))$$

The same comparative static results hold for this decentralized firm as for the Pure Polyarchy with respect to the parameter of the cost function and the number of projects. It can be shown that as the share of the net return that the decentralized firm receives,  $s$ , increases the firm will spend more on information, thus reducing the level of  $\sigma_{gd}$ . If the decentralized firm receives all of the net return ( $s=1$ ), and the centralized firm does not always accept all projects,  $\Phi(X/\sigma_{gc}) < 1$ , the decentralized firm will spend less on information than the Pure Polyarchy. With  $s < 1$ , there is further evidence that the decentralized firm will spend less on information than the Pure Polyarchy.

To consider the level of expenditure on information that the firms in the mixed case would make if their objective was to maximize the industry returns, we consider the objective of the social planner:

$$(9) \text{ Max}_{\sigma_{gc}, \sigma_{gd}} \quad mn \int [ X f(X) \Phi(X/\sigma_{gc}) \Phi(X/\sigma_{gd}) ] dX - n (Y/\sigma_{gd}) - (Y/\sigma_{gc})$$

The first order conditions for this maximization problem are:

$$(10) \quad \int [ X^2 f(X) \phi(X/\sigma_{gc}) \Phi(X/\sigma_{gd}) ] dX - (Y/(n m))$$

$$(11) \quad \int [ X^2 f(X) \phi(X/\sigma_{gd}) \Phi(X/\sigma_{gc}) ] dX - (Y/(m))$$

A sufficient condition for the existence of a local maximum is that the second derivative matrix from the objective function be negative semi-definite.

Comparing the first order conditions of the social planners' problem to those of the individual firms' maximization problem, and noting that  $0 < s < 1$ , it can be shown that all firms spend less on information when making independent profit maximizing decisions than if they were maximizing industry returns.

Further comparative static analysis can be performed for the Pure Hierarchy and the Pure Polyarchy if some structure is assumed for the to the probability distribution of the initial portfolio. In particular, we assume that the initial portfolio of projects is normally distributed with mean  $\alpha$  and variance  $\beta^2$ . The first order condition for the Pure Polyarchy case, after substituting for  $f(X)$  and  $\phi(X/\sigma_\theta)$ , becomes:

$$(12) \quad \frac{1}{\beta\sqrt{2\pi}} \int X^2 \frac{1}{\sqrt{2\pi}} \exp\left\{-\frac{1}{2}\left[\left(\frac{X-\alpha}{\beta}\right)^2 + \left(\frac{X}{\sigma_\theta}\right)^2\right]\right\} dX = \frac{Y}{m}$$

By completing the square in the expression  $\exp(-1/2[(X-\alpha)^2/\beta^2 + X^2/\sigma_\theta^2])$  and rearranging terms, one obtains an expression of the form  $K \int X^2 g(X) dx$ , where  $g(X)$  is a normal density function with mean  $\sigma_\theta^2\alpha/(\beta^2 + \sigma_\theta^2)$  and variance  $\beta^2\sigma_\theta^2/(\beta^2 + \sigma_\theta^2)$ . Noting that  $\int X^2 g(X) dX = E(X^2)$  and that  $E(X^2)$  is equal to the square of the mean plus the variance the following can be obtained:

$$(13) \quad \left\{ \exp\left[ -\frac{1}{2} \frac{\alpha^2}{\beta^2 + \sigma_\theta^2} \right] \right\} \left\{ \frac{\beta^4 \sigma_\theta^3 + \beta^2 \sigma_\theta^5 + \alpha^2 \sigma_\theta^5}{(\beta^2 + \sigma_\theta^2)^{\frac{5}{2}} \sqrt{2\pi}} \right\} = \frac{Y}{m}$$

Equation 13 holds for the Pure Hierarchy with the right-hand side replaced with  $Y/mn$ . It can be shown from this first order condition that an increase in the mean of the initial portfolio will cause an increase in the expenditure

on information,  $\partial\sigma_g/\partial\alpha < 0$ , if  $\alpha > 0$ ,  $\sigma_g^2 > \beta^2$  and  $2\sigma_g^2 > \alpha^2$ . The intuitive explanation of the conditions is as follows. The condition  $\sigma_g^2 > \beta^2$  identifies that firms will invest in reducing uncertainty when the mean of the initial portfolio increases if the variance that they have control over,  $\sigma_g^2$ , is greater than the variance that they have not control over,  $\beta^2$ . As the mean of the initial portfolio increases, firms' expected net return increases enabling them to afford to spend more on information. However, as the mean of the initial portfolio increases, firms know there is a better chance that the projects they consider are good and do not spend as much on information. The condition  $2\sigma_g^2 > \alpha^2$  reflects these two forces.

#### Numerical Example

A numerical example illustrates the impact on expected profits for the Pure Polyarchy and the Pure Hierarchy of changes in the distribution of the initial portfolio, the number of projects examined and the number of decentralized units in the system. Table 1 reports the results for five cases. The profit maximizing level of  $\sigma_g$  was determined from equation 13 and then substituted into equations one and three to obtain the maximum level of expected profits. Numerical integration was used to evaluate equations one and three, since analytical integration is not possible.

Considering Case 1 as the base case and comparing the other cases to it, one observes that, as expected, an increase in the mean of the initial distribution, the number of projects or the number of decentralized units results in an increase in expected profit. An increase in the standard deviation of the initial distribution also results in an increase in expected profit due to the fact that there are now projects in the initial portfolio with a much larger net return.

Table 1. Expected Profit and Optimal Level of  $\sigma_\theta$ 

|                      |                      | <u>Pure Polyarchy</u>      |                                | <u>Pure Hierarchy</u>      |                    |
|----------------------|----------------------|----------------------------|--------------------------------|----------------------------|--------------------|
|                      |                      | Optimal<br>$\sigma_\theta$ | Expected<br>Profit<br>(System) | Optimal<br>$\sigma_\theta$ | Expected<br>Profit |
| $\alpha=5$<br>$m=5$  | $\beta=10$<br>$n=5$  | 12.15                      | 96.95                          | 5.34                       | 144.66             |
| $\alpha=10$<br>$m=5$ | $\beta=10$<br>$n=5$  | 11.00                      | 195.15                         | 5.63                       | 243.48             |
| $\alpha=5$<br>$m=5$  | $\beta=15$<br>$n=5$  | 11.41                      | 146.37                         | 5.80                       | 193.13             |
| $\alpha=5$<br>$m=10$ | $\beta=10$<br>$n=5$  | 8.05                       | 244.35                         | 4.08                       | 310.51             |
| $\alpha=5$<br>$m=5$  | $\beta=10$<br>$n=10$ | 12.15                      | 193.91                         | 4.08                       | 310.51             |

Note:  $\gamma=100$  in all cases.

Expected Profit for the system in the Pure Polyarchy equals the Expected Profit for one firm times the number of firms.

Economies of scale in the acquisition of information account for several of the results presented in Table 1. Expected profit is greater when the firm or firms are able to allocate expenditure on information over a larger domain. One example of this is that expected profit for the Pure Hierarchy is always greater than the system-wide expected profit for the Pure Polyarchy. A second example is that a doubling of the number of projects from Case 1 to Case 4 results in a more than doubling of expected profit for both the Pure Polyarchy and the Pure Hierarchy. Finally a doubling of the number of decentralized units from Case 1 to Case 5 causes the expected profit for the Pure Hierarchy to increase more than two-fold.

### Conclusions

The model presented here identifies systematic ways in which the degree of centralization of decision making authority affects various aspects of economic efficiency. In particular, it is noted that the Pure Hierarchy structure dominates if the objective is to maximize expected profit. If, however, the objective is innovation the Pure Polyarchy dominates since an investment project has the greatest chance of being adopted in this structure. With respect to the agricultural cooperatives, these issues raise questions such as: Were there economic and political factors that lead to the different industry structures when the cooperatives formed? How has the difference in structure affected different aspects of economic efficiency in agricultural cooperatives?

This superior performance by the Pure Hierarchy suggests a limitation of our model and an opportunity for further study. Decision makers in the decentralized units may have specific information regarding profitability that the centralized decision maker does not have. To reflect this, the

model would incorporate a smaller variance when decisions are made in the decentralized units as compared with the centralized units. Further study could also consider alternative probability distributions for  $\theta$ , alternative forms for the cost of information function, and alternative probability distributions for the initial portfolio. The mixed case identified here and other mixed cases require further work, especially given the fact that they are representative of actual firms. Since it appears that analytical solutions will be difficult and, in many cases, impossible for these mixed structures, methods of alternative analysis, such as Monte Carlo simulation, need to be explored.

The theoretical results obtained from this model offer an exciting and challenging opportunity for empirical research. One of the challenges for such research is to derive a control situation to which other cases can be compared. Measuring the cost of information, in light of the fact that firms often employ informal information, will be difficult. In addition, measuring the distribution of  $\theta$  presents a further challenge since errors, by their very nature, are unobservable. The results from such empirical research will be of interest to agents in both cooperatives and investor owned firms, as well as to policy makers. Since additional insights into the effect of centralization of authority on the probability of accepting investment projects, expected profit and acquisition of information could have a significant impact on future actions of owners and managers, the challenges need to be addressed.



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