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RISK ANALYSIS FOR AGRICULTURAL PRODUCTION FIRMS: CONCEPTS, INFORMATION REQUIREMENTS AND POLICY ISSUES

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MODERN INFORMATION SYSTEMS: IMPLICATIONS FOR RISK RESEARCH

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Agriculture is a dynamic industry. The technology utilized in the production of food and fiber has changed much in the past century. Indeed, the industrial revolution has allowed substantial change in the manner in which resources are combined on the farm, with increasing substitution of capital for relatively more expensive labor.

There are several emerging technologies which may dramatically alter the way in which we produce on American farms. Biological technologies hold much promise for increased agricultural output by improving genetic quality of economic plant and animal species or altering the biological process converting inputs into outputs. Robotics and other electromechanical technologies are beginning to emerge, with significant promise for automation of mechanical processes in agriculture. Communications and computer technologies have changed dramatically, allowing substantially greater capabilities with significantly lower levels of investment than heretofore.

It is this last area of technological change, and the consequences that this may hold for an agricultural information system, that I wish to discuss today. In particular, I wish to discuss the implications of information technologies for risk management in the firm, and later, for risk management research.

There are many reasons why this topic is extremely relevant for current discussion. Even though information management has long been an important activity of the successful manager, it is becoming more important in today's world. The technology to collect and analyze data is emerging quickly. Only in the decade of the 1970's was a technology economically feasible for real time collection and processing of data in small businesses. This development allows availability of much greater quantities of data to the manager, and the ability to analyze larger quantities of data with more sophisticated analytical procedures than ever before possible. Combining this with a continued structural change in farming toward fewer and larger farm units, a diminished profit margin, the use of a larger proportion of inputs purchased from off the farm, increased cash flow requirements, and a resulting increase in the financial risk facing the firm, the result is an

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economic incentive for the manager to optimally control the production process and cost sources, and to reliably appraise marketing opportunities in order to remain profitable.

In what follows, I will introduce briefly the concept of an information system for agriculture, both at firm level and for the aggregate. Secondly, I will explore the consequences of this technology upon the incidence of risk for individual firms. Finally, we shall explore the implications for future research, teaching, and extension activities in agriculture.

What is a Management Information System?

The concept of a management information system (MIS) is nothing new. Clearly, managers always have used information when making decisions. This information has varied greatly in the source of data and the method by which data have been processed into information useful in the decision process. Over time, as markets have become more important and as the production process has become more complex, larger amounts of information have been required to make the decision process more precise.

Knowledge is truly an input in the production process. The degree of knowledge available modifies the way in which all other inputs are combined in the production process given the decision maker's particular objective function. However, knowledge is an input which is not available in the same manner as are other inputs. Knowledge is acquired by individuals in many ways, but nearly always is the intellectual composition of many individual facts. These facts may be gathered over time from a variety of sources and experiences.

To pursue this further, let us consider the definitions of knowledge, information and data. According to Webster, data are something given, granted or admitted; things known or assumed; or a premise upon which something can be argued or inferred. Data are a basic unit of fact, not known with certainty, and frequently measured with a degree of imprecision.

Inform is from the Latin informare which means to give form to. Webster defines inform as to give form or character to; to be the formative principle of; or to give, imbue or inspire with some specific quality or character. Information then results from the processing of raw data into something of more substance from which principles can be formed and enlightened decisions made.1/

Knowledge has an even more rigorous definition. Knowledge, according to Webster, is a clear and certain perception of something; the act, fact or state of knowing; or understanding. Knowledge, then, must be acquired over time by each individual, can be gained only through education or experience, and often comes by witnessing a failure of decision making made without certain knowledge. Because knowledge always will be incomplete, i.e., the knowledge base is infinite not finite, the decision maker must make decisions with the information that is available, even though there remains much uncertainty about the accuracy of the information or its applicability to the decision under consideration.

The information needs for decision making lead to systems for data collection, storage and processing. These systems vary greatly in degree or formality, data sources, methods of analysis, and ways that information is used once processed.

A system is a set of interrelated parts with a single purpose. A management information system involves a number of components or activities for the purpose of providing information to the management function. MIS has been defined as "the combination of human and computer-based resources that results in the collection, storage, retrieval, communication and use of data for the purpose of efficient management of operations and for business planning" (Kelly, p. 5): "A very highly organized combination of personnel, equipment, and facilities performing data storage and retrieval, data processing, transmission and display, all in response to the needs of decision makers at all levels of the business" (Cross, p. 15): "The methods by which an organization plans, operates, and controls its activities to meet its goals and objectives by utilizing the resources of money, people, equipment, materials and information" (Glans, et.al., p 3).

For the purposes of the discussion below, a MIS is considered to be a system composed of a database, methods for collection, entry and retrieval of data from storage, and techniques for processing data in a timely fashion into information useful for the decision process.

The Evolution of MIS in Agriculture

Managers of farm and agricultural business have long made use of some form of information system. In the early days of this country, agriculture was very much a subsistence rather than market enterprise. Inputs into the production process largely were drawn from the farm and family resource base. Input and output markets were less important than today. Trade was limited largely to local markets due to poor transportation facilities and transactions often were conducted in barter. Cash flow requirements were small and there was not a need for large quantities of market information.

As the industrial revolution spread, many changes occurred in agriculture. Opportunity costs of implicit resources increased as off-farm employment opportunities became more prevalent. With the rise in opportunity costs of implicit resources, economic profits in farming were diminished. Many individuals previously employed in farming left to seek larger returns in industry (Kislev and Peterson). Remaining farmers expanded their resource bases in an attempt to increase profitability. The result was an increase in reliance on market supplied inputs and off-farm marketing of products; a larger need was created for market information.

Continuation of this structural trend toward fewer and larger farms has resulted in an agriculture where capital largely has been substituted for labor. Cash flow requirements are substantial because of the large number of resources purchased from off-farm markets. Increased use of nonequity capital has increased financial risk on the typical farm. Through the forces of competition, economic profit per unit of output has diminished. Farmers faced greater pressure for accurate control of production and costs. The typical farm has evolved to be more dependent on information, and indications are that we are entering an "Information Age" that likely will require further development of an infrastructure to provide information to farmers (Sonka). The result is a greater need for effective farm information systems.

The Formalization of a MIS

To further explore the potentials that information system technologies hold for agriculture, let us systematically explore the functions of management, and itemize those areas for which high payoff exists for additional information. Following Boehlje and Eidman, the management function can be divided into three processes: (1) Planning, (2) Implementation, and (3) Control. Planning is an organizational function, involving long-run strategic decision making such as selection of the most appropriate enterprises, production technologies, and method of resource control. When completing the planning function, the manager assembles and analyzes a large amount of data from a variety of sources. Data may arise from the firm's accounting records, from historic price series, technical coefficients from manufacturers or agricultural engineers, or from a variety of other sources. Because long term relationships are required, available data are likely to contain much uncertainty. Analysis procedures will need to incorporate sensitivity analyses to allow the manager to make judgements about the reliability of the projected outcomes of decision alternatives.

Implementation involves operational decision making, much of which may be short run in nature. Examples of decisions made may include dairy herd ration selection, breeding programs, sequencing of activities, and market plan implementation. Analyses of implementation decisions involves a mixture of long and short run considerations. Information concerning current resource restrictions may modify implementation of the long term plan. Data available in the farm record will be key in making decisions about implementation of enterprise expansion/contraction or building plans.

The Control process involves establishing standards of performance, comparison of these standards to actual performance, and in the event that actual performance is not up to standards, to recommend modification of the plan to improve performance. The control process, then, is a continuous activity, where both long run (planning) and short run (implementation) decisions are evaluated.

The farm information system must service all three processes of management. This calls for a diversity of data, processing techniques and control devices. Portions of the system must be formalized while other parts will remain informal. For instance, it is difficult to imagine a farm business that should not have a formalized record keeping/accounting module in the MIS. On the other hand, one source of long term price information could be consultation with "experts": The use of marketing consultants, informal discussions with extension specialists and other similar contacts. This portion of the MIS is not highly formalized, and the information may not be highly quantified. However, it well may be a satisfactory source as a basis about which long term decision analysis can begin, and with sufficient sensitivity analysis, serve as a sound basis for those decisions.

Emerging Information Technologies

There have been, in recent years, a number of important developments in the technology for information processing and communication, as well as in the technologies of process control and computer hardware and storage. These hold much promise for improved analysis of decision alternatives.

Until the decade of the 1970's, the relevant computer technology for agricultural applications was batch and timeshare usage of mainframe or minicomputers.2/ There were a number of problems associated with the use of this technology by business managers. Long time lags were typical of batch processing. If the application was characterized by the need to quickly choose a decision alternative, then time related opportunity cost became a primary deterrent of computer usage. Timeshare usage of the computer largely removed this objection. However, many applications remained effectively removed from consideration due to system limitations (e.g., data storage requirements for an on-line farm accounting system) or the need for long periods of connect time, most often with long distance telephone connect charges. For instance, data entry into a farm accounting program based on a mainframe computer at a central site would require substantial connect time. Schmidt also notes that farmers desire to keep financial information confidential and may fear a lack of integrity in batch or timesharing systems. The result was that while timeshare usage of mainframe computers at central sites performed well for many applications involving little data input and applications that were not highly farm specific, they did not satisfy the demand for farm accounting and other input intensive or farm specific problems.

With the introduction of the microcomputer in the last decade, the technical foundation was made for the development of a firm level information system with real time processing available.3/ Real time processing, applications where processing occurs without delay, is crucial for farmer acceptance of information technologies. Real time processing of data reduces substantially the opportunity cost of time delays in information handling, making more feasible the use of computer-based data processing algorithms. Secondly, continuous computer monitoring of sensor devices is required if process control is to be successfully applied in many agricultural applications. Communication requirements and other features restricted the use of remote mainframe computers for process control. However, the availability of inexpensive microcomputer technologies made possible the monitoring of such process control activities for the small business.

Although the early microcomputers were extremely limited in the scope of problem that they could address, hardware limitations now are much less restrictive and software useful for management applications is becoming available. Very large scale integration of computer components has resulted in substantial price declines in computer hardware. Microcomputer hardware, technology that is suited for and affordable by small businesses, now is available which has the capability for analysis techniques of substantial importance.

Computer databases and videotext

There have emerged in recent years several databases and videotext services of importance to farmers. These are provided to farmers both by institutional and private sources. For instance, commodity market news, weather reporting services, and political news are available and often are tailored to farmer clients. Other data services, for instance Compuserve and The Source, report data of interest to a wide variety of individuals. The database can be accessed and data captured to computer media for later processing and use in decision analysis. The implications of such broad and easily accessible data are substantial. The manager, once familiar with a system, can reduce substantially the opportunity cost of data acquisition.

Process Control

Another advancement with great promise for the farm management information system involves the merging of computer technologies with electromechanical control devices. This area, referred to as process control, makes possible the automation of data collection, processing, and the regulation of physical process within the production environment of the business. Whatever the application is, the links between the computer and the process are sensors and actuators. Typically a sensor monitors analogue data, such as changes in temperature or quantity of product produced, that must be transformed into digital data before being presented to the computer. These data may be stored on a computer media for later use by the manager, or may be processed by a computer algorithm and action taken immediately by actuating another electromechnical device. One feature necessary for viable application of process control is the presence of real time computer processing. Prior to the availability of microprocessors, this was not economically feasible for most small business.

Process control applications currently are being used in agricultural enterprises for which production is confined in intensive facilities. For instance, in the dairy enterprise technology exists to allow automatic identification and feeding of individual cows via magnetic identification tags and automated feed dispensers. The quantity of milk produced can be sensed automatically by a device in the milking pipeline, and recorded on computer media along with cow identification number. This data can be processed, allowing input from the herd manager, to adjust the ration fed to the cow in subsequent feeding periods. Datta et. al. reported research results of an on-line milk monitoring system for milk conductivity, milk temperature and milk yield. Using a statistic calculated from milk conductivity, a method of mastitis detection was established whereby 3 consecutive observations of milk conductivity above a critical value would be indicative of mastitis. Application of such a system would allow the manager useful information for herd health and feeding decisions without substantial time commitments of data collection and processing.

There are many other areas where process control already has demonstrated its value in providing decision makers with useful information for the decision process. Process control has allowed the creation of unmanned weather stations and weather collection satellites in space, allowing more data to be measured and processed, thus increasing the quantity, accuracy and length of run of weather forecasts available.

Although process control is now feasible only for enterprises that are easily monitored (e.g., confinement livestock enterprises or greenhouse operations), the future may hold substantial improvements in this area. For instance, crop disease and insect infestations may one day be diagnosed by infrared photography from space or airplane. The commercial application of such technology would be a major step toward a control system for crop production enterprises.

Expert Systems

Artificial intelligence represent a new frontier for use of the computer in agriculture. Artificial intelligence is a field of study that attempts to use computers for tasks traditionally considered to require some form of human intelligence (Stern and Stern). Artificial intelligence provides the potential for further automation for many management decisions. Although the general field of artificial intelligence is still in its infancy, one sub-area of AI which holds promise for application in the near future is refered to as Expert Systems.

An expert system is a computer based algorithm which allows a problem to be addressed in much the same way that a human expert would seek a solution. The primary power of an expert system is informal reasoning based on extensive knowledge obtained from human experts. In most expert systems, the knowledge is included in the form of hundreds of logical comparisons or rules of thumb. Most decisions can be cast as a search for a path from an initial state to a desired final state with many restrictions constraining the set of alternatives which are viable. As Lenat has observed, "most interesting problems also share the characteristic that they are too complex to be solved by random search because the number of choices increases exponentially as one proceeds from the first intersection or decision point". The expert's rules constrain the search of decision alternatives by guiding the program toward the most likely solutions. Lenat concludes the "the essence of artificial intelligence in expert systems to find . . . ways (similar to those of the human expert) for the computer to limit the search for solutions". The expert system program also may be written so that it may learn from past experience in problem solving.

To date, there have been few successful uses of expert systems, and most of these lie outside the domain of agriculture. However, one may see from analogy of these successes that there is fertile ground for similar applications in the agricultural sciences. For instance, one successful application is in the area of medical diagnostics. Expert systems have been developed to diagnose bacterial blood infections (Lenat (p. 207) describes such a system, called MYCIN, developed at Stanford University). The objectives of the program are to determine the particular infection and to recommend a course of treatment. Input into the program is in the form of illness symptoms and results of lab tests. As the program proceeds toward a solution, it may request that additional lab tests be made. The program has been demonstrated capable of performing on par with human practitioners.

The diagonistics of animal and plant diseases should offer few complexities from that of diagnosing diseases in humans. Perhaps, expert systems useful for crop pest management recommendations will be commonplace within the next few decades. One limitation of adoption may be the amount of computer processing capability required to execute such a program. Microcomputers currently have the capability for only the simplest forms of such models. These programs could be made available to users on a timeshare basis on larger computer systems, however.

Robotics

Robotics currently are being used in a variety of ways in industry. The complexity of these applications vary substantially, ranging from relatively simple process control activities (e.g., inserting bolts in an assembly line process) to systems which incorporate artificial intelligence concepts to allow decision making within the process (e.g., making a weld if the positioning of the parts is correct and then evaluating the quality of the weld). Although robotics have been used primarily for assembly processes, there is fertile ground for development of agricultural applications of robotic processes. The use of robots for hazardous activities, for instance, the application of chemical insect or weed control agents, could have a high payoff in terms of increased worker safety.

Interactions of MIS and Risk Management

The very essence of risk in agricultural decision making is uncertain information. If all decisions were made in an environment of perfect knowledge, then the correct course of the decision would be apparent once a complete analysis of all outcomes was made. Clearly, the availability of technologies which will provide additional data for analysis of decision alternatives, increase the accuracy of routinely collected data, or increase the speed, and hence number, of analyses that can be performed, will impact the problem of risk management.

It also is clear that the emerging information technologies have consequences other than for risk management. That is, the availability of better information will allow choices that can increase profitability. Hence, this technology will be of interest to producers of all risk attitudes, not just those who exhibit risk aversion preferences. I will now focus attention on the consequences information system technologies hold for risk management at the firm level.

Sources of risk to private firms:

The firm operates in an environment that has three major components: (1) the physical environment, (2) the economic environment, and (3) the institutional and social environment. It is the physical environment that creates yield or production risk. Farming is an unusual production activity in that it utilizes a biological production process, and for many enterprises, production takes place "under the open sky", in an environment that is almost totally uncontrolled. As a result, there are a great number of uncontrolled variables; factors of production which are exogenous to the farm decision maker. Weather, insect populations and disease infestations all will influence the outcome of a set of production decisions. Because we cannot predict these variables, at least with a high degree of accuracy, the outcome of the production process usually is an uncertain outcome.4/

The risk involved in production may substantially alter the way in which the manager chooses to combine resources in the farm business. If a particular enterprise is perceived as being highly susceptible to an undesirable event, perhaps late summer drought conditions, then a manager may, on the basis of personal preferences, choose not to include this enterprise in the farm plan. Similarly, the manager may choose a production technology which is profit reducing if it will reduce the probability or magnitude of undesirable outcomes from uncertain events. This may explain the choice of irrigation technologies in non-arid regions, or the decision to maintain excess machinery capacity because occasional years will have unusual and unfavorable weather events.

Prices are determined in the firm's economic environment. Because most agricultural product markets are best described by the perfect competition model, producers are price takers, and most economic variables must be considered as exogenous variables in the decision process. Price or market risk can arise both in the input and output markets. Short-run fluctuations in prices can cause considerable fluctuations in costs and revenues. Long-run price fluctuations are even more troublesome. Formation of long-term price expectations is critical in the planning process. Furthermore, relative as well as absolute levels of price are important. Changes in the relative prices of inputs or of outputs will alter the profit maximizing choice of enterprises or production technologies.

Finally, the institutional and social environment may impose other exogenous parameters on the production process, altering the type and quantity of output of the firm or modifying the prices which the market ordinarily would have determined. Government programs and policies, then, introduce still further uncertainty into prices, both on the input and output side. Still another source of uncertainty interjected by institutional sources may be in the form of legal constraints on the production process (Holt). As job safety regulations, tax reporting requirements and other restrictions are introduced, producers are forced to combine resources in ways that were not projected during the long-term planning process that placed the enterprise into existence. The result may be decreased profitability and/or increased variability of profits, at least in the short-run.

To further develop the relationship between the risk sources described above and potentials for risk reduction available through improved MIS, let us consider the classification of productive factors by controllability. Dillon suggests that the variables in a firm's production function can be classified into decision, predetermined, and uncertain factors. The decision variables are those completely under the control of the decision maker (e.g., enterprise choice, production technology employed, crop varieties). The predetermined variables, on the other hand, are known by the decision maker prior to the decision point, but are not alterable by the manager. Examples of predetermined variables are subsoil moisture and fertility at the time of planting decisions. Finally, the uncertain variables are neither known nor controllable by the decision maker at the time of the decision. The uncertain variables will be determined in the future, and hence cannot be known with certainty. Uncertain variables include rainfall to occur later in the year, frost date, and future insect population counts

Although, any decision to be made by the decision maker will influence only the level of the decision variables, the level of predetermined variables and uncertain variables will ultimately influence the outcome of the production process. For instance, soil moisture at planting date may be measured but not controlled (a predetermined variable). However, if some relationship exists between the current level of subsoil moisture and the probability of a future drought event because of inadequate summer rainfall (an uncertain variable), then decision variables (e.g., crop variety choice, plant population, tillage technique, etc) could be altered to increase the probability of a desirable outcome. Hence, information about the predetermined variables and probabilistic forecasts of the likely outcome of uncertain variables will be useful in selection of decision inputs. It is the implication of this last statement which creates many opportunities for improved information collection and processing technologies, and which should help to set an agenda for future research, teaching and extension in the area of risk management.

Implications for Future Research

With this background, let us consider some of the implications for future work in the area of risk management. To this point, our work in risk management has been largely in the development of analytical models and mathematical techniques to aid managers' choice among alternatives, or to understand the elements describing an individual's risk preference. For instance, much work was done in W-149 to improve methods of measuring risk attitudes through elicitation of single-valued utility functions, studying multiple goal objective functions and developing a more general risk efficiency criterion. Work also was done to improve methods of measuring farmers' expectations and relating these to objective measures of risk. Such work has contributed much to our understanding of the way in which certain classes of decision makers function. This is important basic research and is useful in understanding the implications of policy actions or to make production recommendations for broad classes in individuals.

There also was substantial applied risk management research accomplished in the last decade. This has included evaluation of enterprise diversification, use of crop insurance, liquidity management and various marketing strategies as methods of risk management. This has been useful as a way of describing to individual producers the potential of alternative strategies for risk management.

Our previous work in risk management has some shortcomings. Little has been done to understand the way in which managers utilize information in the decision making process. In an evaluation of the work of W-149, Barry concluded that although much useful work was accomplished, "the project was somewhat short on what farmers were actually doing to cope with risk" (p. 4). The work of S-180 has placed more emphasis on understanding the motivations and actions of managers in the risk management decision process. A questionnaire was developed and administered to measure the types of responses used by farmers to reduce risk exposure (Patrick). The results were not clear, however, as it was not possible to discern to what extent decisions, for instance enterprise diversification, were made to reduce risk and to what extent these were done for other considerations, such as to increase the utilization of unpaid labor, or to spread demand for machinery services over a longer production season.

I believe that much additional work is needed to understand how individual managers make decisions. Clearly, risk management is but a single attribute of a multiple attribute objective function. Is risk management a primary consideration in decision making, or is it considered only after other decisions have largely structured enterprise combinations and production technology selection?

There is no real proof that more information leads to better decisions. Information is a vital resource but improving its quantity or quality will only create value if it is used effectively. Are there ways that we can improve the sources of information to managers or to improve analysis techniques available so as to make information use more effective?

I would like to suggest that a new area of emphasis in risk management research be to improve information quality and quantity. This involves a shift of emphasis from measuring risk to improving information available to farmers so as to reduced the uncertainty in the decision environment.

In the above discussions, I have attempted to demonstrate that information system technologies are developing rapidly, and that the characteristics of farming provide many opportunities for profit increases and risk reduction with the adoption of this technology. There remain a number of weak links in the chain, however. Although computer hardware and communications technologies are currently in place to allow much of this potential to be captured, there are many missing software components and items of information that will be needed to reach the full potentials of an agricultural information system. These are areas which could produce large research payoff.

To formalize a management information system that is useful for forward planning in a risky environment, much additional work is needed in the identification and quantification (in a probabilistic sense) of the relationship between uncertain variables of production and decision variables. Further, these relationships should recognize the interactions with those factors of production which are predetermined at the time of decision. This requires substantial basic research to fully understand the production function to include predetermined and uncertain factors. Further, to successfully implement knowledge of the fully specified production function will require increased abilities to forecast uncertain variables. This research should be organized as a total systems approach. Much additional work is required by physical scientists, guided by the data requirements of the economist, in constructing a system to provide useful economic information.

Similar work is needed by economists in the area of physical process control. This represents a tool by which short run production decisions can be controlled to be more nearly optimal. Much work already has been done in this area by physical scientists, and indications are that more will be accomplished. However, it is likely that most of these applications will be operationalized about a physical product maximization principle. Economists can contribute to this development by introducing concepts of economic efficiency, and by modifying the action criteria to recognize risk aversion characteristics of decision makers.

Many analytic procedures exist that can be useful for analysis of farm decisions. Mathematical programming, simulation and optimal control applications all can reasonably be incorporated into analysis of decision alternatives. Much work remains to be done, however, in adapting these to the computer technology likely to exist in the farm information system, and in making these easy to use by the nontechnical user. Furthermore, the analytical procedure should be suited to use the probabilistic data that likely will be provided the decision maker.

There already are many private developers of decision analysis software for farmers. This software will vary in quality and accuracy. Many commercial and public domain data bases are being developed to supply information to agricultural decision makers. These could be very useful for decision analysis if the data are structured in a form that contain useful data content. The economist can play a role in evaluation of software and in guiding the construction of software and databases by commercial developers.

Expert systems also holds great promise for use in the decision making process. Many of those currently underway in areas outside of agriculture are diagnostic in nature, and will require much input from physical scientist in the particular domain. However, great potential also exists for the application of this technique to farm management decision making. For example, long term decision making relative to addition or expansion of farm enterprises could be guided by economic analysis of alternative technologies. This is a new area of opportunity wherein lies great potential. It also is an area in which the economist should be involved to guide the work and help insure that the information is presented in a form useful for decision analysis.

My discussion above has been limited largely to those factors internal to the firm. There also are many questions to be addressed concerning the aggregate effects of widespread adoption of MIS technology. Will there be implications for continued structural change in agriculture? Will increased availability of supply and demand information act as a stabilizing force in markets, thereby decreasing the degree of price variability? If MIS technologies are effective in risk reduction at the firm level, will the farm operator accept a lower risk premium for farm investments, and will economic profits, through the forces of competition, be further reduced in this event? I do not attempt to answer these questions, but to raise these as areas for future research.

Although it is outside the general topic of this paper, there are many implications for the resident instruction and extension faculty as well. As is usually true, adoption of this emerging technology likely will be fraught with many difficulties and errors by managers. To make effective use of the technology will require substantial education on the part of the manager. Clearly this is a role for resident and extension educators.

Risk management is an important feature of modern agriculture, and likely structural changes in agriculture will make risk more, not less, important. There are many changes in information technologies that may open doors of risk considerations that previously were not available. Our challenge as risk researchers should be to find ways to harness this new technology, to increase the quality and quantity of information available to farmers and, hence, to reduce the uncertainty in which decisions are made.

Footnotes

1. Lee and Nicholson suggest that data has "informational" content only if it causes a change in the knowledge of those who hear it. Further, they suggest that information has "value" only if it causes knowledge that, in turn, causes the receivers to select courses of action which produce higher levels of utility than would have resulted without the information.

2. Since the decade of the 1950's, agriculturists have utilized the computer for agricultural applications. The history of this development has been followed elsewhere (Eisgruber; Schmidt) and will not be reproduced here.

3. It was about 1981, with the introduction of 16 bit microcomputer processors and the 64 Kilobyte Random Access Memory chip, that microcomputers began to have a capacity for reasonable sized business applications. Once these hardware innovations were brought to the market, software developer quickly moved to make use of these, providing software which was more capable of analysis of typical business problems.

4. There are a number of factors which may complicate the decision analysis process. Time characteristics of the decision may compound the decision if the period available for analysis is very short, effectively limiting time available for data collection and processing, or if the production period is relatively long, forcing the decision maker to seek data which will remain uncertain for a substantial period of time. In the former case, the presence of a formalized system could be a substantial benefit, allowing data to be collected analyzed in a shorter period. In the latter case, substantial time may exist between the time of decision and the point of final outcome. Hence, data relevant in the decisions may not be reliably obtained.

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