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PROJECTIONS OF RESOURCE ALLOCATION AND PRODUCTION IN KOREAN AGRICULTURE WITH A MICROECONOMIC MODEL

- A Component of the Korean Agricultural Sector Model -

Hartwig de Haen

Paper to be presented at the Summer Researcher Workshop of the Agricultural Economics Research Institute.

Seoul, Korea, 30 July - 4 August 1973

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INTRODUCTION

Background of the Study*

This report describes a study which is part of a comprehensive agricultural sector analysis for Korea under a USAID contract. It is concerned with the incorporation of a microeconomic model of resource allocation and production into an existing general systems simulation model of the overall agricultural sector.[1]

So far the projections of supply and factor input in the Korean agricultural sector model were based on exogenous ("off-line") computations and "guesstimates" made by a committee of experts. The revised model with an endogenous explanation of land allocation, livestock production and farm mechanization is an attempt to view resource utilization, supply and demand as interacting components within one comprehensive system.

The model component is presented at this point in time to the Korean research establishment via this paper although the research on model structure and data collection is still going on. This is done in order to collect further comments and criticism especially from Korean experts and to utilize those comments as the work with the model is continued. However, the reader should be aware of the preliminary character of the study and consider carefully the specific assumptions upon which the results of this modeling phase are based.

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*For a more detailed report on the model see: H. de Haen and Jeung Han Lee, "Dynamic Model of Farm Resource Allocation for Agricultural Planning in Korea--Application of Recursive Programming within a General Systems Simulations Approach," Korean Agricultural Sector Study (KASS) Working Paper 72-1, East Lansing, Michigan State University, October 1972. See also (6).

[1] A full understanding of background and economic-political framework of this study requires knowledge of the research of the Korean Agricultural Sector Study Team (KASS), reported in (9).

Problem Identification

Reallocation of resources in agriculture and particularly the mechanization of basic--thus far relatively labor intensive--activities in crop production appear to be necessary conditions for further economic development in Korea [Lee, (8)]. While the Korean economy as a whole has been growing very rapidly during the last decade, there were considerable differences among major sectors. In the period between 1959 and 1969, the growth rate of GNP (in 1965 prices) was 8.6% for the economy, but only 4.5% for agriculture. Hence, the major contribution for economic development during that period obviously came from the industrial-urban complex, while factor productivity and aggregate production in the farm sector remained relatively unchanged. A continuation of this development in the next decade in connection with the actual population growth rate of between 2.2% and 1.8% would very likely create problems of food shortage and an unsatisfactory income distribution between agriculture and the rest of the economy. These trends would even be worse given the extensive resource transfer from agriculture to other sectors.

The magnitude of these problems will depend on the effects of major factors affecting demand for agricultural products on the one side and the intensity of adjustment processes taking place in agriculture on the other side. The aggregate demand for food will certainly grow considerably, due to rising per capita incomes and population growth. Moreover, its composition will change, resulting in changing relative prices and a changing equilibrium of factor earnings among different commodities. At the same time there will be a remarkable decline in the resource base available for agricultural production. Projections indicate that urban development will require about 20,000 hectares of agricultural land per year and that the agricultural labor force will start to decline by the end of the 1970's, bringing agriculture's share in the total labor force down from 50% to 20% between 1970 and 1985. This development will increase the marginal profitability of land and labor saving technologies and thus very likely initiate corresponding adjustment processes in agriculture.

The questions with which this study deals refer to the intensity and timing of this reallocation process, the composition of enterprises and the investment in labor-saving technology. The analysis of land-saving technologies, such as high yielding varieties, together with higher fertilizer and chemical application will be left out for practical purposes,[2] although it is certainly not considered to be less important. Instead, particular emphasis is given to investment in labor-saving technologies. The model attempts to reflect the choice problem of today's farmers with respect to the level of technology by explaining the competition among human, animal and mechanical power and determining endogenously their respective opportunity costs and returns in alternative kinds of utilization.

Like the overall KASS-model, the study is based on a regional disaggregation, assuming that each of the three regions may have comparative advantages for some specific products. Those advantages may result from low costs for transportation to consumer markets, from specific skills in production and marketing, lower opportunity costs for land and/or labor, or from higher yields due to soil and weather conditions. Given these factors the competition among regions for production quotas and market shares leads to regional specialization which the model tries to explain and to predict for the future.

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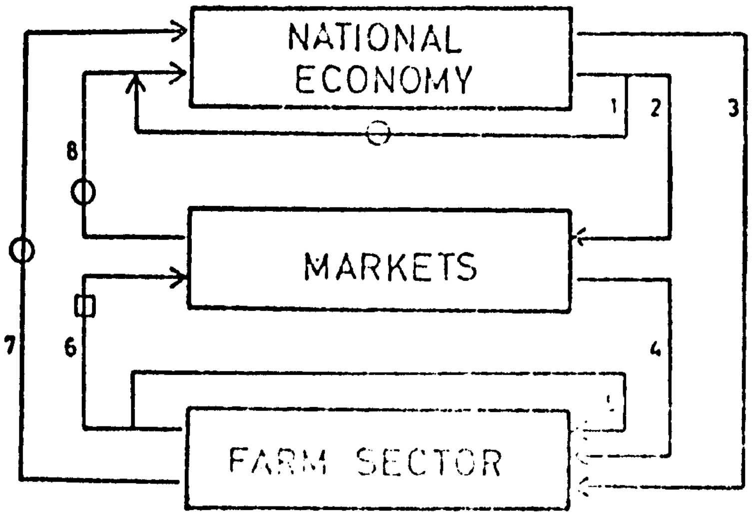
[2] A research project concerned with these problems is currently being done by Lee, Jung Han at Michigan State University.

A MICROECONOMIC DECISION MODEL

Resource Allocation Decisions within an Interdependent System

The fundamental hypothesis pursued in this study is that a comprehensive policy analysis of agricultural development should include the major interactions within the overall socio-economic system. With 50% of the total labor force still working in agriculture and 30% of the total GNP produced by the agricultural sector, there are important feedback effects from agriculture to the national economy and vice versa. These ideas are sketched in Figure 1. An ideal model of agricultural economic development would contain all the linkages contained in the diagram. It should contain both feedback originating from national economic development as well as feedback effects from the agricultural sector to the national aggregate. The first group of interactions contains the lines 1, 2, and 3: (1) future national development is conditioned by past investments, savings, and intersectoral transfers within the aggregate itself; it contains (2) consumer demand from and input supply to agriculture and (3) policy control and information flows from the aggregate and policy level to the farm sector. Resource allocation and production decisions on the farms would further be affected by (4) commodity prices received and input prices paid on markets in previous years and by (5) previous investment and production on the farms themselves. Given the consumer demand and input supply, the market prices for any period would depend also on (6) product supply and input demand from agriculture. The second group, the feedback effects from agriculture, include (7) the flow of resources from agriculture to other sectors and the contribution to national aggregate income generation, public revenue, etc. Prices on markets for food and agricultural inputs would have an impact (8) on some national economic variables and policy instruments.

FIGURE 1: DYNAMIC SYSTEM'S MODEL OF KOREAN AGRICULTURAL DEVELOPMENT: LINKAGES TO MARKETS AND NONAGRICULTURAL SECTORS



O LINKAGES EXCLUDED IN PHASES 1 AND 2
□ LINKAGES EXCLUDED IN PHASE 1

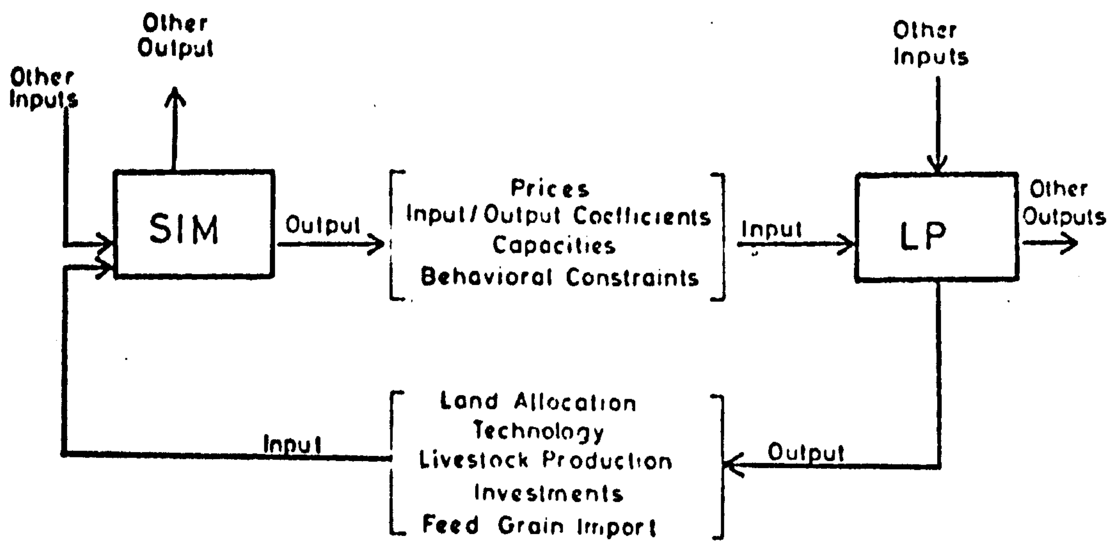
Currently the feedback effects 1, 7, and 8 on the national economy are only implicitly included in projections of consumer income and food expenditures. The emphasis of the current sector study lies on interactions between the farm sector and the various markets, given certain assumptions on the overall economic development.

This particular model component is concerned with explantion and projection of farm firm decisions with respect to resource allocation. A microeconomic framework with activity analysis is used to account for some of the strategic details which appear to be relevant for those decisions [Day and Singh (2)].

The model is run in two phases: in phase 1 resource allocation and production are projected for exogenous price assumptions. In phase 2 the producer prices in any given period depend on interactions of demand and supply as well as on government policies.

Inputs to the decision model of a given period (L.P.) are either lagged outputs from previous L.P. solutions and from components of other parts of the General System's Model (SIM) of the agricultural sector, or they are outputs from components being computed earlier for the same period, or they are projected exogenously. Methodologically one gets a General System's Model with dynamic interactions between a Linear Programming component and a more general simulation model (SIM) as shown in Figure 2.

FIGURE 2: DYNAMIC LINKAGE BETWEEN COMPONENTS OF THE GENERAL SYSTEM'S MODEL (SIM) AND A LINEAR PROGRAMMING COMPONENT (LP)



Actually the whole system is the model of a recursive decision system, where the L.P. component represents the farm firms, and the other components describe the physical and institutional environment, in which the firms operate and in which farmers derive their decisions. A variety of theoretical and empirical studies have been prepared with similar models.[3]

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[3]See e.g. the basic publication by Day (1). Examples for model applications are (2, 7, 3, 4).

In the Korean model the environment is represented by (1) a set of policy determined variables, (2) endogenously generated variables and (3) exogenous variables. Policy variables are mainly prices for those products where market intervention for stabilization and price-support take place (food grain management) and for those inputs (e.g. tillers, fertilizer, etc.) which are controlled by the government. The second group of endogenously generated variables refers mainly to those prices whose level is determined by market mechanisms. In this case a consumer demand sub-model determines the price level by equating supply (from the farm firm component) with demand, the latter being a function of lagged prices, consumer income and population size. Another endogenous variable is the agricultural labor force, projected in a national demographic model. The exogenous variables are crop and livestock yields, technical coefficients and input prices.

The main outputs of the farm firm component (L.P.), computed once every year, are acreages for field crops, utilization of labor, draft cattle and farm machinery, machinery investment and import requirements for feed grain. Moreover the dual solution provides information about the cost structure of agricultural production computed as shadow prices of various resources.

Dynamic Model of Comparative Regional Advantages

The total agricultural area of Korea is divided into three quasi-homogenous regions. Since farm sizes do not differ significantly so far, no further disaggregation is done within the regions. Each region is treated as if it were one unique decision unit to which principles of individual farm development can be applied. Allocation, production and investment activities for all three regions are computed as the solution to a multi-regional activity analysis problem, the data space being determined by previous solutions and exogenous variables.

Multi-regional Activity Analysis

For any given period t, the linear programming problem is given by:

(1) $\Pi^*(t) = \overset{\max}{\bar{z}(t)} \cdot \bar{x}(t)$

(2) s.t. $\underset{=}{A}(t)\bar{x}(t) \leq \bar{y}(t)$

(3) $\bar{x}(t) \geq 0$

Where: $\Pi^*(t)$ is the expected optimal value of the objective function

$\bar{x}(t)$ is the vector of activity levels

$\bar{z}(t)$ is the vector of objective function coefficients (= expected cash return per activity unit)

$\underset{=}{A}(t)$ is the matrix of technical coefficients

$\bar{y}(t)$ is the vector of constraints

All variables are indexed by regions.

In order to relate this decision problem for period t to previous decisions and to influences and information from the environment, three basic sets of dynamic feedback functions are defined. The first is a set of functions which relate the coefficients z_i of the objective function (expected payoffs) to past decision variables, shadow prices, and exogenous variables:

(4) $\bar{z}(t) = z(\bar{x}^*(t-1), \ldots, \bar{x}^*(t-p), \bar{r}^*(t-1), \ldots, \bar{r}^*(t-p), \bar{v}(t))$

Where: $\bar{r}^*(t)$ = vector of optimal dual values (shadow prices) of constraints

$\bar{v}(t)$ = vector of exogenous variables

$*$ = optimality

p = maximal length of a lag

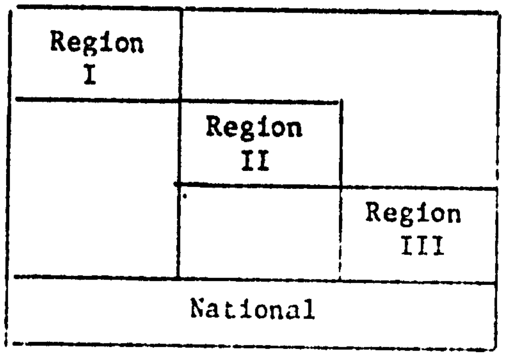
The second is a set of functions for the elements of the constraint vector.

(5) $\bar{b}(t) = b(\bar{b}(0), \bar{x}^*(t-1), \ldots, \bar{x}^*(t-p), \bar{r}^*(t-1), \ldots, \bar{r}^*(t-p), \bar{v}(t))$

The third is a set of functions for the elements of the input-output matrix.

$$(6)\quad \underline{A}(t) = A(\bar{x}^*(t-1), \ldots, \bar{x}^*(t-p), \bar{r}^*(t-1), \ldots, \bar{r}^*(t-p), \bar{v}(t))$$

The L.P. component for each year is block diagonal with one block for each of the three regions:[4]



This blockdiagonal matrix structure makes the modeling of inter-regional competition possible. In the current version of the model, there are three overlapping constraints for all three regions. Two stand for the politically fixed national quota of raw silk and tobacco production. The third is a restriction for feed grain imports. All other constraints are repeated in each region.

Activities

The activities are: (1) Production of various field crops, including forage and pasture management, distinguished by type of technology; (2) Production of livestock products; (3) Planting of orchards and mulberry fields; (4) Investment in farm machinery; (5) Feed grain imports; (6) Various transfer activities. The technology may either be traditional, i.e., using hand and animal tools, or mechanized with a 10 hp-powertiller including the necessary attachments. In the case of rice production there is a third separate technology: transplanting of rice by mechanical rice transplanter. The livestock

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[4] For a complete model description, see de Haen, H. (6).

activities are dairy, Korean cattle, hogs, eggs and broiler production. Cattle can be kept either as draft cattle or for beef production.

Constraints

The constraints for each region include land capacities for paddy, upland and double cropping. They include limitations for labor, draft cattle and machinery during two peak seasons, constraints for the current herd size of livestock enterprises, flexibility constraints for acreages of field crops, adoption constraints on investment, and several balance equations for feed inputs.

For simplification it is assumed that all land can be mechanized and that there are no differences in labor requirements or input-output ratios for different locations within a region.[5]

In addition to physical resources and transfer balances the model contains a variety of so-called flexibility constraints to account for the limited ability of the regional aggregate of farms as a whole to adjust to new data constellations. The pure resource allocation model without any additional constraints on year-to-year changes would only then be a good predictor for the economic activities (vector $\bar{x}$ in the L.P. problem), if the following conditions were given for each farm contained in the aggregate:[6]

(1) Every farmer adjusts production and resource allocation including investment immediately to new prices and technical coefficients.

(2) New enterprises are immediately accepted if they are profitable.

(3) Resources are allocated in such a way that their marginal value products are alike in all enterprises.

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[5]The formulation of constraints for physical resources, herd size and balance equations corresponds with well-known planning models for farm management problems and will not be described here.

[6]See also Cigno, A (3).

Such an assumption is not likely to be realistic. Instead one may assume that adjustment to new socio-economic data occurs with a time lag, because only a few farmers are willing to adopt new ideas immediately anticipating profits from their decisions, whereas others stick to their old plans until the new situation has proven to be permanently favorable. Moreover, in an attempt to avoid risk, farmers hesitate to expand commodities with a great variability of yields or prices.

The model tries to reflect the "suboptimal" and cautious behavior of farmers by incorporating additional adaptive constraints which guarantee that production patterns in any year do not deviate by more than a certain proportion from the organization during the previous year. If $x(t)$ is the vector of production activities and $\bar{\beta}_u$ and $\bar{\beta}_l$ sets of upper and lower bounds on production levels, the flexibility constraints can be written as:

$$(7)\quad \bar{\beta}_l\ \bar{x}\ (t-1) \leq \bar{x}\ (t) \leq \bar{\beta}_u\ \bar{x}\ (t-1)$$

Optimization takes place only within the boundaries defined by these behavioral constraints. Only if a certain configuration of economic data continues to be in effect over several years will the system adjust its development toward the new "optimum". In the meantime the respective flexibility constraint will hold and the respective shadow price will measure the extent to which the marginal value product of this activity is greater (if the upper bound holds) than the value imputed to the flow of services from the physical resources required by the respective enterprise.

Similarly the level of investment in new machinery is restricted to a certain proportion of the existing stock of machines invested in previous years. This reflects the adoption behavior of farmers during the transition process, where learning and diffusion of new ideas are accelerated as the number of previous adopters increases.

Governmental policies restrict the production of tobacco and raw silk as well as the amount of feed grain imports on the national level. The inter-regional competition for participation in these quotas is represented in the model by overall national constraints for land allocation to tobacco and new mulberry fields and for feed grain imports:

$$(8) \quad \sum_{k=1}^{3} \sum_{j \epsilon A_i} a_{ij}^k x_j^k(t) \leq y_i(t)$$

$i \epsilon N$ (set of national constraints)

k - regions

A_i: (set of activities requiring the national constraint i)

Objective Function

The model assumes that farmers try, within the limits of the current physical and institutional constraints, to realize those combinations of enterprises and activities which maximize the expected income without running an unbearable risk of losing a basis for family subsistence.

Dynamic Feedback and Exogenous Variables

In order to account for the dynamic properties of the sectoral adjustment and growth process, a dynamic feedback operator is defined which relates the values of the objective function coefficients, of constraints and of matrix coefficients to preceeding L.P. solutions, to variables being computed in other parts of the simulation model and to exogenously projected variables.

Dynamic Generation of Ojective Function Coefficients

Profit expectations are assumed to be the actual realized figures lagged by one year. They are generally a function of previous yields, prices for outputs and variable inputs and input quantities, all of the latter being projected by various components of the simulation model. For perennial production activities the objective function coefficient includes the yearly average net returns during the mature production phase minus proportional replacement costs plus proportional salvage returns.

Farmers' decisions to replant old orchards or mulberry fields or to expand the existing capacity are based on the marginal value product imputed to their existing perennials in previous years. The costs of machinery investment are composed of interest costs and depreciation converted to constant average costs per year. The variable costs of machinery utilization appear as cost elements in the respective production activities.

Dynamic Feedback for Farm Resources

Farm resources comprise cultivated land, labor, machinery, pasture land, orchards, mulberry fields and livestock herds. Total land and labor capacities are exogenous variables for the RLP component, originating from exogenous projections and from the demographic model respectively. In order to obtain capacities available for allocation decisions, pre-occupied areas (newly planted fields) or pre-occupied labor (for intercropping under pre-mature orchards and mulberry fields) are substracted. The feedback function for labor constraints is written as follows:

$$(9) \quad y_i(t) = \ell(t) \cdot b_i(t) - \sum_{j \in R} \sum_{s=1}^{N'_j} b_{ij} x_j(t-s)$$

$i \epsilon W$ - set of labor constraints

ℓ - projected agricultural labor force

b_{ij} - capacity in hours per season and worker

N'_j - length of pre-mature phase (years) of perennial crop activity j

In order to account for learning and increasing efficiency in field work as the educational level is improved and mechanization is introduced, the coefficient b_i in equation (9) is gradually increased toward an upper limit:

The capacity of machinery j is expressed in hours per season and is a function of investment in previous years. Depreciation is approximated by dividing the average lifetime S_i into three segments with increasing rates of depreciation.

Pasture land, although in most cases collectively used in the villages, is treated as a farm resource in the model, the capacity being exogenously projected in a study of upland development (10).

The technically maximal herd sizes of female breeding animals $y_{i \epsilon V}$ are computed as a function of last year's actually utilized herd x, of the potential net addition from the young female herd and of imports, determined by policy:

(10) $$y_i(t) = x_{j_i}(t) + \beta_i x_{j_i}(t-S_j) + \delta_j(t)$$

$i \epsilon V$ - set of capacities for livestock herds

$j_i \epsilon VP$ - set of livestock activities

β - net rate of potential herd expansion per unit of activity

δ - imports

S_j - maturation time (years) of young female animals

The capacity of fields with perennial crops is equal to the sum of hectares presently in age cohorts 2-4, derived from a distributed lag model with four production cohorts, contained in the existing simulation model. The model is described elsewhere (1).

Dynamics of Flexibility and Adoption Constraints

As discussed earlier, some additional behavioral constraints are imposed on the year-to-year changes in land allocation and livestock production patterns, thus defining a safety zone for the current production decisions. Both the upper and the lower bounds are a function of the previous year's optimal level of the decision variables (See equation 7). As a first approximation, the upper and lower flexibility coefficients, β_u and β_p, were set equal to [1 + the average of the three biggest negative or positive change rates during the last ten years]. The safety considerations played a role in determining farmers' decisions in the past, then the largest change rates in production patterns rather than average rates would indicate the size of those behavioral constraints.

Another set of constraints is used to prevent drastic increases in stocks of specific machines, an assumption which seemed particularly important in the current process of transition from mostly hand and animal power to mechanized production. Assuming that farmers relate their net investment decisions with a rate λ_i to the stock of that investment good which is currently available and assuming a depreciation rate a_i, one gets maximum gross investments x_j from the following difference equation:

$$(12) \quad x_j(t) \leq y_i(t) = (\lambda_i + a_i) Y_i(t-1)$$

$$j \in I_g; \quad i \in IC$$

Where to each $j \in I_g$ there corresponds exactly one $i \in IC$. I_g is a set of gross investment activites. IC is a set of investment constraints.

MODEL RESULTS FOR PHASE 1

As indicated in the section labeled Resource Allocation Decision within an Interdependent System, model results are obtained in two phases; one with exogenously projected product prices and one where prices are determined endogenously in the market component and fed back to generate new price expectations in the resource allocation component.[7] Following are some selected results from phase 1.

Only if exogenously projected prices are identical with prices equating supply and demand in the model, will Phase 1 and 2 give the same result. However such an identity cannot be expected. Unlike reality, the phase 1 model market does not feed back any signals to the producers if supply did not equal demand at the expected price. Hence, no adjustment of supply to changing market conditions will occur.

At this point in time, no results can be presented for a historical reference period. Instead an evaluation of the model has to be based on criteria like internal consistency, compatibility with informed people's judgement and a comparison of historical and projected future trends.

Trends in Production Patterns

Generally the model projections continue the trends in land allocation observed in the past: barley, wheat, summer grain and, to some extent, potatoes decline in acreage while vegetables, tobacco and, in more recent years, forage crops increase. The results for region 3, shown in Figure 3, are representative for the other regions also. The rapid expansion of vegetables can be explained by the relatively high returns per hectare projected for the planning period. Unlike results in regions 1 and 2, potatoes are competitive with other grains in region 3. For tobacco with a growing national quota, the results are displayed in Figure 4: new quota tends to be used by regions 1 and 3, whereas region 2 seems to have comparative advantages for other crops and reduces the tobacco acreage.

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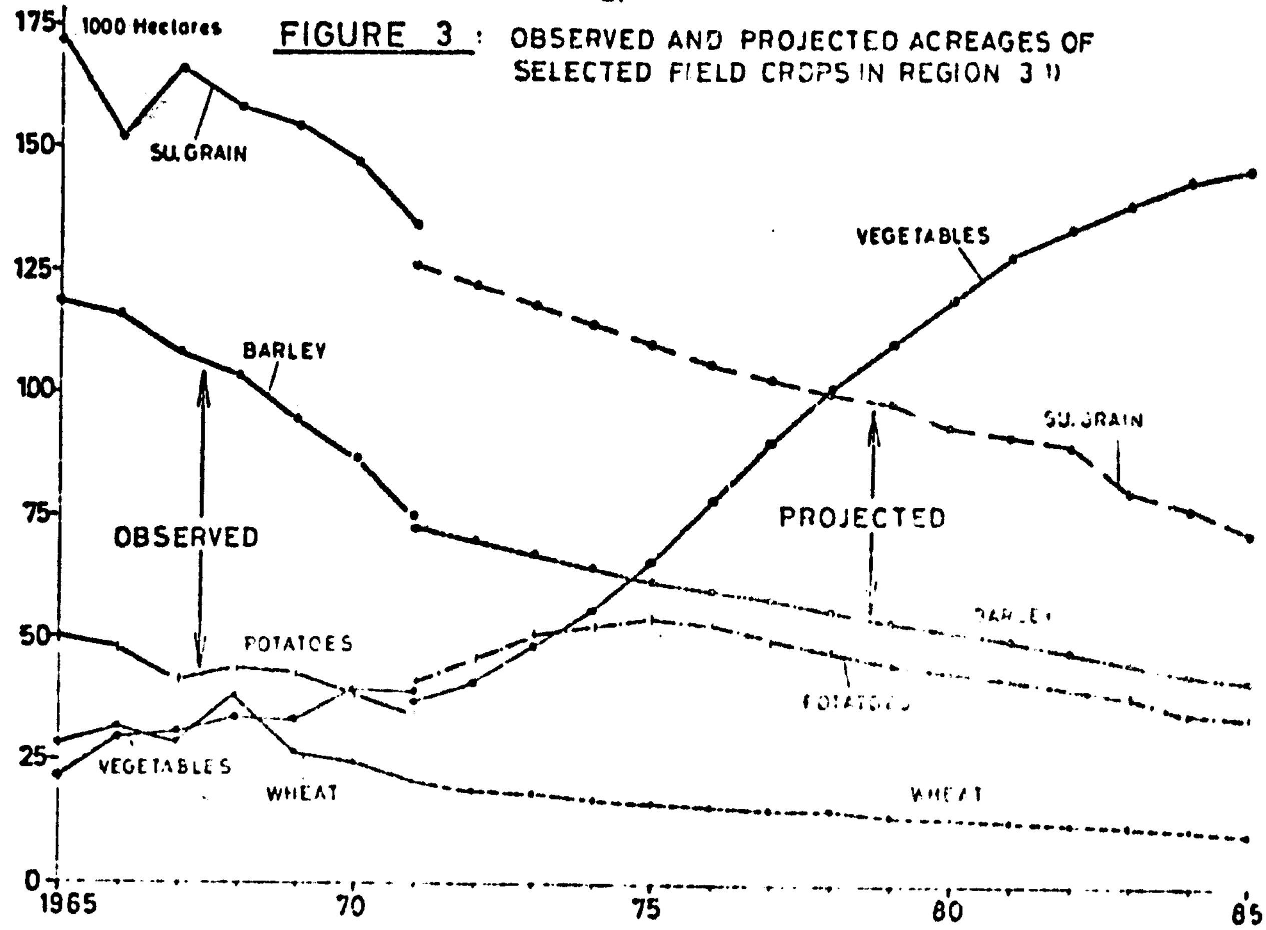
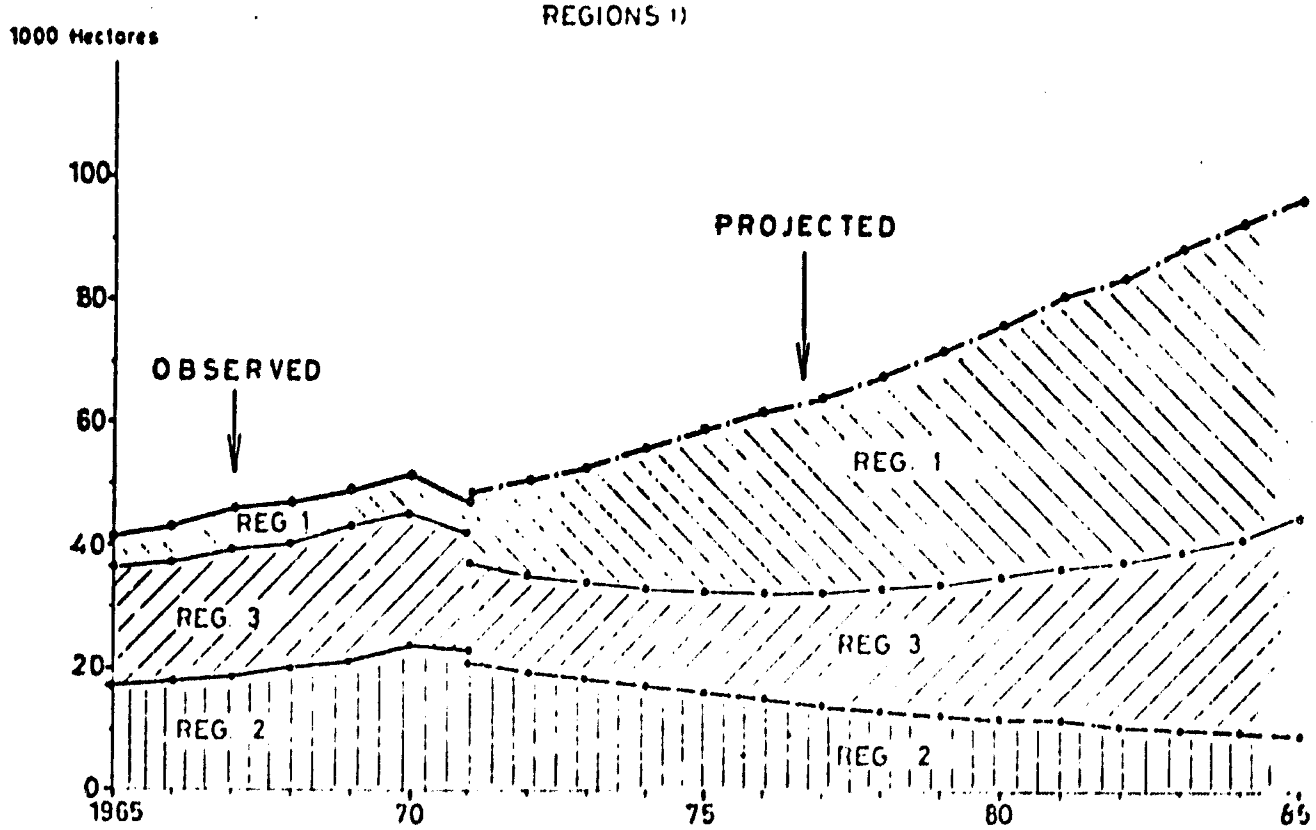
[7] The computer runs had to start with phase 1 because the dynamic linkage of demand and supply models in phae 2 requires additional programming which is still underway.

FIGURE 3 : OBSERVED AND PROJECTED ACREAGES OF SELECTED FIELD CROPS IN REGION 3 1)



1) Policy Alternative 2
Run Alternative 1

FIGURE 4: OBSERVED AND PROJECTED DISTRIBUTION OF NATIONAL TOBACCO QUOTA AMONG REGIONS 1)



1) Policy Alternative 2
Run Alternative 1

Rice production, with high returns per hectare and hardly any alternatives on paddy land, is not affected by the competition process mentioned above. The total projected paddy land acreage is always fully utilized, with the absolute area declining due to urban development (Figure 9).

The clear trend in land allocation may be realistic for the near future.[8] In the long run, however, the unbalanced development of cropping areas, especially the increasing vegetable supply would certainly initiate price responses with the tendency of bringing the marginal factor productivities in different enterprises closer together.

Figures 5, 6, and 7 show some results on livestock production. The knowledge on technologies, costs, and returns in livestock production is still very limited and hence the results should be examined critically. Dairy production, a rapidly growing enterprise in the past, continues its growth for two to ten years and then remains at a constant level thereafter. (A decline of the herd size was not allowed in the model.) One reason for the weak competitive position of dairy production may be the low model price for milk (48.5 won/kg for 1971) which has been considerably exceeded in reality. Hog production is growing at the maximum feasible rate of 8% although like in the case of Korean cattle and egg production, a growing herd size requires a substitution of garbage by purchased concentrates in the feed mix (Figure 6).

The Korean cattle herd size is growing throughout the planning period. An example is given in Figure 7 for region 1. The figure also contains the composition of draft and beef cattle for two run alternatives of the model. In run 1--the basic run--a 5% net increase in yields is assumed for mechanized production. This favors mechanization and a reduction of draft cattle. In run 2

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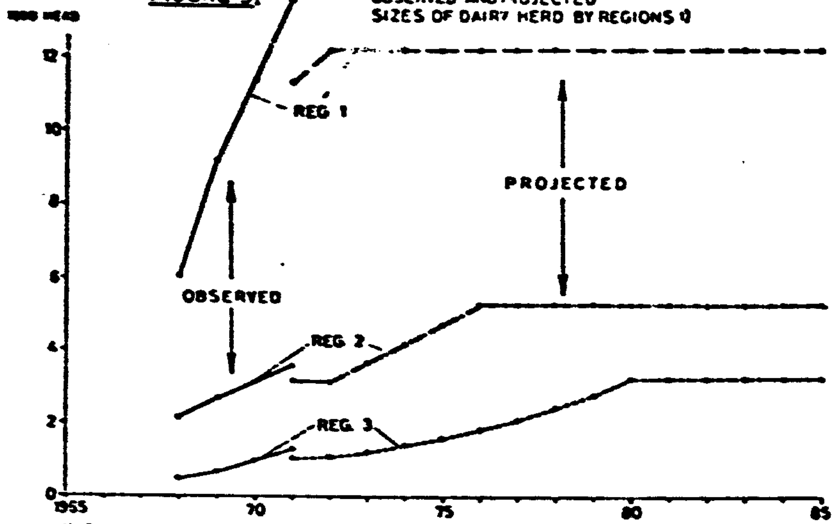
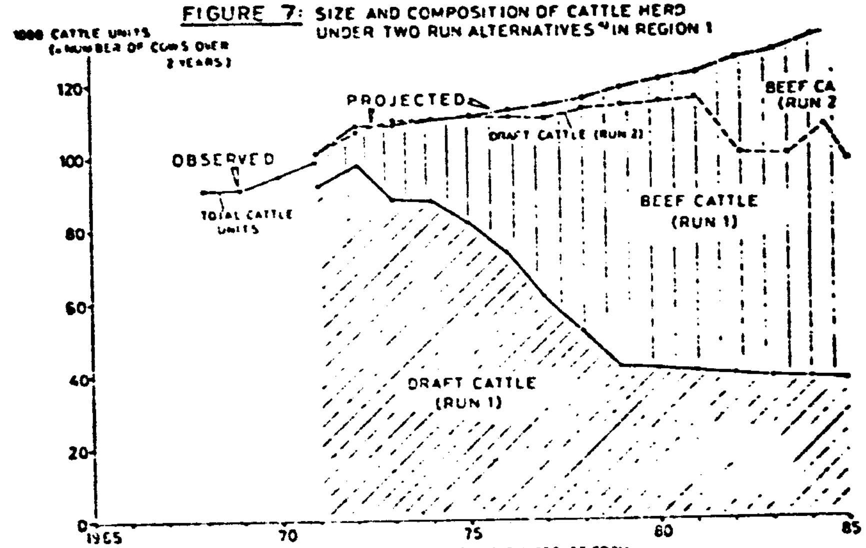
[8] Several farm interviews supported the hypothesis that vegetable production is considered to have remarkable comparative advantages at the moment. Barley is given low priority. However, the farmers did also indicate extra requirements in skills and capital for modern vegetable production.

FIGURE 5: OBSERVED AND PROJECTED SIZES OF DAIRY HERD BY REGIONS 1)



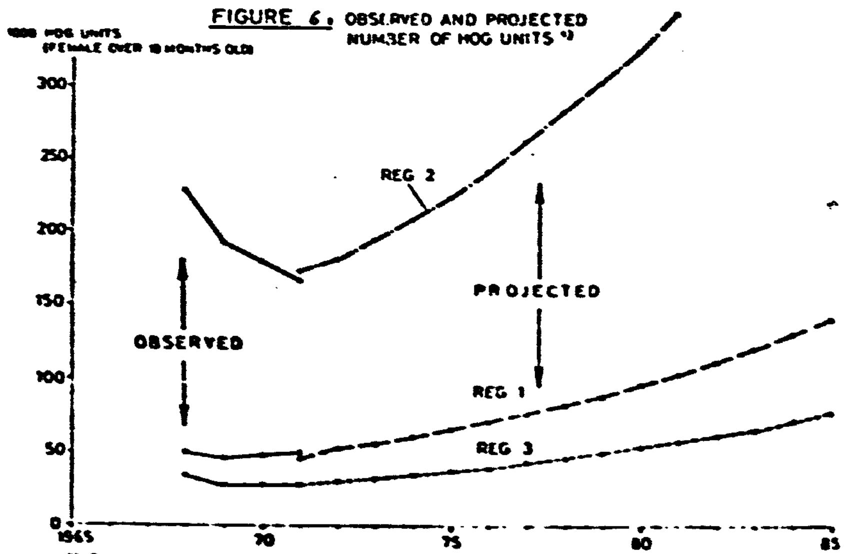
1) Policy Alternative 2
Run Alternative 1

FIGURE 7: SIZE AND COMPOSITION OF CATTLE HERD UNDER TWO RUN ALTERNATIVES 1) IN REGION 1



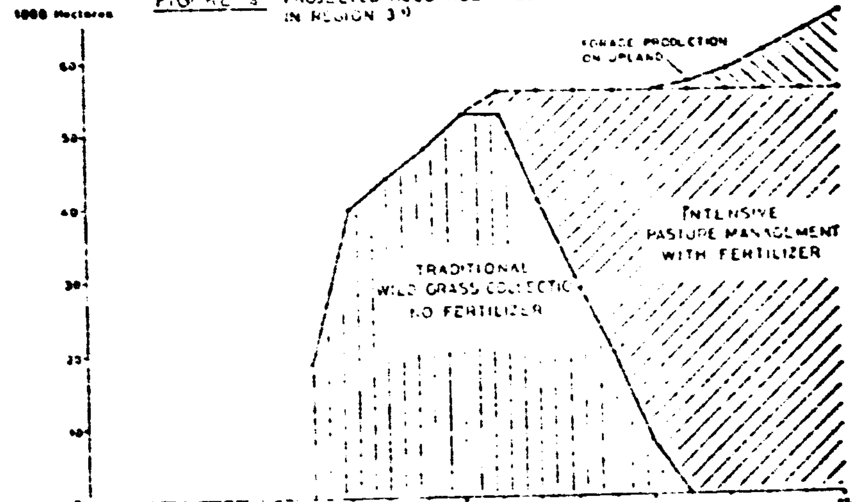
RUN 1 5% YIELD INCREASE FROM MECHANIZATION
RUN 2 NO YIELD INCREASE FROM MECHANIZATION

FIGURE 6: OBSERVED AND PROJECTED NUMBER OF HOG UNITS 1)



1) Policy Alternative 2
Run Alternative 1

FIGURE 8 PROJECTED ROUGHAGE PRODUCTION AND PASTURE MANAGEMENT IN REGION 3 1)



1) Policy Alternative 2
Run Alternative 1

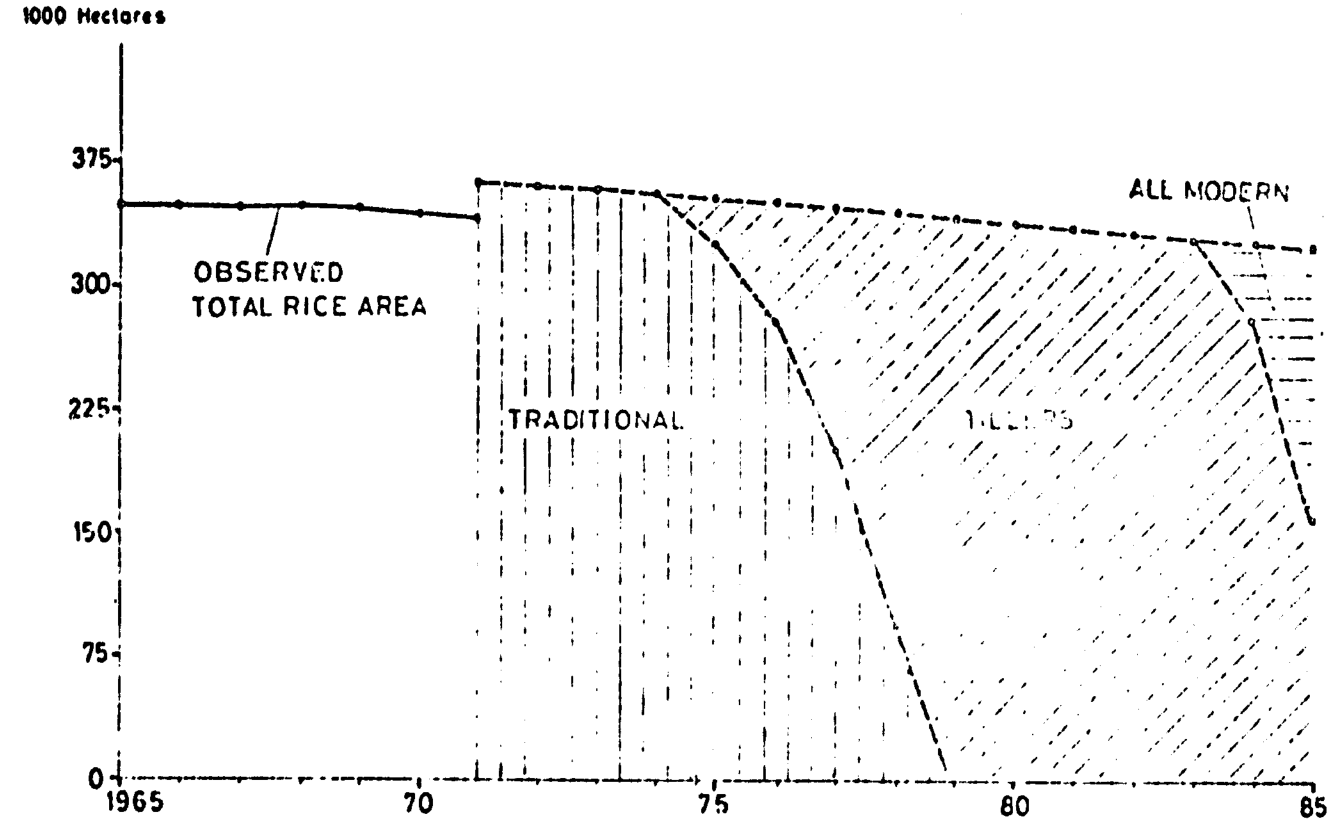
no yield effect from mechanization is assumed, and the substitution of draft cattle by beef cattle starts much later and proceeds slower.

Increasing livestock production requires a growing feed base. Figure 8 displays for region 3 how the traditional wild grass land, which does not have opportunity costs from competing crops, is more and more utilized and then gradually substituted by intensive pasture management on the same land. As soon as all uncultivated land is intensified, the model results show an increasing acreage of upland being used for modern forage production.

Projected Technology Use and Investment

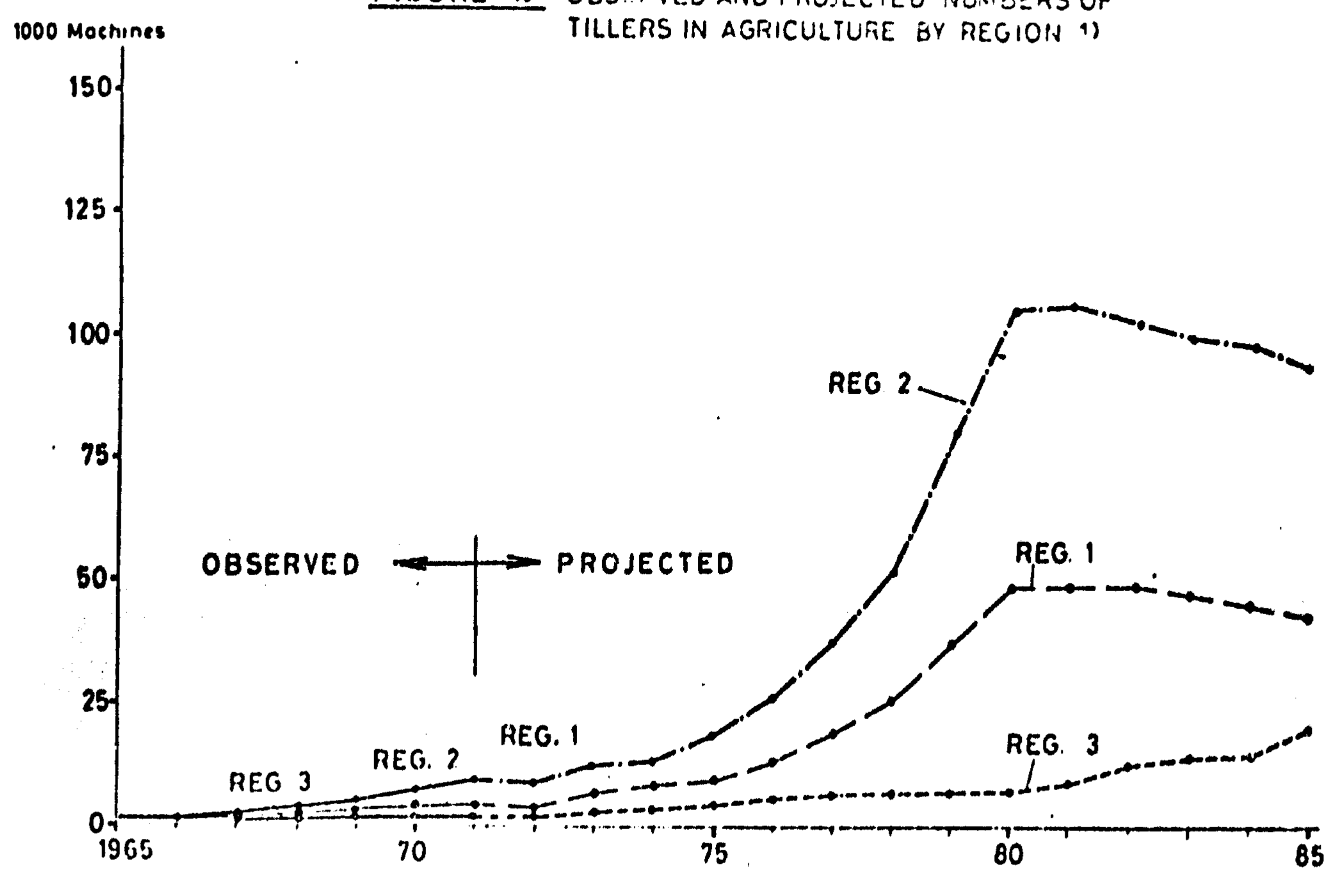
Mechanization of crop production may result from rising opportunity costs of both human and animal labor. The shadow prices of the respective constraints in the model indicate which factor was relevant for any given period or whether both sources of power were scarce. During the first five to nine years of the planning period, it is mainly the alternative use of cattle as source of beef supply that leads to the investment in power tillers (run 1). However, mechanization proceeds very slowly during this time if no yield increase is assumed for mechanized technologies. Beef production is assumed to yield 80% higher outputs with only 20% higher inputs than draft cattle. According to the model results, this generally does not pay off the costs of mechanization if no additional yield effects are assumed and if labor does not have any costs. For the second part of the planning period, beginning with 1979, projections by the demographic component of the KASS model indicate a drastic decline of the agricultural labor force. The resulting increase in opportunity costs of labor give another important incentive for mechanization, first during the fall season, but also later in June where rice transplanters are introduced around 1983. Figures 9 and 10 illustrate this development. The total number of tillers

FIGURE 9: OBSERVED AND PROJECTED RICE ACREAGE BY TECHNOLOGY IN REGION 1 1)



1) Policy Alternative 2
Run Alternative 1

FIGURE 10: OBSERVED AND PROJECTED NUMBERS OF TILLERS IN AGRICULTURE BY REGION 1)



1) Policy Alternative 2
Run Alternative 1

grows very rapidly first in regions 1 and 2 and then in region 3. The decline during the 1980's has to be explained by the land withdrawal for urban development. At this time draft cattle are only used for enterprises where no modernization was allowed in the model, e.g. for intercropping under fruit and mulberry trees.

Key Parameters for Model Results

Following is a brief list of key parameters which seem to have an important influence on the system's development. They may indicate needs for further research and data collection. In some cases they may also give hints for agricultural policy as to where control and guidance of resource allocation and production might be very effective.

Key parameters with respect to cropping patterns and livestock production are:

(1) Gross income and feed requirements

(2) Marginal costs of roughage production, and

(3) Level of import restrictions for feed grains

The composition of field crops and its development through time is very much determined by the gross income per hectare of the respective crops. Given the extremely wide range of gross returns among field crops projected for the planning period, labor requirements and machinery costs have minor impact on establishing the cropping pattern. Vegetables and tobacco, for instance, yield higher returns of both land and labor than other crops. The fact that no market feedback was included in this phase 1 model has particular consequences for the projected supply response of livestock production. At the assumed price for milk, dairy production is not competitive with beef production as soon as the roughage basis becomes scarce. Only in region 3, where the marginal costs of roughage production are lower, does dairy production grow for a longer period.

Given the relatively low price elasticity of milk, a model with market feedback would have resulted in more rapid price increases and a corresponding response in the dairy herd size. The run alternative 1 was obtained without any restrictions on feed imports. An alternative 3 was obtained with imports restricted to 150,000 MT per year. The resulting increase in the costs of feed inputs affect mainly egg production which is reduced considerably. But also the hog production level is sensitive with respect to the price of barley.

Key parameters on technological change are:

(1) The labor-saving effect of mechanization

(2) The yield effect from mechanization

(3) The size of the agricultural labor force and particularly the time profile of the migration process

(4) The efficiency coefficient for labor, and

(5) The time profiles of depreciation functions for farm machinery

The importance of (1) and (2) has been discussed before. The model is particularly sensitive with respect to the dynamics of the labor force. The data used in the model indicate an increasing rural population until 1979 and thereafter a very rapid decline. Unless this development is compensated by increasing efficiency of human labor and rising opportunity costs for draft cattle, it results in a very slow progress in mechanization during the 1970's and a very high pressure to mechanize thereafter. The limitations to the speed of modernization imposed by learning and adoption behavior even result in idle land in the 1980's if the process does not start and is not accelerated early enough. However, no reliable information on efficiency of human labor, the working capacity and the life cycle of farm machinery is thus far available.

TENTATIVE CONCLUSIONS AND SUMMARY

A dynamic microeconomic model of farmers' decisions with respect to resource allocation and production was developed as a component of a comprehensive simulation model. Results are obtained for phase 1, where prices are projected exogenously and no feedback from commodity markets is included. A presentation of some selected results indicates both some positive features and some weaknesses of the model at this stage.

The positive features may be summarized as follows: Projections of resource allocation with the model allow for automatic consistency checks for supply and utilization of resources. They include information about the economic forces underlying growth or decline of resources, measured as shadow prices, that cannot be obtained by non-simultaneous system-models. The model is adaptive in the way that it contains feedback mechanisms relating current plans to past experience. The results, although not yet fully acceptable, seem to support the hypothesis of rational behavior under limited information. Finally, the model structure includes explicitly the competition mechanism between human, animal and mechanical power that regulates the process of technical change in agriculture.

The weaknesses of the model are: some important factors of production so far have been left out; they include mainly investment capital[9] and the skills of people. The limited availability of both resources may have a considerable impact on production patterns (e.g. restriction of modern vegetable production more than the results indicate) and the speed of the modernization process. Another weakness of the current model lies in the data supply. Too many data

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[9] An incorporation of the capital market was left out (1) for lack of data and (2) assuming that the public sector would supply the required capital at the assumed interest rate.

do not differ between regions with the consequence that the projected regional production patterns are very similar. This is particularly true for prices, but also for yields and labor requirements. Whether the model can be a useful instrument for detailed policy analysis as well as for educational purposes in Korea cannot be answered at this moment. A final answer has to be delayed until this component is endogenously linked to the demand component and the rest of the sector model. However, even at this stage it may give some insight into the manifold interdependencies within the farm sector which finally determine the development process in agriculture.

One example where tentative conclusions may be drawn has to do with the supply of feed grains, which is a pre-condition for the growth of livestock production. If the projected prices for agriculture would indeed be realistic for the future, barley would probably become less and less competitive and the decline in acreage, observed in the past, would continue in the future also. High shadow prices on the lower flexibility bounds for barley acreage indicate that even the computed decline in acreage is "suboptimal" in the pure economic sense. A revision of barley price policies, as initiated recently, and further research on new varieties appear to be necessary consequences. The results for region 3 even indicate that only a small change of the barley-potato price ratio may be necessary to make potato production more attractive than barley in certain areas.

Another conclusion is the need to further support the introduction of labor-saving technologies early enough in the 1970's in order to meet the problems of labor scarcity in the 1980's. Appropriate repair systems and training facilities and possibly further investment incentives should be created now, even if the need for mechanization may not yet be seen by many farmers. A delay might probably lead to extensification of land utilization or even to a slowdown of the off-farm migration process. The final answer depends very much on the dynamics of the agricultural labor force development which is an exogenous variable for this model component. The question may be raised here, how the migration rates would be affected if mechanization would indeed proceed slowly and the marginal value product of labor in agriculture would be raised as indicated in the model. In this context it is also interesting to investigate the supply of seasonal labor which might offset some of the major bottlenecks and which may depend very much on the success of regional industrialization policies which are currently encouraged by the government. The model does not give any answers to these questions. However, further insights might be obtained if the model were run for alternative assumptions on the level and the timing of this off-farm migration process.

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