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TASK FINAL REPORT

on

BENEFITS OF AN IMPROVED
WHEAT CROP INFORMATION SYSTEM
(Report No. BCL-OA-TFR-76-12)

by

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BENEFITS OF AN IMPROVED WHEAT CROP
INFORMATION SYSTEM

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INTRODUCTION

In 1974-1976, ECON Incorporated, of Princeton, New Jersey, conducted a series of studies for the National Aeronautics and Space Administration (NASA), Office of Applications. These studies dealt with estimation and analysis of benefits to be derived from improving worldwide wheat crop information through a remote sensing system. ECON developed two different econometric models in its series of studies--one is identified as the Bradford-Kelejian-Andrews Model of The Value of Information for Crop Forecasting in a Market System; the second is the Worldwide Wheat Crop Information Benefits Model, authored primarily by Dr. Klaus P. Heiss. The reports on these analyses are, of necessity, complex, highly detailed, and difficult for the layman to follow.

In addition, through a contract with Battelle's Columbus Laboratories, NASA initiated independent reviews of the ECON work. Three

reviewers, well recognized econometricians, were selected, and carried out their critique of the ECON work in February and March, 1976. They were:

<u>Reviewer</u>	<u>Model</u>
Professor Lester Thurow Massachusetts Institute of Technology	Bradford-Kelejian-Andrews Model, and Worldwide Wheat Model
Dr. Ira Horowitz U.S. Department of Justice (on leave from the University of Florida)	Bradford-Kelejian-Andrews Model
Dr. C. W. J. Granger University of California, San Diego	Worldwide Wheat Model

This Battelle report summarizes the ECON work and the results of the independent reviews. It attempts to put this information into layman's terms and to present the benefits that can realistically be expected from a LANDSAT-type remote sensing system. Further, it presents the mechanisms by which these benefits can be expected to accrue.

Topically, this report first deals with the benefits, including the nature of expected information improvements, how and why they can lead to benefits to society, and the estimated magnitude of the expected benefits. Secondly, the report presents a brief description of the ECON models, how they work, their results, and a summary of the pertinent aspects of each review.

Briefly, the ECON analyses show that substantial benefits will accrue from implementation of an improved wheat crop information system based on remote sensing. The specific estimates differ, but are substantially

in excess of estimated system costs. Basically, these benefits will be derived from

- Improved estimates and forecasts of wheat supplies
- Somewhat reduced wheat prices resulting from reduced uncertainty, somewhat reduced production costs, and a different pattern of levels and dispersion of inventory holdings
- Increased exports of U.S. wheat.

These benefits will flow both to U.S. consumers and to consumers in the rest of the world. The benefits to the U.S. will be substantial, but the benefits to the rest of the world will be much greater, because of the current poor state of crop information in most other countries.

The reviewers offered suggestions for improvement and expansion of the ECON work, but generally agreed that these are well-performed analyses that have developed reasonable estimates of benefits. One exception was Professor Thurow, who had reservations about the Worldwide Wheat Model.

BENEFITS FROM IMPROVED WHEAT CROP INFORMATIONNature of Potential Improvements

The proposed next stage of the LANDSAT program is currently expected to provide

- Improved accuracy of land area measurements, with resolution to approximately 5 acres
- Increased frequency of coverage; every 9 days with a 2-satellite system (depending, of course, on cloud cover)
- Improved ability to differentiate among crops
- Faster data availability.

This, then, translates into improved worldwide crop production area information to be collected and disseminated more frequently than with current systems. This area information is expected to be used by systems being developed in the joint USDA-NASA Large Area Crop Information Experiment (LACIE), along with other information, to produce estimates or forecasts of crop yields and thus estimates of total production for major producing areas of the world.

Wheat has been chosen as the target crop for experimentation and for analysis of benefits. Wheat is one of the major crops of the United States, and is a major product of international commerce. The United States is the world's largest exporter of wheat, sending on the order of two-thirds of its production to the world market each year, thus providing some 50 percent of the wheat that moves in international commerce. Wheat

also is produced in many other parts of the world. Canada, France, Australia, and Argentina are principal exporters, and there is some production for domestic use in virtually all regions of the world. Some countries, such as Japan, West Germany, the United Kingdom, and the Netherlands are relatively consistent deficit producers and, therefore, consistent importers of wheat. Import demands for most countries, however, vary considerably from year to year, depending on the level of domestic production, the state of the country's economy, and many other factors. Total world demand for wheat tends to be relatively consistent with secular trends from year to year, but the world supply varies considerably depending on weather, other natural occurrences, and producer decisions.

Current Information Systems

Current sources of information on wheat production include:

- The Statistical Reporting Service of the U.S. Department of Agriculture (USDA), which provides monthly forecasts of U.S. wheat production throughout the growing season, plus preliminary and final estimates of actual total production at the end of the season. These forecasts and estimates are based on a comprehensive statistical sampling/survey process.

- The Foreign Agricultural Service and the Economic Research Service of the USDA provide periodic outlook information on U.S. and key foreign wheat production, along with annual estimates of wheat production by country. This information is based in part on analyses of the Statistical Reporting

Service surveys of the U.S., plus information from U.S. Agricultural Attachés in other countries and various other sources.

- The Food and Agriculture Organization of the United Nations which publishes annual estimates of crop production on a country-by-country basis using information provided by individual countries plus observations of U.N. analysts based in the region.
- Individual country statistics which vary widely in coverage, periodicity, and reliability--some key countries, such as the USSR, publish little or no information.
- Private grain trade forecasting and estimating systems, including individual company estimates and the Chicago Board of Trade statistics--availability of which varies because of the proprietary nature of some of the information.

The information and forecasts produced by the USDA on U.S. domestic production are considered to be the most extensive and reliable publicly available statistics. These forecasts are generated from acreage (area) information developed in a monthly large-scale statistical survey by crop reporting district throughout the United States. Yield is determined separately based on yield trends, assumptions regarding weather, plus sample measurements of disease and pest losses, and "status" of the crop during the growing season. The USDA has a goal of keeping its year-end estimates of national annual crop production (for major crops such

as wheat) within a tolerance of 2 percent. The ECON analysis of actual errors in USDA forecasts and estimates of the U.S. wheat crop indicate that the actual error for forecasts and estimates in the period 1959-1974, has been over 8 percent for the early part of the season (May and June). This error reduces to under 2 percent by the end of the winter wheat harvest season (August and September), and to 0.68 percent at the end of the crop year.

The major types or sources of errors that now exist in the USDA system include:

Before Harvest Forecasts

- Crop measurement errors for both acreage and yield
- Time lag between measurement and published forecast
- Changes in weather, etc., i.e., nature
- The difference between planted and harvested acreages
- Statistical "error", which results from the process used.*

After Harvest Estimates

- Crop measurement errors for both acreage and yield
- Time lag until reported.

This process has evolved over many years, is highly scientific in nature, and is being continually updated and revised to reduce errors. However, even with this effort, some private companies feel the need to augment

* This does not imply that the USDA uses an incorrect procedure, only that statistical error is present in all statistical sampling processes, primarily because one is measuring less than the total population.

the USDA information with their own sources and estimating/forecasting procedures.

For foreign crops, the information picture is quite different. The process of gathering and reporting information on actual and potential wheat (as well as other crop) production varies tremendously from country to country. Often this is not a routine nor a scientific process as it is in the United States. Furthermore, as ECON Incorporated points out, there is no reasonable way to measure error because it is difficult to determine the true level of crop production in many countries even long after harvest. Some countries, such as the Soviet Union, publish very little or no information, which in that particular case creates problems, because they have been "in and out" of the market in a substantial way over the last few years. The USDA is beginning to work out processes with their counterparts in the USSR to try to provide some advance information on crop production. However, the success of these efforts is yet to be seen. Also, most of the companies in the international grain trade have their own processes to develop private forecasts and estimates of key crop production in selected parts of the world.

Improvements with Remote Sensing

Given current levels of technology for enhancement and interpretation of remote imagery, area measurements can be made with virtually any desired level of accuracy if cost is not a consideration. Cost effective individual field area measurements can be made with errors of no more than 5 percent. If, then, an efficient sampling technique is developed

and applied to reduce the impact of cloud cover and of pure sampling error, crop area measurements of 95 percent accuracy can be obtained.

The problem of planted versus harvested acreage still remains. Early in the production season for any given region, the crop area measured will be planted acreage. During the growing season, decisions may be made to abandon or change the cropping pattern of any given field, for a variety of reasons, and some acreage will be lost from natural occurrences. Presumably, the LANDSAT system will make continued observation of planted acreages until harvest is complete, thus allowing adjustments to be made in forecasts of harvested acreage throughout the season.

Thus, area measurements and forecasts can be made, using remote sensing inputs, much more accurately than existing systems allow for production areas outside of the United States. For the United States, area accuracies are relatively comparable, but the remote sensing technology may allow for larger samples to be taken at a lower cost.

On the yield side of the production forecasting equation ($\text{Production} = \text{Yield} \times \text{Acreage}$), the planned remote sensing information to be derived from LANDSAT will provide little if any input. The LACIE experiment is to develop systems for providing improved yield forecasts using weather and other information. The statistical properties of a nonexistent future system is speculative, as properly pointed out by ECON Incorporated, however, the early LACIE goals were to achieve 90 percent accuracy with 90 percent confidence (i.e., 90 percent accuracy at least 9 times out of 10, with no bias). According to the ECON analysis, if LACIE achieves these goals, the resulting world production forecast variances (given the above accuracy of area measurements) will be less

than for the current USDA forecasts made in May, compared with 8.8 percent under the USDA system), but will be about the same at the end of the harvest season (i.e., 2 percent or less for the November-December forecast/estimate). This represents some improvement in information concerning the U.S. crop, and a very substantial improvement in rest-of-the-world information.

Another factor in comparing a remote sensing data-based system with current systems is the timeliness of reports, and the time from measurement to publication of an estimate or forecast. In the United States, the USDA publishes an initial forecast of the coming year's wheat production in December, when all winter wheat plantings are complete. Then, monthly forecasts are made starting in May and continuing through the harvest season. Preliminary final crop estimates are made in December and then revised periodically as more information becomes available. The monthly forecasts are released on the 10th to the 12th of the month, and are based on a mail survey plus probability sample surveys that were initiated on about the 23rd of the previous month. Thus, the time from start of the measurement process to publication is approximately 20 days.

A two-satellite remote sensing system will take measurements of each area samples every 9 days, depending on cloud cover conditions. At present, there is no formal and routine system established for processing, estimating, and publishing crop forecast information, but presumably, at least monthly national forecasts will be made. Thus, this will be at least comparable to the current U.S. system, and far superior to the current information availability for the rest of the world.

Use of Potential Improvements

The wheat production/marketing system is composed of

- (1) Grain production
- (2) Assembly, collection, and storage
- (3) Domestic marketing and use
- (4) International marketing and use.

Grain Production

Wheat production in temperate zones is of two types:

- Winter wheat which is planted just prior to the winter season (September–November in the U.S.), and harvested in early summer (June–July in the U.S.)
- Spring wheat which is planted in the Spring (march–May in the U.S.), and harvested in late summer through early autumn (August–October in the U.S.).

During the production process, the farmer has a series of basic decisions to make:

- How much acreage to plant
- The amount of fertilizer and pesticide to apply to the growing crop
- Irrigation decisions where this is applicable
- Whether to continue production or change to an alternative crop during the growing season
- When to harvest (or whether to abandon)
- When to sell his crop (how long to store).

Winter wheat is typically grown in the more humid production areas, therefore decisions regarding plowing down a crop and planting an alternative are more applicable than in spring wheat areas. Spring wheat is typically grown in dryer areas where the cropping alternatives are fewer than in the more humid areas. However, decisions to change crops or to abandon acreage are not taken lightly--conditions have to be severe and the future outlook very bleak--because a substantial sunk investment is at stake. Furthermore, if the producer abandons his crop, he is foregoing a cash income that is usually required to pay for production costs that have already been incurred, e.g., pesticides, seed, and fertilizer.

These producer decisions are based on

- Anticipated wheat prices
- Anticipated prices of alternative crops
- Anticipated and actual growing conditions
- Anticipated and actual input costs.

Because a high percentage of the U.S. wheat crop is exported, world conditions heavily influence U.S. wheat prices. Of primary impact is the anticipated production in the U.S. and in other parts of the world, including production for both export and for domestic consumption. Improved and more timely information on both the U.S. and the rest-of-the-world production should allow improved price forecasting. Indeed, it should make for less violent price fluctuation, because production uncertainty is one major factor in causing price volatility. Therefore, improved information on actual and anticipated wheat production throughout the world should enable wheat producers collectively to make improved planting and

other production decisions.* Production acreage should become more closely attuned to market requirements. Thus, the uncertainty resulting from unknown market conditions should be lessened. This leaves then the vagaries of nature as the primary source of uncertainty for the producer. Even the market impacts of natural occurrences should be somewhat lessened with improved worldwide production information, because producers in one area then will be able to adjust somewhat for conditions in another area.

Assembly, Collection, and Storage

As grain leaves the farm it flows through a series of nearby and more distant assembly and storage points. This system of points, or elevators, begins with the nearby country elevator. Then the grain may move to a regional elevator and/or a terminal elevator. The regional elevators collect grain from the country elevators, and the terminal elevators collect from both country and regional facilities. The terminal facilities are normally located in areas of major use or at major shipping points. These are interconnected by the transportation system--highway, rail, and water. For wheat, another set of elevators is important, as well: the export elevator which collects grain from all of the above and loads it onto ships. These vessels then unload into port elevators at the receiving ports. From these port elevators the grain moves into the internal distribution system of the receiving country.

* The term "actual and anticipated" is used, because some planting and harvesting takes place continuously in the world because of the seasonal variation in the different regions.

Storage or inventory decisions may be made at any or all of these points.* Storage is important because harvest occurs over a relatively short period, while use is relatively constant throughout the year. There are two major types of inventory decisions--one involves the building of inventory for use (i.e., the grain inventories of a flour miller), and the second involves building inventories in anticipation of future market conditions (or speculation).

Farmers may hold inventory either on the farm or at the local or regional elevator. Elevator operators at various points may hold inventory on their own account, or on the account of a supplier or a customer. Thus, there are many inventory decision-makers in the system, some sophisticated, such as the major grain trading companies, and others relatively naive.

Again the inventory decision is predicated on anticipated supplies and prices of grain. If these conditions are known in advance with greater certainty than at present, then more rational or effective inventory decisions can be made. Currently, inventory buildup may be either too large or too small for future conditions. Too large inventories are costly in terms of storage costs and when they are sold, may depress prices. Too small inventories may mean restricted future consumption and higher prices.

Furthermore, inventory holding is subject to substantial risk of price change. To offset this risk, inventories are frequently hedged. That is, in its simplest form, cash or spot transactions such as purchases for inventory, are offset by counter-transactions in the futures market. A purchase on the cash market is thus offset by the sale of contracts for

* Most export elevators operate on a basis of rapid turnover and thus do not hold inventories for long periods.

future delivery in the futures market. When inventory is sold, the futures contracts are cancelled out by purchasing them back. As price levels in both markets are expected to move somewhat in concert, the inventory holder thus is afforded some protection from future price change.

Again, information of improved reliability concerning expected future conditions will enable inventory holders to make better hedging decisions and will lessen their degree of risk to some extent. In fact, if sufficiently reliable information could be provided that future price levels could be known with a reasonable degree of certainty, the practice of hedging could be reduced. This occurred when price support programs were at their peak in the United States. The need for hedging was reduced, because future prices were known with reasonable certainty. This alone could reduce the cost of inventory holding, because hedging is not without cost.

Domestic and International Marketing

The mechanics of domestic and international grain marketing are much the same in the essentials. However, international marketing is much more complex in that it is done at long distances, with longer lengths of time between transaction and delivery, in different currencies, and with somewhat different trading rules and terms. Within the United States, grain may begin its movement to market either as the result of a fixed order, or on speculative action, with the seller hoping to make a sale before the grain actually arrives at its destination. Orders and transactions may be made by various means--they may be carried out by agents of buyers and

sellers on the trading floor of various formal markets, such as the Chicago Board of Trade. Or, they may be placed by buyers at the offices of grain traders or commissionmen. Or, they may be negotiated over long periods of time.

Buyers may be millers, animal feeders, their representatives, or middlemen. Sellers may be producers (rarely), agricultural cooperatives, commercial grain traders, or individual independent elevator operators (however, most of the major elevators are owned or operated by grain traders or cooperatives).

Grain trading is a highly competitive marketing situation in which both parties attempt to establish conditions and terms to their best advantage. In this type of process, timely and accurate information is indispensable. This is why the major trading companies have established their own information systems.

The United States tends to be a residual supplier to the world market. In this role, because it is the world's largest export supplier, the United States is often looked upon as a "gap" filler, rather than a consistent trading partner. In times of stress, because the United States has such a large supply that is normally available to the world market without restriction, those in short supply can look to the United States to meet their needs. This attitude has perhaps contributed to price fluctuations in recent years. There are those who believe that increasing the availability of supply information will increase the tendency of others to view the United States in that role. The argument is that U.S. producers and marketers might be at a relative disadvantage

compared with their current position of having superior information, and they might have to suffer the consequences of increased price fluctuation and price risk. The ECON analysis does not deal directly with this argument. At first glance, it would appear that this type of discussion is more pertinent to information dissemination than information collection and development. However, it is unlikely that other countries will allow information to be collected without receiving the results in a timely fashion. The ECON reports do point out that foreign users of the information will likely benefit to a greater extent than U.S. users, but both parties do benefit substantially. Furthermore, in such classic examples as the "Russian wheat deal" of 1972, it is clear that the United States was at a disadvantage from lack of information about conditions in the USSR. Had such information been available earlier, the market would have reacted earlier to this information and prices would have risen gradually during the marketing season. Of course, neither party could have accurately foreseen the adverse weather conditions that were going to prevail in the U.S. and elsewhere during the planting and harvesting seasons of that year, making for shorter-than-normal supplies (nor would the proposed LANDSAT system assist greatly in developing such information).

In Battelle's opinion, increased information availability will be unlikely to worsen the position of the U.S. in the grain trade in an absolute sense. It may benefit others relatively more, but both the U.S. and the rest of the world will likely gain. Improved decisions by both exporters and importers might lead to greater price stability, improved production efficiency, and improved inventory management.

Benefits of Improved Information

The benefits of improved worldwide wheat production information derive from

- Reduced price fluctuation and somewhat lower average prices because of more perfect information about actual and potential wheat supplies on a worldwide basis
- Reduced uncertainty for producers and for inventory holders, again because of more perfect information about supply
- Reduced tendency to hold purely speculative inventories
--inventory decisions will be made given a "truer" indication of the actual state of supply
- Improved production planning.

The ECON Concepts

In the ECON analysis, it is proposed, that with improved information, the supply curve for wheat, following any given harvest, will shift outward from its current position, i.e., increase. Thus, for any given harvest, a greater quantity of wheat will be offered to the market at any price level, or, in other words, offering prices will be lower for any given quantity offered. The mechanism by which this will come about derives from the above. That is, costs of production and storage will be somewhat lower. And, because of the reduced uncertainty, producers and marketers will be willing to accept a lower return on investments and

lower profits (uncertainty leads to higher risk, and a portion of profit normally is to compensate for risk assumption).

Benefits in the ECON analyses are measured basically in terms of changes in consumers' and producers' surpluses. These are abstract concepts that are basically defined as follows:

- Consumers' surplus is the benefit to consumers as a group derived from the fact that, for any given market price, there will be some consumers willing to purchase at higher prices, if they are forced to buy at these prices. Thus they derive a "windfall" gain from the lower market price. If the market price is lowered, consumers' surplus increases and vice versa, assuming a demand curve that slopes downward to the right.

- Producers' surplus is a somewhat similar concept and refers to the collective benefit that derives from the fact that, for any given market price, there will be some producers willing to sell at lower prices. Thus, they derive what can be termed a "windfall" profit from the market price. Reductions in market price reduce producers' surplus, and vice versa, assuming a supply curve that slopes upward to the right.

Thus, for any change in market-price levels, the producers' and consumers' surpluses change in opposite directions. These concepts relate to total social welfare or social benefits. The net benefit to society depends on the relative shapes and slopes of the demand and supply curves.

The application of these concepts to the measurement of benefits from improved crop information was questioned by the reviewers of the ECON

work. Professor L. Thurow offered that other benefits might also be measured, such as the benefit to society of preventing [↑]reductions in consumption below some critical level.* Thurow also felt that real income effects of changes in the prices of wheat should be taken into account as well. Dr. C.W.J. Granger, while being uncomfortable with the general concept, noted that "the fact that the measure used is accorded wide approval by economists does give it some real status and cannot be lightly dismissed".**

Quantitative Estimates

In quantitative terms, over the long term, ECON estimates from one of its two models--the Worldwide Wheat Model--that U.S. consumers will benefit \$287 million per year (in 1975 dollars) from average lower wheat prices. At the same time, U.S. producers are expected to lose approximately \$393 million per year because of these lower prices. Offsetting part of this producer loss are an estimated \$280 million in production efficiency gains because of improved information. Thus, net benefits to U.S. society are approximately \$174 million per year in 1975 dollars. ECON estimates that on the order of 10 years will be required to realize this annual benefit level.

The U.S. is expected to further benefit through increased trade revenues to the extent of some \$334 million per year--these increased

* Thurow, L.C., Massachusetts Institute of Technology, Letter and Memorandum to Dr. A.C. Robinson, Battelle's Columbus Laboratories, March 12, 1976.

** Granger, C.W.J., University of California, San Diego, Letter to Dr. A.C. Robinson, Battelle's Columbus Laboratories, March 1976, p 8.

revenues are not directly additive with the above benefits. Further analysis will be required to determine net benefits to U.S. society from increased trade revenues that are in the same terms as the consumer and producer surplus gains estimated above. The specifics of these benefits will depend upon the character of the U.S. economy at the time, however, general benefits from increased trade are

- An increased final demand for U.S. output that can lead to higher employment and increased domestic earnings
- Increased purchasing power for foreign goods that are imported
- Monetary effects, i.e., an increase in the domestic money supply resulting from an inflow of money to the U.S. (unless offset by foreign purchases or other outflows)
- An increase in the demand for the U.S. dollar relative to other currencies, that will strengthen the U.S. foreign exchange position.

These benefits may be offset by

- An increased rate of depletion of U.S. natural resources
- The possibility of an inflationary effect of increasing the money supply, depending on the character of the economy at the time the increase takes place.

It is also important to note that the rest of the world gains from increased information, probably to a much greater extent than does

the United States. However, ECON, in its later work, does not make an estimate of the magnitude of these rest-of-the-world effects.

In its second set of analyses, the Bradford-Kelejian-Andrews (B-K-A) models, ECON attempted to measure the impact of improved information in a somewhat different manner. These models incorporate the concept that less-than-perfect information results in an economic loss, through improper inventory decisions made because of wrong perceptions of the true state of supply at any point in time. Improvements in the information base that will result in less imperfect information than under current conditions will result in a lesser loss than is now experienced. In this case, benefit is a negative loss, and is measured in about the same terms as before, i.e., consumer surplus plus producer surplus minus the cost of inventory holding. The results of the B-K-A analysis are more complex than with the previous model and are presented with several alternative possibilities. However, in their "standard" case, they estimate the loss to the U.S. under current conditions as \$40 million (1975 dollars), and the loss to the rest of the world as \$393 million, or a total of \$433 million. If the crop measurement errors are reduced by 50 percent, the net loss to the U.S. from still imperfect information would be \$10 million and to the rest of the world \$138 million, or a total of \$148 million. Thus, the net benefit (or reduction in loss) would be some \$30 million to the United States and \$295 million to the rest of the world, or a total of \$325 million. It should be noted that the B-K-A analyses relate only to the impacts of improved inventory decision-making (resulting from an improved perception of the true situation at any point in time).

The reviewers generally felt that these are relatively reasonable results but that it would be more realistic to present ranges of potential benefits rather than point estimates. Also, they generally felt that the sensitivity of the results to various simplifying assumptions made during the analysis should be investigated before final benefit estimates are made. ECON is now carrying out this further analysis.

Alternatives

Some of the reviewers, Thurow especially, expressed concern that the ECON analysis paid too little attention to alternative means of achieving benefits than through improved information.* One alternative suggested was a change in policy regarding foreign access to U.S. supplies of grain. In particular it was suggested that foreign access be restricted only to the portion of supply that is not required to meet anticipated U.S. domestic demand. This significant change in the traditional free market policy of the United States would not be cost free. Without further detailed analysis one cannot compare these costs and their resulting benefits to those of an improved information system.

* Thurow, Op.Cit.

THE ECON MODELS

ECON Incorporated has developed and presented two sets of econometric models dealing with the measurement of potential benefits of improved wheat crop information. Both of these models are complex, but both also are simplified versions of reality, as is the case with any econometric model. Simplifications have to be made to accommodate ease and cost of calculations and manipulations in the models. In the B-K-A inventory decision models, some effort was made to determine the impact of some simplifying assumptions but not others. In the worldwide wheat model no sensitivity analysis was performed. ECON is carrying out further work in this direction.

The discussion of the models is even further simplified in this paper. This discussion is taken both from the original reports and from Dr. P. Kochanowski's abstract of these reports*.

The Bradford-Kelejain-Andrews ModelThe Model

As discussed earlier, this model relates to the benefits that can be expected from improved inventory decision-making given improved crop information that will result in an improved perception of the true state of supply (considering domestic and foreign demand and supply). In particular, the model generates benefits by showing that improved information will lead to a pattern of inventory holding such that the variance

* Kochanowski, P., NASA (on leave from the University of Indiana), Draft of Abstract of ECON Incorporated Studies, April 16, 1976.

or instability of wheat supply will be reduced. Information improvements are in the form of reduced variance in crop forecasting or estimating errors (i.e., less variance in over- and underestimation of the upcoming crop). This reduction in supply variance leads to somewhat lower average prices. In addition, the average level of inventories will be somewhat less, making for lower total storage costs. These changes then lead to changes in the level of consumer and producer surplus, which taken together with storage costs result in welfare benefits to the United States and the rest of the world.

A simplified explanation of the basic steps involved is

<u>Action</u>	<u>Result</u>
1. Improved information from remote sensing	Improved crop forecasts (reduction in the variance of crop forecasts errors)
2. Improved crop forecasts	A different time pattern and level of inventory buildups and depletions, since crop forecasts are inputs into inventory holding decisions
3. Different time pattern and level of inventory buildups and depletions	Reduction in the variance of the supply of the commodity available for consumption
4. Reduction in the variance of supply	Welfare gains (given certain mathematical properties of the welfare function).

Critique

This model was reviewed by Dr. I. Horowitz* and Dr. L. Thurow.** Both reviewers commented that they considered this analysis to be competent and sophisticated, leading to reasonable results. However, they felt that improvements could be made in the approach and in the model itself.

Results. While the reviewers indicated that they felt the results were reasonable they both were concerned about the "certainty with which the results were reported". They felt that the sensitivity of the results to the basic assumptions and data inputs should be explored in much greater depth than was indicated in the reports. It is Battelle's understanding that ECON is now carrying out some of these sensitivity analyses. In particular, both reviewers believe that there is a nonlinearity in the actual situation that has not been taken into account in the model, which assumes a linear form for simplicity. The model contains the further assumption that inventory holders will act to maximize social welfare in opposition to their own welfare or profit, that Horowitz, in particular, questions.

Welfare Function. Both reviewers questioned the B-K-A welfare function that utilized consumer and producer surplus as the sole indicator of social welfare. Thurow suggests that there are additional benefits to more stable prices and to providing an assurance that consumption will not

* Horowitz, I., Department of Justice (on leave from the University of Florida), Letter to Dr. A. C. Robinson, Battelle's Columbus Laboratories,

** Thurow, Op.Cit.

fall below some critical level. These other benefits have not been taken into account in the model. Horowitz goes on to suggest some different approaches to a welfare (objective) function for use in the model.

Inventory Decision Model. The B-K-A model utilizes an optimization rule for inventory holding that essentially states that inventories are to be held to the point at which the anticipated marginal revenue of an additional unit is equal to the marginal cost of storing that unit. Both reviewers commented on this rule--Thurow felt that the estimates of storage cost were too low, but generally accepted the rule. Horowitz, however, argues that this rule was inadequate based on a large currently available body of uncertainty-related literature. He again suggested some alternative approaches that he believed could be implemented within the framework of the model.

Other Comments. Thurow suggested that alternatives to improved information for achieving price and consumption smoothing, such as policy changes, might be explored. Whether such approaches would be more efficient than developing improved information is not known without further analysis.

Both reviewers questioned the probability distributions used in the model regarding forecast errors. The question is whether in reality such errors are truly random and whether their probability distribution is symmetrical.

Thurow further commented, that of the two models, the B-K-A is the correct general approach for evaluating the impact of improved information.

Worldwide Wheat ModelThe Model

This is an econometric model of wheat supply and demand, considering the United States and the Rest of the World (R.O.W.) as the two parties in the world market. Basically, the model shows that improved forecasting will result in more realistic futures prices that in turn will lead to an outward shift (increase) in the supply of wheat available for consumption from any harvest. This results from a lower average level of inventory holding, and from producer efficiencies because of the improved information. The following simplified steps show the working of the model.

<u>Action</u>	<u>Results</u>
1. Improved information	Improved crop forecasts
2. Improved crop forecasts	Changes in the pattern and level of wheat futures prices from a wheat futures price adjustment equation
3. Changes in wheat futures	Changes in: Demand for Commercial Stocks (U.S.) Area harvested (U.S.) Area Harvested (R.O.W.)
4. Changes in: Demand for Commercial Stocks (U.S.) Area harvested (U.S.) Area harvested (R.O.W.)	Expansion of supply of wheat available for consumption

<u>Action</u>	<u>Results</u>
5. Expansion of supply available for consumption	Decrease in equilibrium wheat prices and increase in equilibrium wheat quantity
6. Decreases in equilibrium wheat prices and increase in equilibrium wheat quantity	Net benefits in terms of producers' and consumers' surpluses.

Critique

This model was reviewed by Dr. L. Thurow* and Dr. C. Granger.* They tended to differ in their evaluation of the usefulness of this approach --Granger felt that this was a sound piece of work with acceptable and worthwhile estimates of benefits, while Thurow disagreed with the model of wheat supplies and demand as well as the technique for measuring benefits. Comments tended to group around five subject areas: the measures of social welfare employed in the model; the probability distribution used for crop forecast errors; the export demand elasticities; improved information versus improved forecasts; and nonsymmetrical cost functions with respect to crop forecast errors.

Welfare Measurement. Both reviewers were uncomfortable with the use of changes in consumers' and producers' surplus as measures of social benefit. Thurow stated that the technique is correct only for small changes and argued that the real income effects of changes in wheat prices should not be ignored. Granger, on the other hand, while not completely accepting

* Thurow, Op.Cit.; Granger, Op.Cit.

the technique, did not offer alternatives and stated that since the concept is generally accepted by economists it does have some status.

Probability Distribution of Forecast Error. The model assumes a normal distribution for forecast errors--this distribution becomes an input into benefit calculations and thus is important. Granger generally accepted this approach, but felt that it could be refined somewhat. Thurow, on the other hand, doubted this basic assumption and went on to indicate that the signs of the errors as pointed out in the report did not indicate randomness--the December forecasts compared with the September forecasts tended to err on the high side many more times than on the low side. He also felt that the calculations should take into account that, while weather may be normally distributed, crop yields resulting from weather changes are not--for example, dry weather at some point in the growth cycle may have long-term impacts that cannot be corrected by later wetter weather.

Export Demand Elasticities. ECON did not explicitly determine export demand elasticities in the model. Thurow felt that because the U.S. is a residual supplier for some countries and a main supplier for others these groups of countries should be treated separately. For example, the European demand is small and depends on their domestic supply conditions; therefore, their demand has virtually zero price elasticity--i.e., they will take a given quantity without regard to price. On the other hand, for other countries, price is an important factor in determining the quantity demanded from the U.S.

Information Versus Forecasts. If improved information is not used effectively it does not necessarily result in improved forecasts. Granger points out that there are alternative ways to improve forecasts, and that NASA should be concerned not only with improving informational inputs, but also with the development of a more effective "complete forecast package".

Nonsymmetric Cost Functions. Granger felt that an interesting aspect of the ECON model was its use of nonsymmetric cost functions with regard to forecast errors. That is, if a forecast error leads to market shortages in one period, these shortages will not be completely made up in subsequent periods. Therefore, crop overestimates may lead to greater costs than underestimates. While these functions were not estimated in the ECON work, Granger felt that such estimates might be helpful to NASA system designers.

Overall Evaluation

As indicated earlier, the two reviewers were of opposite opinions regarding the validity and worth of this model. Thurow did not accept the approach. He felt that because U.S. price supports and crop controls existed over the period of data used for estimating supply and demand functions, these estimates were not valid. He felt that the modelers failed to take these market constraints into account and, therefore, their point estimates of benefits could not be accepted. He suggested that the report be expanded to provide a variety of estimates for benefits allowing supply and demand elasticities to vary. Furthermore, while he basically

accepted the concept of an outward shift in the supply curve (which is at the heart of the ECON analysis), he criticized ECON for not indicating how this is calculated in the model.

Granger generally accepted the ECON work, while offering suggestions for expansion. He based his judgment on generally used statistical evaluations of the model coefficients and estimates. Thus, he generally was satisfied with the statistical confidence levels of the model.

Both reviewers were of the opinion that the empirical results should be subjected to sensitivity tests and the results reported. Both felt that range rather than point estimates of benefits should be provided based on these sensitivity analyses. Both, however, felt that the benefits obtained were reasonable, and Granger further pointed out that "further refinements of the study may lead to changes in the actual figure for the potential benefits of the new system. I feel that any revised figures are as equally likely to be changed upwards as downwards, and that it is most unlikely that benefits will be anything but considerably greater than projected costs".*

* Granger, Op.Cit. p 9.

COMPARISON OF ECON AND EARTH
RESOURCES SURVEY STUDIES

The Earth Resources Survey Study

The Earth Resources Survey (ERS) Benefit-Cost Study was prepared by the Earth Satellite Corporation and the Booz-Allen Applied Research Corporation for the U.S. Department of the Interior, Geological Survey (Contract No. 135-9). The report (Vol. VI) was presented on November 22, 1974. This report was concerned with four types of impacts from a satellite survey system:

Distributional Impacts

Environmental Impacts

Social Impacts

International Impacts.

Of these, only the international impact analysis is directly comparable with the ECON studies.

This study concentrated on international trade impacts and impacts on the U.S. balance of payments from (1) exportation of this new technology and (2) changes in agricultural trade resulting from application of the improved information. The study considered primarily agricultural trade, concentrating on wheat and rice, with particular emphasis on wheat.

The study considered a wide variety of situations, cases, and assumptions. An "excess supply-demand framework" was used for much of the analysis that incorporated estimates of impacts on consumer welfare and on the volume of trade. A quantitative model was constructed, examining two cases of wheat exports:

- (1) U.S. trade with Western Europe, Japan, and developing nations
- (2) U.S. trade with the USSR and the People's Republic of China (PRC).

The specific data used and details of the calculations are not given, but the geometric and algebraic arguments are clearly presented.

The ERS study measures consumer welfare changes as changes in the total value (price times quantity) of product (wheat) consumed in the United States. Increases in total value of consumption are counted as increases in consumer welfare and vice versa. Changes in trade are calculated as changes in total value (price times quantity) of exports from the U.S. to the area of concern.

Some of the key basic assumptions of the analysis are:

- (1) The ERS system will have the capability of a 10 to 30 percent improvement in the accuracy of publicly available information
- (2) The accuracy of currently available information on production in the U.S., Western Europe, Japan, and developing countries is now comparable in all of these areas; i.e., importers in those countries have comparable information to that available to exporters in the U.S.
- (3) Importers in the USSR and the PRC now have more accurate private information on production in those areas, than is available to U.S. exporters.

- (4) Overestimates of foreign production have an equal but opposite effect as underestimates and each is expected to occur about one-half of the time--i.e., the "loss" function is symmetrical.
- (5) In the quantitative analysis, wheat was initially priced at \$4.00 per bushel, the elasticity of domestic demand was assumed to be -0.1 and of foreign import demand -0.5.

The results of the wheat analyses were:

- (1) The U.S. would lose annually a total of \$2.8 to \$7.4 million (unadjusted for cloud cover) in wheat trade and consumer welfare to Western Europe, Japan, and the developing nations from the use of improved information.
- (2) The U.S. would gain \$5.3 to \$16.1 million annually in consumer welfare and trade with the USSR and the PRC.
- (3) Net gains to the U.S. from improved inventory management range from \$2.5 to \$8.7 million. Adjustments for cloud cover make the net benefit in wheat \$0.4 to \$1.5 million for a one-satellite system and \$2.5 to \$8.7 million for a two-satellite system.

From this analysis, the conclusion is reached that the U.S. should improve publicly available information on foreign wheat production only to the level of accuracy of information already available to importers. Carrying the accuracy to higher levels will decrease benefits to the exporters, i.e., the U.S.

Comparison with ECON Studies

There are several substantial differences between the two sets of studies:

- (1) The ECON studies are more quantitative, more complex, more exhaustive, and the quantitative parameters and co-efficients appear to be derived from a more extensive statistical analysis than the ERS studies.
- (2) On the other hand, the ERS studies are logical constructs and consider a wider range of assumptions and potential circumstances than do the ECON studies.
- (3) The measures of benefit are somewhat different, especially with regard to consumer benefit--ECON uses changes in consumers' surplus as a measure and ERS uses changes in the value of consumption, termed consumer welfare, as a measure --the impact that this will make on final estimates of total benefit is difficult to say, and depends on the specific shape and slope of the demand and supply curves used in the analyses.
- (4) In addition to consumer surplus, the ECON studies also consider producers' surplus in their measure of benefits.
- (5) A major difference is that the ECON studies consider a larger number of avenues to achieve benefit than do the ERS studies--in addition to price and quantity changes due to more accurate information leading to improved judgments of the "true" expected import demand position, ECON considers such impacts as

- (a) Changes in the export and domestic supply curve for the U.S. resulting from production efficiencies due to improved information
 - (b) Changes in the pattern and level of inventory build-ups in the U.S. and depletions due to improved information
 - (c) Changes in the variance of supply
 - (d) Changes in the perception of import demand based on improved information
 - (e) Influence of an asymmetric loss function; i.e., that over and underestimates of demand have different impacts (see p. 31).
- (6) The ERS studies tend to focus on inventory management in the importing countries that can be influenced by improved information, while the ECON studies tend to concentrate on production and inventory management in the U.S., relating to both domestic consumption and export.

Both of these are interesting sets of studies. In summary, the basic differences seem to resolve to one of approach to the problem, and the fact that while the ERS discussion considers a wide variety of factors and possible impacts, the ERS quantitative analysis really considers a lesser range of impact possibilities than in the ECON studies. It is difficult to comment on the relative "accuracy" of the alternative estimates, given the information available to Battelle. However, it appears that the ERS studies understate the benefit picture, assuming that the ECON hypotheses and analyses are at all correct. This is particularly true considering potential benefits to the U.S. as an exporter. The ERS studies

concentrate on the potential actions and impacts of importers, while the ECON studies consider the actions of importers, export inventory holders, and producers. In both analyses, the rest of the world tends to benefit to a greater extent than does the U.S., but in the ECON studies, the U.S. benefit is of much greater magnitude than in the ERS studies.

The ERS report does point out one important factor. Both sets of studies were conducted under the basic assumption that the major consideration in determining import demand is the difference between demand and domestic supply in the importing countries. In some important cases, such as the USSR and the PRC, other considerations, such as foreign exchange balances, other planning targets, and other decision factors may be very important in determining actual import demand. In this type of situation, improved information on actual and expected production is less important in estimating expected demand than in those situations where the decision is based mainly on supply/demand considerations.

In conclusion, the ECON studies, taken together, tend to provide a more comprehensive estimate of potential benefits from a LANDSAT system in the case of wheat, than does the ERS study of international impacts. However, neither set of studies provides a truly complete estimate. As one of the reviewers of the ECON studies stated, it is likely that actual total benefits will be even greater than those estimated.