THE NATIONAL MODEL OF SWEDEN

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Foreword

Understanding the policy options available to alleviate the food problem has been the focal point of the Food and Agriculture Program (FAP) of the International Institute for Applied Systems Analysis (IIASA) since the program began in 1977.

National agricultural systems are highly interdependent, and yet major policy options exist at the national level. To explore these options, therefore, it is necessary both to develop policy models for national economies and to link them together by trade and by capital transfers. For greater realism the models in this scheme of analysis are kept descriptive rather than normative. Models of some 20 countries (where the CMEA and EC countries with common agricultural policies are counted as single units), which together account for nearly 80% of such important agricultural attributes as area, production, population, exports and imports, are linked together to constitute the basic linked system.

Originally intended as a part of this system and to explore the agricultural policy options available to Sweden in the context of its open economy, a policy analysis model was developed for Sweden by Olof Bolin and Ewa Rabinowicz in collaboration with the FAP of IIASA.

In this Research Report the authors present the national model of Sweden. I am convinced that, in addition to being an excellent reflection of a specific Swedish approach, it also gives the reader the flavor of the general IIASA methodology.

FERENC RABAR
Food and Agriculture Program
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Preface

The Swedish model follows the general structure of models linkable to the system of national models developed by IIASA's Food and Agriculture Program. In this report we describe what is specific to the Swedish case within the framework of model characteristics and policy problems. The linkage system as well as the data base, generalized for all national models, are described elsewhere.

Work on the Swedish model started in 1978 and was finished in 1984. Many papers, articles, reports, and books have been published concerning the model and its results, mainly in Swedish. Many people have contributed – about seven person-years in total. To all those involved, both in Sweden and at IIASA, as well as to the funders of this project, we would like to express our gratitude. For us, it has been an extremely exciting experience linking not only the Swedish model to its counterparts, but also international scientists and their knowledge.

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PART 1

General Model Descriptions, Results, and Policy Insights

1.1. Issues and Objectives

1.1.1. Swedish agricultural policy – goals, means, problems

Swedish agricultural policy and its basic characteristics are demonstrated by means of partial welfare analysis and, in a rather concentrated and basic form, in *Figure 1.* While the figure might look very complex, it is in fact a drastic simplification of the general principles of Swedish agricultural policy. The main objectives of that policy are to reach

(1) Self-sufficiency.
(2) A fair level of farm income.
(3) An efficient use of agricultural resources.
(4) A reasonable level of consumer prices.

The two most important instruments used to reach these goals are border protection of producer prices and consumer price subsidies.

In *free trade* quantities q_{cw} and q_{pw} would be consumed and produced, respectively, and net imports would be $q_{cw} - q_{pw}$. In this case consumer surplus is represented by the area ABM and producer surplus by the area MCO.

With *border protection* (i.e., the distance $PP_1 - P_w$) and consumer *price subsidies* (the distance a), the situation will change. If the protected domestic price, PP_1 is above the domestic equilibrium price p^x, more will be produced than can be consumed and net exports will be the result. This is the Swedish case for most agricultural products today (1985). However, if farmers themselves have to finance the "export losses" (which is the case for animal commodities), this will mean a reduced producer price to them, i.e., the price PP_2. PP_2 is a weighted average price for domestic consumption commodities, which are sold

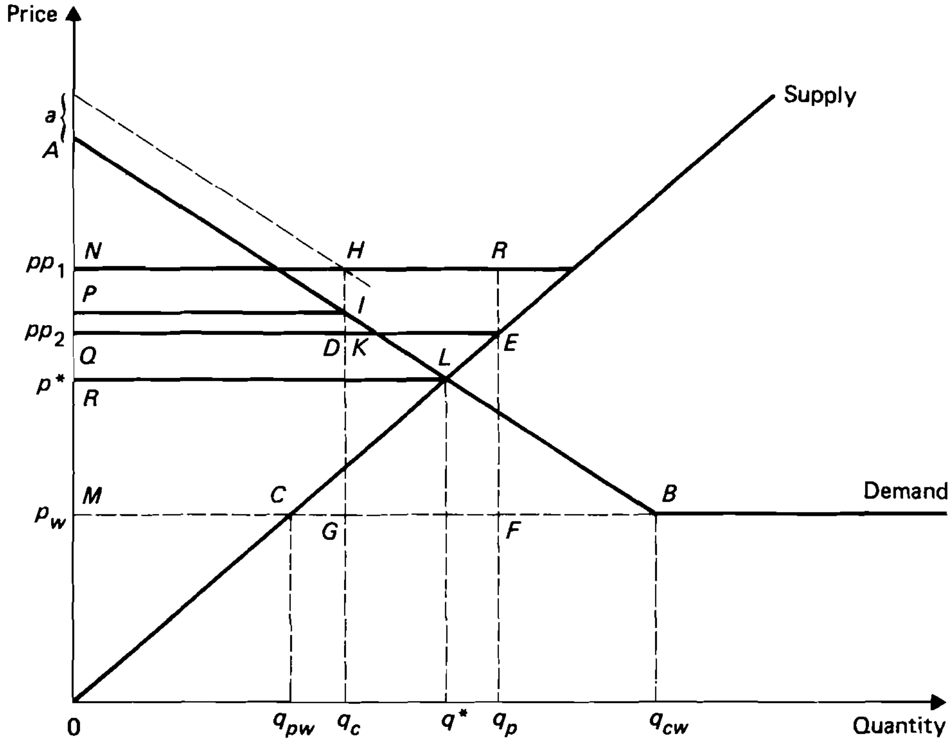

Figure 1. Swedish agricultural policy – means and welfare consequences.

for price PP_1, and exports, which are sold for price P_w. Actually, this means that the areas *NHDQ* and *DEFG* are of equal size.

With these two basic market interventions, consumer surplus will be reduced from *ABM* in free trade to *AIP*, and producer surplus will be raised from *MCO* to *QEO*. Furthermore, the government has to spend the area *NHIP* as a price subsidy to consumers. Border protection and consumer price subsidies will, accordingly, lead to ***net welfare losses*** corresponding to the areas $NHIP + PIKQ + LBC - KEL$.

In ***Figure 1***, the two basic price instruments of Sweden's agricultural policy are shown as border protection $(PP_1 - P_w)$ and a consumer price subsidy (a). Let us now study how efficient they are in reaching the four objectives of the agricultural policy mentioned above.

The ***self-sufficiency goal*** aims at a balance between domestic production and consumption, i.e., quantity q^*. However, if border protection is reduced from the present level to reach equilibrium price p^*, farmers will lose (the area *QELR*), and the ***income goal*** is threatened. The two goals, consequently, conflict and cannot be reached by a single instrument. Another conflict is that the goal of ***low, or reasonable, consumer prices*** means lower farm incomes. Again, the conflict cannot be solved by the product price instrument alone.

The *efficiency goal* is not directly controlled by price policy. In reality, technological change will shift the supply curve to the right. Policymakers take this into account when they choose border protection to attain the income goal. Accordingly, protected prices might be reduced by rapid productivity increases.

In addition to these four main policy goals, other objectives are often stressed. One is to keep the existing *arable land* area at its present level. Another one is to support agriculture in *backward areas* to balance regional development. A third subgoal is to reduce *environmental problems*, e.g., those caused by nitrogen leaching stemming from agricultural production. Consumers also want *high-quality food* and reduced pesticide residues in commodities. Finally, many people want to reduce the country's *dependence on imported inputs.*

1.1.2. Welfare consequences of increased border protection

If the level of border protection, the main instrument of Swedish agricultural policy, is increased, the society as a whole will, of course, lose more. Farmers will benefit because the price elasticity of demand for food is below $|-1|$. However, the elasticity of demand is generally not independent of the level of the consumption. As the level of border protection increases, the elasticity of demand will increase and eventually become price-elastic, i.e., greater than $|-1|$.

Consequently, if farmers themselves must finance "export losses", there will be an optimal level of border protection from their point of view. This is illustrated by point A in *Figure 2*.

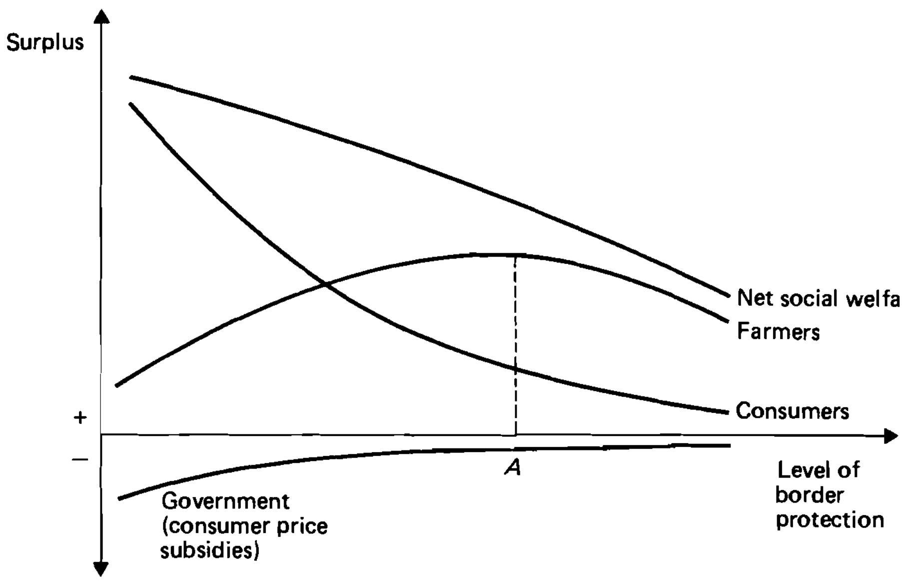

Figure 2. Welfare consequences of increased border protection when Swedish farmers themselves finance export losses.

Finally, it should be mentioned that the majority of the border protection support, motivated by income considerations, goes to the larger farms in the most productive agricultural areas in the southern regions of Sweden. Consequently, the income support mainly benefits those farmers and districts that suffer the fewest income problems. However, farmers in northern Sweden qualify for some additional support to compensate for their less favorable production conditions.

1.2. Policy Options

1.2.1. Current problems

As shown above, Swedish agriculture, partly as a consequence of government policy, faces a series of interrelated problems. The most important are:

(1) Excess supply: Large surpluses now exist for most agricultural commodities that can be produced in Sweden. There is even an occasional excess supply of sugar, in spite of previous ambitions to import some quantities of that commodity from developing countries. Surplus production of pork is approaching 30%. Since surpluses are sold at prices below domestic prices, they create increasing problems over time.

(2) Rapidly rising food prices: Consumer food prices – in particular, for those commodities covered by the agricultural price support system – have been increasing faster than the general price level, causing consumer discontent and falling demand for food. Swedish consumption figures for meat are, at present, among the lowest in Western Europe.

(3) Weak financial position of new farmers: New farmers have special problems owing to their extensive investment requirements and the high price of real estate, which have raised their indebtedness and their vulnerability to fluctuations in the interest rate.

(4) Lack of clarity in agricultural policy: The increasing complexity of agricultural policy, as is the case for most developed countries, may be inherently inefficient. In any event, its content is not very clear to most people.

1.2.2. Causes

The main reason for the present problems in the country's agricultural sector is the inconsistency between the ends and means of Sweden's agricultural policy. The policy aims (at least formally) to achieve the farm income and self-sufficiency objectives through the same basic measure: border protection of agricultural commodities. This, of course, is not possible, except by pure chance. Since more emphasis has been put on the farm income objective, prices have tended to escalate, resulting in excess supply during almost the entire post-World War II period. The surplus production crisis, however, has recently become acute as a result of both general economic and agricultural developments during the 1970s.

To begin with, agricultural commodity prices have risen faster than the general price level. This is explained by such factors as the strong political position of farmers, rural bias of public opinion, fear of global food shortages in the future, etc. During the same period, slower growth of the nonagricultural sector reduced industry's demand for agricultural labor. Furthermore, in 1973, generous food price subsidies were introduced, presumably in anticipation of a general election that year. In response to the push and pull factors described above and the subsidy-induced, increased consumer demand, farm investments and production rose substantially. However, as the period of strong economic growth diminished to low or even negative levels, household disposable incomes declined and so did the demand for food. Finally, increasing deficits forced the government to remove food subsidies (except for fluid milk) in 1983, causing sharp increases in consumer food prices, further depressing food consumption and accelerating growth of food surpluses.

Thus, the present crisis stems partly from an inconsistent and erratic agricultural policy: food subsidies were introduced when disposable real incomes were still increasing and removed during a period of decreasing purchasing power of households.

In explaining the development of agricultural policy, one should, of course, acknowledge that its setting and implementation are not necessarily a rational means-and-ends exercise. Rent-seeking activities of farmers, vote-chasing politicians, and budget-maximizing bureaucrats must be considered as well. These issues cannot be elaborated here, but a few facts should be noted.

Swedish farmers are well organized, with agribusiness cooperatives and the farmers union strongly allied. The "farmers' party" (*centerpartiet*) is a potential coalition partner in creating a majority for either the left or right wing of Parliament. This explains why neither wing is very interested in any radical change, in spite of a growing awareness of the high costs and low efficiency of the present policy, as shown in the welfare analysis of Section 1.1.

In 1983 the government appointed a Food Committee to propose solutions to the present crisis. The committee, however, produced no comprehensive solution, only some proposals for small changes in the present policy. The main stumbling block for the committee was the arable land issue. Although the desire to preserve agricultural land is not an official goal of Sweden's agricultural policy, it has nevertheless become one of the main controversies. Preserving agricultural land (the alternative being primarily afforestation) is seen as one of the positive externalities, or public goods, of agricultural production. At the same time, it can be argued that Sweden already has an excess supply of agricultural land, if agricultural policy is meant to keep production levels in balance with domestic food demand.

1.2.3. Suggested solutions

Public debate on agricultural policy has recently become very intense in Sweden, and many solutions have been proposed by various groups. The suggestions, varying from minor changes to general revisions of the present policy, include the following:

(1) Supply management:

- (a) Quotas on milk production.
- (b) Ban on investments in farm buildings.
- (c) Set-asides in livestock and grain production.
- (d) Taxes or fees on fertilizers and feed inputs.

(2) Demand expansion:

- (a) Lower value-added tax on food.
- (b) Reintroduction of food subsidies.
- (c) Export subsidies.

(3) Creating alternative uses for farm resources or farm products:

- (a) Biomass production for energy purposes.
- (b) Increased domestic production of protein feed (previously imported).

(4) Price-setting for agricultural commodities:

- (a) Relaxation of the automatic compensation rule for production cost increases.
- (b) Free trade in agriculture products, possibly supplemented by selective measures for marginal farmers, marginal land, and backward areas.

Some of the suggested measures have been implemented. The temporary ban on investment activities has been working for some years – probably just altering the time frame of investment behavior. Taxes on fertilizers have been introduced, partly to limit production and partly to limit the use of fertilizers for environmental reasons. The quota (two-price) system for milk production was introduced in July 1985.

In short, Sweden's agricultural policy can go in one of two major directions. One way would be to continue the present policy by adding more regulations, mainly through supply management measures, thereby moving the system closer toward an entirely regulated monopoly. For the milk market, this is already the case. Farmers are now able to control production: they already govern the milk-processing sector, and they are allowed to maximize their total revenues by pursuing price-discriminatory production choices between different milk products. The other major policy direction would be to deregulate agriculture and liberalize agricultural trade. This free-trade agricultural policy might be coupled with direct support to marginal farmers, marginal lands, and marginal regions threatened by deregulation. This alternative policy would not be easy to implement, at least in the near future.

1.3. Description of the Swedish Agricultural Sector

1.3.1. Agricultural structure

Arable land in Sweden amounts to about 3 million ha (hectares) today. During the 1950s and early 1960s, about half a million hectares were abandoned. In the 1970s the rate of decline slowed, and the stock of arable land is now almost constant. Average farm size has doubled during the last 20 years and is now 25.5 ha. Large differences exist, however, between the northern and the southern parts of Sweden. The small farms are mainly found in the north (see *Table 1*).

Production has become more concentrated over time, not only in terms of land area per farm, but also number of animals per farm. Some 3% of the poultry farms account for about 85% of total poultry products. Two thirds of pork production come from one tenth of the hog farms.

Owing to the relative dominance of small farms, most farmers depend on off-farm income. Only about 30% of all farmers receive more than 50% of their total income from agriculture.

Table 1. Arable land, number of farms, and average farm size in Swedish regions, 1982.

Region	*Arable land* (ha)	*Number of farms*	*Average farm size* (ha)
South and central	2 410 964	82 956	29.1
North	550 252	33 394	16.5
All Sweden	2 961 216	116 350	25.5

Table 2. (*a*) Cost and (*b*) revenue structure of Swedish agriculture, 1982.

(*a*) *Cost category*	*Cost* (billion SEK)	*Cost* (%)
Inputs of nondurable goods	6.7	35
Inputs of services	2.0	10
Repair and maintenance	1.3	7
Hired labor	1.1	6
Capital costs	5.1	26
Net revenue	3.1	16
Total	19.3	100

(*b*) *Product category*	*Revenue* (billion SEK)	*Revenue* (%)
Milk	7.5	39
All kinds of meat	6.5	33
Other livestock commodities	1.3	7
Grains	1.9	10
Other vegetable commodities	2.1	11
Total	19.3	100

Agriculture's contribution to the gross domestic product (GDP) amounts to about 2%, while its share of total employment is about 3.5%. The cost and revenue structure for the sector as a whole in 1982 is illustrated by *Table 2.*

Sweden nowadays is a net exporter of most agricultural commodities. Imports mainly consist of commodities that are impossible (or very expensive) to produce in Sweden, such as coffee, tea, tropical fruits, and some vegetables. On the input side, Sweden depends heavily on imports of farm machinery, fertilizers, pesticides, and protein feed.

If one considers not just agriculture but the whole food sector – including processing, distribution, and nonhousehold consumption as well – the contribution to GDP increases from 2% to 8%. One logical reason for analyzing the food sector as a whole is that agricultural policy affects not only the primary production but subsequent parts of the food chain as well, given the special Swedish condition that farmers (through their cooperatives) dominate the processing industries. Cooperative market shares for milk, slaughterhouses, and milling vary between 80% and 100%.

1.3.2. Institutional setting of Sweden's food policy

Sweden's current agricultural policy was born more than 50 years ago, originating in the 1930s as a result of the Great Depression and political cooperation (vote trading) between the farmers' party and the labor party. During its more than 50-year-long history, the policy has been reevaluated several times by governmental agricultural committees. The outcome has consistently been more or less the same: reaffirming the general goals of farmer income security, self-sufficiency, and efficiency. As far as the implementation of the policy is concerned, the emphasis placed on these different goals has changed over time, as have attitudes toward agriculture, for instance, between the growth period of the 1960s and the stagflation period of the 1970s.

Price policy (border protection, consumer price subsidies, and internal market regulations) is handled by the National Agricultural Marketing Board. Structural policy (including land acquisition laws, credit, and extension service) is implemented by 24 County Agricultural Boards supervised by the National Board of Agriculture. The agricultural sector is, of course, affected by many other control systems such as:

(1) Rules for the general use of Swedish land and water.
(2) Soil and natural conservation acts.
(3) Environmental policy.
(4) Animal protection rules.
(5) Laws regulating the veterinary and sanitary conditions of the food chain.
(6) Tax policy.

1.4. General Framework of the Model

This section gives a rather general and simplified overview of the model. A technical description is found in Part 2.

The general structure of the Swedish production model is shown in *Figure 3*. Driving forces in production are lagged prices derived from the exchange component. Production is determined in two stages: in the first stage, resource levels are set; in the second stage, resources are allocated to different commodities in plant and animal production. The following variables act as restraints on behavior: existing stocks of land and capital, savings, weather, and the annually changing state of technology in two farm sectors – one consisting of part-time (small) farms and one of full-time (large) farms.

Basic characteristics of the production model are:

(1) Resource demand in plant production is derived from a capital–labor accelerator, in which the gap between optimal and existing input levels determines the speed of adjustment.
(2) The pattern of substituting roughage area for areas of other crops is described by a Spillman function, indicating that the rate of substitution at lower levels of roughage land are increasing.
(3) The supply of farm labor is partly determined by farmers' "income requirements".
(4) The rate of change in the number of small farms is the driving force in structural change.
(5) Resource demand in plant production is given priority over resource demand in annual production, indicating that the latter is more responsive to changing income requirements.

Production allocation models (two for each agricultural sector) are of a nonlinear optimizing type with econometrically estimated parameters. A linear expenditure system, LES, is used to describe consumer behavior. These models are elaborated in Part 2.

Agricultural policy is modeled in a two-stage process. First, the total amount of annual support to farmers (i.e., desired income increase) is determined. The main driving forces in this stage are cost increases from rising input prices, development of the income parity between farmers and industrial workers, and productivity rate in farming.

In the second stage, the total amount of support is allocated among different commodities as price increases. In this stage, commodity-specific world market prices, degrees of self-sufficiency, price elasticities, and the existing shares of each commodity in the total consumer budget are important factors.

The policy model is estimated from behavior during the 1970s. This positivistic approach might be substituted for normative approaches in order to formulate alternative policies, stressing other goals or other rankings of goals and means. Policies are, in each case, endogenously determined in the model.

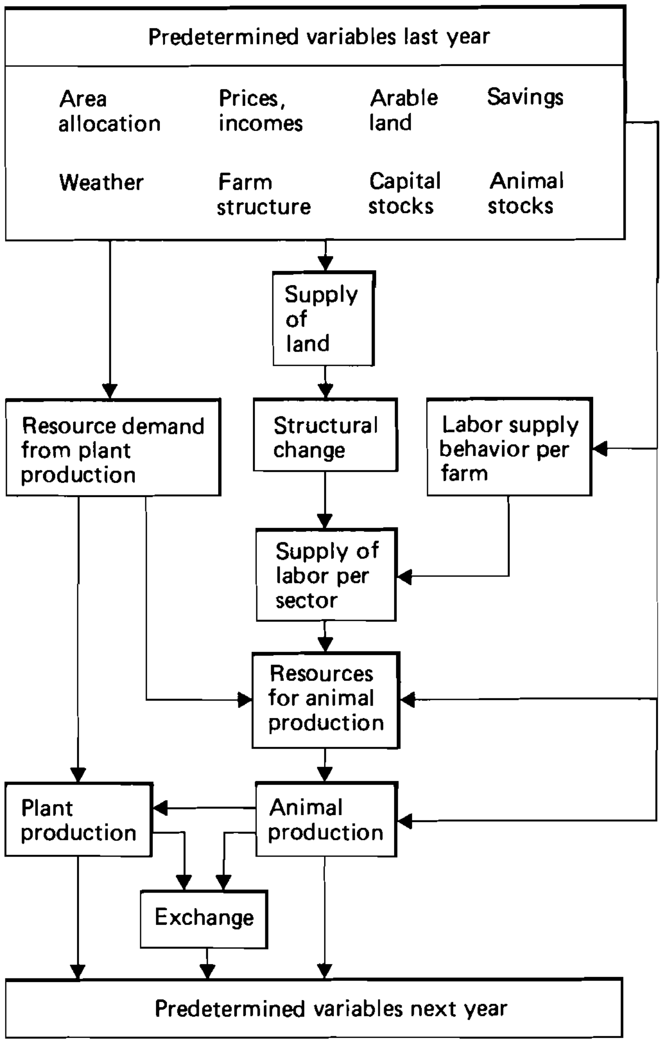

Figure 3. The Swedish agricultural production model.

The Swedish model also includes some components of ecology and energy. Energy can be produced by agricultural resources, such as biomass, ethanol, and straw from grains, for heating purposes, etc. Energy consumption is described for each scenario to show how much energy is used in each sector, each year and in each stage of the food chain. This is done by commodity-wise energy consumption coefficients. The economic impacts of ecology-oriented policies are described by different scenarios showing the consequences of reduced nitrogen or pesticide use.

1.5. Analysis of Issues through Model Runs

In this section we show the results from a base run up to the year 2001, a free-trade run, and a run in which farmers are allowed to optimize the price distribution within the limits of the total support amount. We also present results illuminating the problems of ecology and energy.

1.5.1. Continuation of past policies

If the model is run for the period 1982–2001 with historically estimated behavior of production, consumption, and policy, border protection of agriculture tends to increase, as illustrated in *Table 3*. This run is based on constant world market prices, namely, average levels for the period 1970–1981, calculated at the International Institute for Applied Systems Analysis (IIASA).

Table 3. Swedish border protection at farm gate level for 1970–1981 and estimated total change for 1982–2001, by commodity (shown as percentages above world market price levels).

Commodity	*Average for 1970–1981*	*Estimated change for 1982–2001*	*Total in 2001*
Wheat	19	4	23
Coarse grains	27	2	29
Protein feed	39	5	44
Sugar	32	7	39
Bovine and ovine	73	13	86
Pork	4	-3	1
Poultry	5	8	13
Milk	26	6	32

All commodities except pork are increasingly protected over time against the world market. The average level of border protection is estimated to be about 28% at the farm gate level in the year 2001. Pork prices are depressed by the increasing surpluses. As the price of nonagricultural commodities is kept constant, the estimated agricultural price policy pushes the general price level upward, creating more inflation. Price developments are mainly driven by cost push in agriculture and changing surplus levels for livestock commodities. The surpluses of agricultural commodities that are considered to be the major problem today will increase, especially for milk and grains. Thus, maintaining the current agriculture policy will make the situation even worse in the future.

The base run clearly illustrates the rapid change now taking place in agricultural structure. Of the existing 110 000 farms, 25 000 are calculated to disappear by the year 2001 if the present policy is prolonged. Arable land abandoned by small farms will be used to increase average size of surviving farms. This means, above all, a rapid reduction of labor input in agriculture and a strong productivity growth in the sector.

In spite of the rapid decline in the number of farms and in labor input, production will be sustained, with small exceptions for pork, bovine, and ovine commodities. This is explained by the increased contributions of buildings, machinery, fertilizers, and an almost constant input of arable land over the period.

Food consumption, especially of meat, will tend to increase, as the result of real income growth of 0.8% annually. If income grows at a slower rate, surplus problems will become more severe.

1.5.2. Free-trade scenario

To estimate the costs and analyze other consequences of the existing agricultural policy, a simulation has been made in which there is "no agricultural price policy at all".

Under free-trade assumptions, world market prices (as an average for 1970–1982) equal domestic prices, as there would be neither border protection nor consumer price subsidies. Current policy is assumed to change gradually during the period 1982–1986, and results are shown for the year 2001 in *Table 4*.

The most challenging result in *Table 4* is the inelastic production behavior. It is rather inverse: in spite of drastically reduced producer prices, production actually increases somewhat. Among the plausible explanations for this, four factors might be mentioned:

(1) Many farmers are almost trapped at certain production levels because of large fixed and small variable costs. To sustain their income levels (and perhaps also increase them), continued production is the most profitable alternative. Some farmers react to declining income by increasing their labor input.

(2) Farm land prices (as well as prices for feed and animals) will fall. This will buffer the profitability consequences of falling commodity prices, at least for new farmers.

(3) Even if total agricultural production in value terms remains rather constant, there will be changes in production mix. The advent of free trade encourages the production of animal commodities and discourages grain-growing, becaused the effective rate of protection is larger for grains than for livestock commodities. In fact, current protection policy may even be negative for pork. For animal commodities, the price policy has meant higher prices for both outputs and inputs. In the 1970s, pork producers consequently seem to have lost ground as a result of agricultural border protection.

(4) Free trade will also accelerate structural change: an additional 16000 small farms will disappear up to year 2001, compared with the base run. At the same time, large farms (above 20 ha of arable land) will grow in size when the land belonging to the small farms is transferred to the growth

Table 4. Consequences of a free-trade agricultural policy in Sweden, in 2001 (1982 prices).

Effect on:	*Producers/ production*	*Consumers/ consumption*	*Government*	*Net social welfare*
Prices (%)	−27.8	−4.5		
Production and consumption behavior (%)	+ 1.2	+2.2		
Welfare (billion SEK): surplus	− 4.6	+2.7	+3.3	+1.4

sector. This partly explains the inelastic supply behavior of the agricultural sector under free-trade policy, as existing resources will increasingly be used in the large-farm sector with its typically higher level of technology.

As the marginal value of durable resources, such as buildings and land, will strongly decline, real estate prices can be expected to fall drastically, perhaps by 50%. Thus, farmers will lose a substantial portion of their net wealth. However, if they were compensated for their losses out of the net social profit of free trade, all parties could gain from free trade, making such a policy change a "positive-sum game", in the jargon of some scenarists.

Calorie intake per person per day would increase under free trade as the consumption of meat, sugar, poultry, and grains increases. Fat consumption, however, would tend to decline because of reduced consumption of milk, fats, oils, and pork. The new consumption pattern would reflect changes in relative prices, real income, and price and income elasticities for various commodities over time.

1.5.3. Comparing the present policy with the free-trade scenario

The "social costs" of the present agricultural policy, as we have modeled it, might be about SEK 1.4 billion annually, calculated in welfare terms. The discounted value of this total might be SEK 70 billion (if the real interest rate is 2%). Losers under free trade would be farmers, if they were not compensated for the expected drop in property values. Winners would be taxpayers and consumers. Other factors, difficult to quantify in a welfare calculation, are listed in *Table 5*.

1.5.4. Ecology runs

Our "ecology runs" of the Swedish model show the economic consequences of reducing fertilizer and pesticide use in agricultural production, either by banning these inputs or taxing them. Suggestions for such policies and estimates of their

Table 5. Advantages and disadvantages of a free-trade agricultural policy in Sweden (compared with current policy).

Advantages of free trade	*Disadvantages of free trade*
Consumers and taxpayers gain SEK 6 billion/year	Farmers lose SEK 4.6 billion/year
Higher agricultural productivity	Faster loss of small farms
Lower land prices	Farmers lose net worth
Reduced bureaucracy	Increased dependence on world market
Reduced fertilizer use	Increased regional imbalance

consequences were proposed by biologists and policymakers at an early stage of the modeling process. In a later stage, these experts had an opportunity to see modeled results of their suggestions and to revise them. The model rerun procedure continued until no further changes were proposed.

Table 6 displays results from a rather extreme run, done in this iterative way. Fertilizers were totally banned and just a few pesticides allowed. The estimated fertilizer response functions were adjusted at the microlevel, according to the biologists recommendations, and run for two possible outcomes: mild or strong response. The policy is "introduced" in 1970; *Table 6* shows the results for 1982.

Table 6. Effects of banning fertilizer use and some pesticides (compared with base run), 1982: BR = base run, MR = mild response (%), SR = strong response (%).

	Yield			*Acreage distribution*		
Crop	*BR*[a]	*MR*	*SR*	*BR*[b]	*MR*	*SR*
Winter wheat	4.47	-31	-45	271.0	- 3	- 20
Spring wheat	4.23	-10	-30	56.8	- 30	- 33
Coarse grains	3.53	-23	-39	1352.4	- 16	- 20
Oilseed	2.13	-21	-37	151.9	- 22	+ 17
Potatoes	30.27	-17	-20	29.7	+ 64	+ 87
Sugar beets	42.23	-10	-23	51.5	± 0	± 0
Pasture				943.3	+ 14	+ 15
Fallow				110.0	+115	+115
Total				3002.3	± 0	- 1

[a] 1000 kg/ha.
[b] 1000 ha.

In the "mild response" alternative, the gross domestic product of agriculture (GDPA) would decrease rather marginally. The "strong response" alternative would reduce the GDPA more severely, by about 12%, and Sweden would in this case become a net importer of grains.

In runs where tax policy raises fertilizer prices and thereby reduces its use, the GDPA falls even lower. However, to reduce fertilizer use by 50%, its price must rise sharply, by about 300%. Of course, agricultural GDP falls most steeply if the fertilizer price is raised by a tax that is not returned to agriculture, compared with the case where the tax revenue is returned through direct grants or higher commodity prices.

1.5.5. Energy runs

Energy aspects of agricultural policy have been modeled in two basically different ways. First, we estimated energy consumption coefficients to assess the energy input in production at different stages of the food chain. Second, we took into account the fact that agricultural resources can be used to produce energy raw materials, such as energy-wood or ethanol. We applied the first approach in every scenario, but used the second approach only to show energy production in special energy policy scenarios.

In *Tables 7* and *8*, the development and distribution of energy use for three major commodities are illustrated.

How might the agricultural sector best contribute to energy saving or energy production from a social point of view? In *Table 9* results are summarized from three "saving runs" and three "producing runs".

Energy-saving policies would not add very much to total GDP. Most energy could be saved by changing consumption patterns, but this would require a rather restrictive price policy toward consumers, especially a drastically increased milk price, which would entail a high social cost.

Energy for heating purposes might be produced profitably by straw from grains or by short-rotation forestry on arable land. Transferring grains to a gasoline substitute would, however, mean a great loss to society, given existing price relations. The real price of energy would have to increase by about 5% annually up to the year 2000 to make ethanol a profitable alternative, at that time.

Table 7. Development of energy – input coefficients (KWh/kg) between 1956 and 1972.

Commodity	*1956*	*1972*	*Percentage change*
Wheat	2.0	1.4	-30
Pork	7.1	10.8	+52
Milk	1.1	1.5	+36

Table 8. Energy input (%) in primary and processing sectors, 1972.

Commodity	*Primary sector*	*Processing*	*Total*
Wheat	7	93	100
Pork	29	71	100
Milk	45	55	100

Table 9. Energy saved or produced in agriculture and consequences for total GDP.

Model run	*Energy saved or produced* (TWh)	*Change in GDP per unit of energy* (SEK/kWh)
Energy saving:		
50% reduction in fertilizer use	2.1	0.02
100% reduction in fertilizer use	4.3	0
Increased consumption of vegetables/reduced consumption of animal products	8.9	-5.35
Energy production:		
straw-based	8.8	0.10
wood-based	19.9	0.01
grain-based	1.6	-0.42

1.6. Policy Insights and Prescriptions

1.6.1. Production

Perhaps the most challenging result, elaborated in Section 1.5.2, from the different model runs is the low elasticity of production or supply, at least downward. Apparently, it is easier to expand production capacity than to contract it. The distribution of production capacity among different commodities is, however, more sensitive to changing prices.

The low elasticity of supply is confirmed by historical experiences in Sweden and abroad. Lower world grain prices and free trade usually create expansion in the livestock sectors, and lower product prices hurt the farmer/owner rather than depressing agricultural production itself. Bankruptcy might lead to restructuring of agricultural sectors, but the new owners almost always elect to sustain or even expand production.

Thus, no substantial reduction of production can be attained by a general reduction of farm prices, at least not in the short or medium term. On the other hand, high prices might expand production considerably in the long run. So, the government has the delicate task of setting prices adequate to reduce surplus production and to raise farmers incomes. This is virtually impossible if prices are the only policy instrument available.

One possible, but perhaps not very realistic, solution would be to introduce free trade and thereby eliminate surplus problems. If this step drastically reduced farmer incomes, they could be compensated by direct grants. However, in the long run the income effect of this policy might be marginal because of factors buffering the profitability consequences of reduced border protection. Buffer factors would include lower feed, livestock, and land prices as well as higher productivity through structural improvement.

If valid, the low elasticity of supply invalidates the main argument for keeping border protection – namely, the self-sufficiency argument. A free-trade policy would in a foreseeable future keep production at reasonable levels. Furthermore, the existing level of arable land would probably be kept in production under a free-trade policy. Even if this turned out not to be the case, border protection is an expensive and inefficient way to keep arable land in production.

1.6.2. Consumption

As a rule, elasticities of demand for food commodities (according to income and price) are lower than unity, which means that farmers cannot raise their income by reducing consumer prices. Farmer incomes can, of course, be raised by increasing consumer purchasing power, even at a decreasing rate. The development of consumer purchasing power is, however, beyond the control of farmers and policymakers in most cases.

On the other hand, higher consumer prices are beneficial to farmers, even if this stimulates larger surpluses that must be exported at low world market prices. This situation, however, is costly for the society as a whole, especially for consumers and taxpayers.

A free-trade policy would undoubtedly expand consumption, giving rise to worries about nutritional effects. There often exists, however, a large gap between the amount of food purchased and actual human intake. This "waste" might be as large as 20–30% and seems to increase over time.

1.6.3. Policy

In spite of growing excess supplies of food over time, many factors support sustained, possibly somewhat reduced, border protection for the Swedish agricultural sector:

(1) This policy has prevailed for more than 50 years.
(2) Goals and means have remained constant throughout that period in spite of several large public policy reviews and occasional sharp conflicts over goals and means.
(3) The situation is almost the same in most of the developed economies of the western world.
(4) Public choice theory indicates that farmers, as well as other interest groups involved, are successful rent-seekers.

New problems, sometimes created by the existing regulatory system itself, tend to be "solved" by imposing new regulations; and the result is an ever-expanding regulatory system. Factors that might counteract this development include increasing deficits in public funds, favorable development of world market prices, or large efficiency gaps between regulated and nonregulated economic activities. In the near future, none of these factors seriously threatens the current tendency toward a more politically controlled food sector.

Our model analysis shows that agricultural price policy, in spite of its complexity, can be formally represented and analyzed in welfare terms. Our analysis, furthermore, suggests that the current policy produces considerable welfare losses for Swedish society as a whole.

1.6.4. Energy and ecology

A by-product from agricultural production, such as straw from grains, is already a profitable energy resource. Short-rotation forestry is rather close to becoming a profitable production alternative on arable land at existing prices. Production is, however, still suffering from great uncertainties about yields and methods.

Ethanol and rapeseed oil have a long way to go to become profitable. Only if the real price of crude oil increases by about 5% annually, up to year 2001, will these commodities become competitive at the beginning of the next century.

Saving energy in agricultural production through reduced use of fertilizer or through changed consumption patterns is not a profitable alternative if price policy is used to attain those goals. Banning fertilizer use might, however, yield a net social gain, because the present border protection policy stimulates overuse of fertilizers and, thereby, larger costly surpluses.

A new insight from the modeling work might be the rather flat fertilizer response curves estimated at the national level. Such estimates have been made earlier at the micro level, where the response, of course, is more pronounced.

1.6.5. Model improvements

The model could be improved in at least four areas. The first concerns labor supply at the farm level. The present model indicates a backward-bending farm labor supply curve. This might be true in certain circumstances, but the model should be more detailed on this point.

The second improvement concerns the arable land model. In the present version, the total stock of arable land depends heavily on the profitability of milk produciton, which affects both the need for roughage area and the number of small farmers. These two factors together determine the amount of land withdrawn from production. Beyond a certain level, even a drastic reduction in milk production would reduce the amount of arable land just marginally. Is this true, or is the land input more sensitive to other economic factors? In short, what are the opportunity costs of using land in farming?

The third area of possible improvements is "the rest of the economy", now represented by one commodity. As agriculture, especially the consumption of food, depends so heavily on the development of rest of the economy, this should be modeled in a more elaborate way, at least for one major export and one domestic-oriented consumption sector.

Finally, the policy model could be made more informative by including detailed and inside knowledge about the policy decision processes, based perhaps on public choice theories. This would prove difficult because the annual price negotiations are partly closed sessions with no public oversight. At present, we can see only the inputs to and the final outcome of that "black box".

PART 2

The Mathematical Model, Specifications, and Estimations

2.1. The Supply Model: Introduction

In this part, the general structure of the production model shown in *Figure 3* is elaborated in more detail. Estimation results are also presented. Since the model consists of two farm sectors and 19 commodities, results for some submodels are only exemplified to avoid too many details.

As a rule, OLS-estimation techniques are used. If not, the alternative estimation procedure is described. Due to the hierarchical structure of the model, as explained in Section 1.4, the simultaneity problem is avoided in estimating the equations.

2.2. Structural Change and Supply of Resources

2.2.1. Number of farms

The agricultural sector is divided into two sectors representing "full-time" (more than 20 hectares of arable land) and "part-time" farms (less than 20 hectares). The core of the structural change process, that is, the enlargement of the average farm size, is the behavior of small farms. By contraction, small farms supply resources (mainly land) for the expansion of large farms. The rate of change in the number of small farms depends on the profitability in farming compared to profitability in activities outside agriculture. Since small farmers are milk producers to a large extent, relative profitability is represented by the relative price of milk. The rate of change in number of small farms is thus explained as follows:

$$\frac{\Delta SFF1}{SFF1} = \underset{(3.93)}{e^{16.9}} \underset{(-4.56)}{\left[\frac{P_{10}}{P_{19}}\right]^{-3.07}} \qquad (t\text{-value}) \qquad (2.1)$$

where

Δ	indicates time differential
$SFF1$	is the number of small farms
P_{10}	is the milk price
P_{19}	is the price in the nonagricultural sector
e	is natural logarithm
R^2	is 0.71
DW	is 1.36

Given the number of small farms, their arable land resources are calculated by using the relation between the average farm size and the number of farms in that group. Remaining land is distributed among the large farms.

2.2.2. Supply of arable land

Arable land consists of three components: pasture (A_p), fallow (A_f) and cropland (A_c).

$$A_p = e^{3.19} \times N^{0.57} \times t^{-0.01} \qquad (2.2)$$

(4.20) (5.48) (-0.40) (t-value)

$$A_f = e^{-7.69}(A_p + A_f + A_c)_{-1}^{1.55} \times D^{0.31} \qquad (2.3)$$

(-1.33) (2.15) (3.38) (t-value)

$$\frac{\Delta A_c}{\Delta(A_p + A_f)} = -1 + \left[\frac{A_p + A_f}{A_p + A_f + A_c}\right]_{-1}^{1.35} \qquad (2.4)$$

(3.89) (t-value)

N is the number of dairy cattle. D is a dummy variable taking into account a change in the data base due to a new registration procedure. Acreage of pasture (A_p) is estimated as a function of the number of cows and the rate of "technical change" represented by time (t). Subscript -1 indicates a one-period time lag. Fallow land (A_f) is a single function of the development of the total land stock. Pasture land released by a declining number of dairy cattle might be abandoned or transformed to cropland (A_c), depending on the quality of the land. As a land quality indicator, the share of pasture land out of total land stock is used. The transformation is described by a Spillman function (2.4). For equations (2.2) and (2.3), $R^2 = 0.99$ and $DW = 1.5$; for equation (2.4), $DW = 1.20$.

The land model focuses on technical relationships rather than on pure economic factors. When alternative approaches, based on the relative profitability of plant production, have been used, these show a very weak or insignificant impact of prices. This is perhaps due to lack of sufficient variability in prices. Equations (2.2–2.4) have been estimated on time series data for the period 1950–1978, since the main changes in the total supply of arable land occurred during the late 1950s and the early 1960s.

2.2.3. Farm family labor supply

The supply of family labor (i.e., the number of hours per farm and year, FL) is explained by the income earned per hour (W) and a time trend (as a proxy for technical development). From the theoretical point of view, nothing can be said about the slope of the labor supply function since positive as well as negative slopes are consistent with theory. Our estimated functions exhibit negative slopes, indicating that farmers compensate for decreasing income per hour by working more and by working less if income is improving.

$$FL1 = \underset{(-17.74)}{0.003} \times \underset{(-14.8)}{t^{-0.17}} \times \underset{(-1.21)}{W1^{-0.19}} \qquad (t\text{-value}) \tag{2.5}$$

$$FL2 = \underset{(-13.37)}{0.008} \times \underset{(-1.09)}{t^{-0.09}} \times W2^{-0.31} \qquad (-0.95)(t\text{-value}) \tag{2.6}$$

For equations (2.5) and (2.6), respectively, $R^2 = 0.97$ and 0.82; $DW = 1.31$ and 1.0. The total supply of farm labor is then calculated as

$$TFL1 = FL1 \times SFF1 \tag{2.7}$$

$$TFL2 = FL2 \times SFF2 \tag{2.8}$$

2.2.4 Hired labor

The total input of hired labor (HL) is estimated for each farm sector as a function of the price ratio of capital and hired labor (PHL/PK) and a time trend.

$$HL1 = \underset{(27.52)}{e^{2.67}} \times \underset{(15.36)}{(PK/PHL)^{2.18}} \times \underset{(-1.78)}{t^{-0.09}} \qquad (t\text{-value}) \tag{2.9}$$

$$HL2 = \underset{(37.30)}{e^{3.95}} \times \underset{(6.80)}{(PK/PHL)^{1.05}} \times \underset{(-0.84)}{t^{-0.05}} \qquad (t\text{-value}) \tag{2.10}$$

For equations (2.9) and (2.10), respectively, $R^2 = 0.99$ and 0.98; $DW = 2.8$ and 0.6. Total agricultural labor supply is finally determined by adding hired labor to equations (2.7) and (2.8).

2.2.5. Agricultural investment

Two types of investment goods in farming are distinguished: machinery and buildings.

Machinery

Investments in machinery are explained as a process of substitution of mechanical equipment for labor. Optimal levels of labor inputs and capital stocks are calculated for seven different crops in the two farm sectors, based on Cobb–Douglas production functions with constant returns to scale and on prices of labor and capital. Actual application rates are then determined by an accelerator-type of model.

$$\frac{K_{ij}}{L_{ij}} = c_{ij}\left[\frac{OK_{ij}}{OL_{ij}}\right]^{d_{ij}} \qquad \begin{array}{l} i = 1,\ldots,7 \\ j = 1,2 \end{array} \tag{2.11}$$

K and L are existing levels of capital and labor, respectively. OK and OL are the optimal levels of capital and labor for the seven crops in the two farming sectors.

Equalizing marginal products of labor and capital with the price ratio between capital and labor P_k/P_l results in the following optimal levels of labor (OL) and capital (OK):

$$OL_{ij} = \frac{A_{ij}}{a_{ij}}\left[\frac{P_k}{P_l} \times \frac{1 - b_{ij}}{b_{ij}}\right]^{b_{ij}} \tag{2.12}$$

$$OK_{ij} = \left[\frac{A_{ij}}{a_{ij}} \times OL_{ij}^{b_{ij}-1}\right]^{\frac{1}{b_{ij}}} \tag{2.13}$$

A_{ij} is the existing level of acreage of each crop in each farm sector; a and b are coefficients in the production functions:

$$A_{ij} = a_{ij}K_{ij}^{b_{ij}} \times L_{ij}^{1-b_{ij}} \tag{2.14}$$

Estimation and testing

The production functions (2.14) have been estimated for the seven crops and the two farm sectors. Crop-specific data on capital and labor inputs are not directly available. Time series, however, have been generated, combining public income statistics, bookkeeping results from annual surveys, and special productivity studies, to separate aggregate input volumes of labor and capital for different crops and sectors over time.

In *Table 10* coefficients in the production functions are shown. All the parameters are significant at the 5% level and t-values are high. The large sector has a higher capital elasticity for all commodities.

In the next step, the accelerator functions (1.11) are estimated, and the total levels of hired labor and capital in plant production can be calculated as:

$$\sum_{i=1}^{7}\sum_{j=1}^{2} K_{ij} = K \qquad \sum_{i=1}^{7}\sum_{j=1}^{2} L_{ij} = L$$

Table 10. Parameters of the plant production function.

	Small farms		*Large farms*	
Commodity	a_{i1}	b_{i1}	a_{i2}	b_{i2}
Wheat	829.6	0.4749	775.2	0.6162
Coarse grains	840.4	0.4678	793.4	0.6081
Oilseed	701.9	0.4875	625.9	0.6469
Sugar beet	113.3	0.7802	102.5	0.8502
Potatoes	116.2	0.5050	127.2	0.6763
Beans, etc.	789.9	0.4779	711.2	0.6358
Roughage	742.2	0.322	575.0	0.5624

Total net investment in machinery is finally given by:

$$K(t) - K(t-1)$$

and can (corrected for depreciation) be compared with data on gross investments in machinery. As an alternative, K and L can be compared to data on machinery stocks and labor inputs, indicating a good correspondence with model results, particularly for labor. As far as machinery investments are concerned, one should note that many other factors, such as inflation expectations, tax system changes, etc., which cannot be included here, also affect investment behavior.

Buildings

The growth rate in farm buildings ($\Delta BK/BK$) is explained as a function of profitability in livestock production.

$$\frac{\Delta BK}{BK} = -0.04 + 0.06 \times P_{10}/P_{19} \tag{2.15}$$

(-11.73) (13.54) (t-value)

$R^2 = 0.92$ and $DW = 1.95$.

The two farm sectors' shares of the total building capital (SBK) depend on the number of farms in each sector and are estimated as

$$SBK1 = (0.09 + 0.004 \times t) \times SFF1 \tag{2.16}$$

$$SBK2 = (0.28 + 0.009 \times t) \times SFF2 \tag{2.17}$$

and normalized as

$$NSBK1 = \frac{SBK1}{SBK1 + SBK2} \tag{2.18}$$

$$NSBK2 = 1 - NSBK1 \tag{2.19}$$

Consequently, the building capital in each sector is calculated as

$$BK1 = NSBK1 \times BK \tag{2.20}$$

$$BK2 = NSBK2 \times BK \tag{2.21}$$

2.2.6. Fertilizers

In the plant allocation models, net revenues to land, labor, capital, and fertilizers are maximized. The reason for including fertilizers among the fixed factors in the allocation procedure is to stabilize the plant model solution. As production functions for most plant commodities are logarithmic, fertilizer inputs will become very sensitive to price changes at the upper end of the yield response function. Furthermore, the procedure can be justified by the facts that the relative distribution will be the same without the restriction and that the use of fertilizer represents a "level of technology". The total level of fertilizers is determined as:

$$F = e^{3.5} \times t^{0.81} \times \left[\frac{P_V}{P_F}\right]^{0.66} \tag{2.22}$$

where P_V is a plant commodity producer price index, and P_F is the price of fertilizers.

2.3. Plant Production

The plant production model distributes the total acreage of cropland (A_c) and the total volume of fertilizers (F) among six crops: wheat (winter and spring), coarse grains, oilseeds, potatoes, and sugar beets. Farmers are assumed to maximize the following objective function, i.e., net revenues, in plant production:

$$\text{Max } Z = \sum_{i=1}^{6} (A_i \times Y_i \times P_i - A_i \times CC_i) \tag{2.23}$$

with respect to

$$Y_i = \alpha_i A_i^{\beta_i} + \left[e^{\alpha_i t} \times \gamma_i \times \ln\left[\frac{F_i}{A_i}\right]\right] \tag{2.24}$$

$i = 1,2,3,5,6$

and

$$Y_i = \alpha_i A_i^{\beta_i} + \gamma_i \frac{F_i}{A_i} - \delta_i \left[\frac{F_i}{A_i}\right]^2$$

for $i = 4$ (rapeseed)

$\Sigma A_i = A_c$

$\Sigma F_i = F$

Where for each commodity i:

A_i = acreage
Y_i = yield per hectare
P_i = price
F_i = fertilizer
CC_i = capital and labor costs per hectare (excluding fertilizer) simulated by the accelerator model in Section 2.2.5.

The yield functions (2.24) are of an additive type consisting of a natural fertility component and a fertilizer-induced part. The two parts have been estimated independently by using time-series and cross-section data, which are put together and tuned into the model as described in the next section.

2.3.1. Estimation of the plant model

Data on the total use of fertilizers and fertilizer prices are well known. Crop-specific application rates of fertilizer use, however, are not available except for two points in time: 1971 and 1978. This information is not enough to estimate the yield functions, but can be used to check the reliability of estimation results.

In an earlier, slightly different version of the model, an attempt was made to generate the missing fertilizer observations by solving the model analytically according to the fertilizer use per hectare, assuming that farmers are profit-maximizers, and estimating the yield functions using the resulting "synthetic observations" on fertilizer use and known data on A_i. The outcome of that procedure was discouraging. Since variations in acreage are of limited scope and since favorable weather conditions might increase yield size (and the acreage volume of a crop as well), the use of time series data in a straightforward manner did not capture the decreasing marginal productivity of land.

To account for this characteristic, a mixed approach has been used combining cross-section and time series data. The relation between the natural fertility component and the acreage size of each crop was assessed by cross-section analysis, using data on the county level (24 observations). Knowing the acreage of each crop as well as the natural level of fertility in each county, a relation between the fertility component and the total acreage input has been calculated, assuming that the best county will enter production first and then an increasing number of counties will be included, one by one, in order of decreasing fertility. In this way, the following function has been estimated for each crop:

$$NF_i = \alpha_i A_i^{\beta_i} \qquad (2.25)$$

where NF_i is the "natural fertility" component of the yield for crop i, and A_i is the total acreage input to crop i.

The natural fertility level of each county is, of course, not known; but a fertility index was constructed, using factor analysis on variables such as length of the growing season, average temperature, assessed land values, yield of meadows, and yield of agricultural land during a past decade when the input of fertilizer was rather low.

The "fertilizer part" of the yield function was estimated using time series data and assuming that the availability of fertilizer is unlimited, i.e., that fertilizer is applied by profit-maximizing farmers up to the point where the marginal value product equals the price of fertilizer. Inserting optimal application rates of fertilizer into the yield functions (logarithmic and quadratic), one gets:

$$Y_i = a_i W_i + \gamma_i \ln \left[\frac{\gamma_i P_i}{P_f} \right] \tag{2.26}$$

$$Y_i = a_i W_i + \gamma_i \left[\frac{P_i \gamma_i - P_f}{2\delta_i P_i} \right] - \delta_i \left[\frac{P_i \gamma_i - P_f}{2\delta_i P_i} \right]^2 \tag{2.27}$$

P_f is the fertilizer price, and W_i is a weather index. At this stage, the influence of variations in acreage on yield was ignored. As a weather index, the annual assessment of yield outcome for each commodity was used. The assessment is based on a scale 0–5, 5 indicating a very good yield. The prediction comes from the crop outlook reports prepared annually by the county agricultural boards.

Since fertilizer use has increased between 1971 and 1978 in spite of a higher real price, the fertilizer coefficients in the yield functions above were made time-dependent to capture the increased productivity of fertilizer use over time. Three different time trends were introduced: linear, logarithmic, and asymptotic [as in equation (2.37) below]. Six different functions were estimated for each crop with the NLS technique. The selection of the functions used in the model was based on two criteria: statistical performance and reasonableness. The latter included a comparison between the actual application rates of fertilizer in

Table 11. Plant production functions (yield per hectare).

Crop	*Production function*	*DW*
Winter wheat	$930.9\,W + 141e^{0.05037t} \ln (F/A)$	1.56
t-value	(11.6) (2.87) (3.85)	
Spring wheat	$794.0\,W + 119.9e^{0.0594t} \ln (F/A)$	0.86
t-value	(6.17) (1.7) (2.51)	
Coarse grains	$779.65\,W + 93.62e^{0.05689t} \ln (F/A)$	2.24
t-value	(11.3) (2.12) (2.75)	
Sugar beets	$100.40\,W + 14.12e^{0.0184t} \ln (F/A)$	1.62
t-value	(7.75) (1.90) (1.59)	

1971 and 1978 and the optimal application rates implied by each function. Except for rapeseed, the logarithmic functions performed better than the others, generating applications rates very close to the actual ones.

Results of these estimations are exemplified in *Table 11*, in which W, F, and A are crop-specific values.

2.3.2. Other estimates

For simulation purposes, the two parts of the yield functions were joined by replacing the weather component in the previously estimated functions with a natural fertility component, assuming that natural fertility at the mean acreage equals the "normal weather" impact.

$$\left[\sum_{t=1}^{T} A_{it}/T\right]^{\beta_i} = \sum_{t=1}^{T} W_{it}/T \tag{2.28}$$

where T is the number of observations, and $t = 1,\ldots,18$.

Furthermore, a fertilizer constraint was imposed on the model. Since actual and optimal fertilizer rates were close to each other, estimated functions are consistent with the total availability of fertilizers. In simulations the outcome of the model will be more stable if the fertilizer constraint is used.

2.4. Livestock Production

2.4.1. Activities and by-products

Livestock categories are used to represent activities in the livestock production model. Such activities produce more than one commodity as a rule. In most cases, by-products can be treated in a purely technical way as price-independent coefficients. In the case of milk and meat produced by bovine animals, however, there is considerable substitutability and by-products can be expected to be price-dependent. One way of solving the problem, which is chosen here, is to introduce an additional activity: meat-producing bovine animals. Dairy cattle (including replacement), as the other "bovine activity", are thus assumed to produce milk and meat in fixed proportions. Substitution between by-products is in this way replaced by substitution between activities.

By-products within activities are calculated per animal as constants with a time trend. The livestock model consists of four livestock categories: dairy cattle, beef cattle, hogs, and poultry.

2.4.2. Feed requirements

Different feed commodities can be partly or entirely substituted for each other. Farmers are assumed to choose a feed mix that minimizes feed costs, subject to the condition that N_j (the number of livestock category j) is raised.

$$\text{Min } Z_j = \sum_{i=1}^{8} Pf_i \times fe_{ij} \qquad \begin{array}{l} i = 1,\ldots,8 \\ j = 1,\ldots,4 \end{array} \tag{2.29}$$

With respect to

$$N_j = \alpha_j \prod_{i=1}^{8} (fe_{ij})^{\beta_{ij}} \tag{2.30}$$

$$\sum_{i=1}^{8} \beta_{ij} = 1 \tag{2.31}$$

where Pf_i = expected price of feed input i; fe_{ij} = feed use of input i to animal category j; and α and β are production function coefficients.

The production elasticities of feed, β_{ij}, have been estimated as shares of the total feed costs based on past average use of the feed inputs in each of the four animal categories.

2.4.3. Net revenues

The outcome of the feed mix optimization procedure (the feed requirements for the four livestock categories) is combined with the by-product coefficients used to calculate the expected net revenues from each livestock category per animal as:

$$NR_j = \sum_{m=1}^{z_j} B_{mj} \times P_m - \sum_{i=1}^{8} pf_i \times fe_{ij} \times 1/Nj \tag{2.32}$$

where B_m = by-product m, and P_m = price of by-product m.

2.4.4. Livestock production submodel

Farmers are assumed to maximize the sum of net revenues in deciding upon the number of animals and the type of livestock they are willing to raise. The availability of labor and building stocks are limiting factors. The labor that is available for livestock production ($LA1 + LA2$) is what is left after the labor requirements in plant production have been met in both farm sectors.

$$LA1 = TFL1 + HL1 - \sum_{i=1}^{7} L_{i1} \tag{2.33}$$

$$LA2 = TFL2 + HL2 - \sum_{i=1}^{7} L_{i2} \tag{2.34}$$

Calculations for the two farming sectors are made separately, using the same type of production function.

The technology in livestock production is represented by Cobb–Douglas functions including, as arguments, the total availability of labor for animal production and building capital as well as the relative shares of capital and labor allocated to the different livestock categories. In that way, the production functions exhibit constant returns to scale for the production system as a whole and diminishing returns to scale if the distribution of the factors of production among the various livestock categories changes. The rationale behind this type of function is that, while it is possible to reallocate capital between different livestock categories, it is costly in terms of efficiency since capital is not entirely homogenous but adapted to the particular livestock category.

In calculating the expected net revenue per animal, a two-year time lag is used. The model for the small-farm sector is as follows:

$$\text{Max } Z = \sum_{j=1}^{4} NR_{j1} \times N_{j1} \tag{2.35}$$

With respect to

$$N_{j1} = C_{j1} B_{K1}^{\epsilon_{j1}} \times LA1^{1-\epsilon_{j1}} \left[\frac{BK1_j}{BK1}\right]^{Y_{j1}} \left[\frac{LA1_j}{LA1}\right]^{W_{j1}} \quad ; \tag{2.36}$$

$$\sum_{j=1}^{4} BK1_j = BK1 \quad ; \quad \sum_{j=1}^{4} LA1_j = LA1$$

$BK1_j$ is building capital in sector 1 used for animal category j, and $LA1_j$ is animal labor in sector 1 used for animal category j.

Technical progress is represented by time-dependent production elasticities, i.e., embodied technical progress.

$$\epsilon_{j1} = - \varphi_1(1 + e^{-\varphi_2 t}) \tag{2.37}$$

For the large-farm sector, the model is the same, but the technical progress function is:

$$\epsilon_{j2} = \varphi_3 \times \left[1 - \frac{\varphi_4}{1 + \varphi_5 t}\right] \tag{2.38}$$

2.4.5. Estimation of the model

Time series data for the allocation of labor time and building stocks to the different livestock categories are not available. Neither the labor nor the capital inputs for a specific livestock category can be expressed as explicit functions of prices and production function parameters. Instead the estimation is made through an iterative procedure (developed by G. Fischer at IIASA), starting with assumed values of the parameters.

Given these parameters, the optimization problem can be solved by generating "observations" on LA_j and BK_j (sector index skipped). These "observations" are then used to generate a new set of values for the parameters by minimizing the following function:

$$\text{Min } Q = \sum_{j=1}^{4} \sum_{t=61}^{76} \left[\frac{\hat{N}_{jt} - N_{jt}}{N_{jt}} \right]^2 + W_1 \sum_{j=1}^{4} \left[\left[\frac{\hat{B}K_j,70 - BK_j,70}{BK_j,70} \right]^2 + \left[\frac{\hat{L}A_j,70 - LA_j,70}{LA_j,70} \right]^2 \right] \tag{2.39}$$

$BK_j,70$ and $LA_j,70$ used in function (2.39) are values of the livestock-specific labor and capital intensities in 1970 generated by normative experience. They are used, together with the weighting factor W_1, in order to keep the outcome of the model within reasonable bounds. Results of estimation are given below:

Small-farm sector, 1976:

$$N_{11} = 2977 \times BK1^{0.0475} \times LA1^{0.9525} \left[\frac{BK11}{BK1} \right]^{0.07848} \left[\frac{LA11}{LA1} \right]^{0.0267}$$

$$N_{21} = 1845 \times BK1^{0.1794} \times LA1^{0.8206} \left[\frac{BK12}{BK1} \right]^{0.0821} \left[\frac{LA12}{LA1} \right]^{0.0114}$$

$$N_{31} = 1963 \times BK1^{0.4118} \times LA1^{0.5881} \left[\frac{BK13}{BK1} \right]^{0.047} \left[\frac{LA13}{LA1} \right]^{0.026}$$

$$N_{41} = 19.93 \times BK1^{0.2136} \times LA1^{0.7863} \left[\frac{BK14}{BK1} \right]^{0.0399} \left[\frac{LA14}{LA1} \right]^{0.0109}$$

Number of parameters	20
Number of parameters with low t-values	3
Number of parameters at bounds	6
Shadow price of capital	5.6%
Shadow price of labor	49.6 SEK

Large-farm sector, 1976:

$$N_{12} = 1744 \times BK2^{0.375} \times LA2^{0.6249} \left[\frac{BK21}{BK2} \right]^{0.07816} \left[\frac{LA21}{LA2} \right]^{0.0255}$$

$$N_{22} = 3114 \times BK2^{0.2609} \times LA2^{0.739} \left[\frac{BK22}{BK2}\right]^{0.0855} \left[\frac{LA22}{LA2}\right]^{0.0114}$$

$$N_{32} = 4460 \times BK2^{0.5271} \times LA2^{0.4769} \left[\frac{BK23}{BK2}\right]^{0.0475} \left[\frac{LA23}{LA2}\right]^{0.0025}$$

$$N_{42} = 33.63 \times BK2^{0.3949} \times LA2^{0.6050} \left[\frac{BK24}{BK2}\right]^{0.041} \left[\frac{LA24}{LA2}\right]^{0.099}$$

Number of parameters	20
Number of parameters with low t-values	2
Number of parameters at bounds	2
Shadow price of capital	8.1%
Shadow price of labor	112.9 SEK

2.5. Nonagricultural Production

Resources in the "rest of the economy" sector are calculated by subtracting the resource requirements of agricultural production from the total resource supply in the economy.

$$TLNA = POP \times PART - TLA$$

$$CAPNA = CAP - CAPA$$

POP is the total population, $PART$ is the labor participation rate, $TLNA$ and $CAPNA$ are labor and capital inputs in nonagriculture, TLA and $CAPA$ are total inputs of labor and capital in agriculture, and CAP is the total capital stock in the Swedish economy. Technology is represented by a Cobb–Douglas production function with time-dependent factor-share elasticities.

$$Q_{19} = \underset{(42.76)}{108021} \times CAPNA^{\Sigma} \times TLNA^{1-\Sigma} \qquad \underset{(t\text{-value})}{DW = 1.1} \qquad (2.40)$$

$$\Sigma = \frac{\underset{(42.12)}{0.231}}{1 + e^{\underset{(-12.08)}{-0.19}t}}$$

2.6. Consumer Behavior

In describing consumer behavior, the linear expenditure system with habit formation has been used:

$$X_{it} = \alpha_i + \delta_i X_{i,t-1} + \frac{\beta_i}{P_{i,t}} \left[Y_t - \sum_{j=1}^{n} (\alpha_j + \delta_j X_{j,t-1}) P_{j,t} \right] \tag{2.41}$$

$$Y_t = \sum_{j=1}^{n} X_{j,t} P_{j,t} \tag{2.42}$$

$$\sum_{i=1}^{n} \beta_i = 1 \tag{2.43}$$

where Y_t = total private consumption in period t, and X_{it} = consumption of commodity i in period t.

The equation system has been estimated for the period 1961–1976. Commodity 5, protein feed, has been excluded since it is not consumed by humans. Consumed quantities are measured in raw material equivalents, according to the IIASA commodity list. Consumer prices are calculated by dividing expenditures for each commodity by the consumed quantities. Expenditure figures are based on food consumption data on 157 processed food products. Expenditures are aggregated for 19 commodities, according to the content of the main raw material component. Results are shown in *Table 12*.

2.7. Government Behavior and the Policy Model

2.7.1. Domestic target prices

The idea behind the policy model is to represent the two-step price negotiation system in which desired prices are set. The total desired income growth in agriculture (TA) is determined in the first step, depending partly on production costs and partly on income parity compensation – consequently, being independent of the market for different agricultural products. TA, in the second step, is split among the different agricultural commodities as price increases. This distribution is affected by world market prices, especially for plant products, since the excess supply is sold on the world market. For animal products, the degree of self-sufficiency is important because the policy aims at a balance between production and domestic consumption. Furthermore, the share of TA for a specific commodity depends on the commodity's share in consumption previous years.

Desired prices are formulated according to the following equation:

$$P^*_{it} = P^*_{i,t-1} + \frac{\bar{Sh}_i \times TA_t}{X_{i,t-1}} \tag{2.44}$$

where TA_t is the total compensation amount, $\bar{Sh}_i$ is the normalized value share of commodity i in TA, and $X_{i,t-1}$ is the (human) consumption of commodity i in the previous year.

Table 12. Results of the estimation of the demand equation system (standard error within brackets).

Commodity	α_i	δ_i	β_i	R^2
Wheat	3 937.2 (-)[a]	0.89036 (0.02152)	0.00405 (0.00096)	0.87529
Rice	648.3 (499.0)	0.98618 (0.03255)	0.00001 (-)	0.93435
Coarse grains	19 891.2 (33 686.4)	0.51261 (0.25016)	0.00193 (0.00083)	0.61348
Oils and fats	4 214.7 (24 761.5)	0.10633 (0.24859)	0.00831 (0.00233)	0.71999
Sugar	286 546.7 (303 291.5)	0.06048 (0.96575)	0.00186 (0.80169)	0.50464
Bovine	96 042.6 (21 097.4)	0.05 (-)	0.01083 (0.00524)	0.27795
Pork	27 580.9 (20 169.6)	0.56601 (0.17067)	0.01388 (0.00362)	0.97986
Poultry, etc.	6 900.9 (319.1)	0.05 (-)	0.00504 (0.00027)	0.98639
Milk	26 829.6 (-)	0.92331 (0.03734)	0.00370 (0.00212)	0.40431
Vegetables	5 617.7 (23 665.2)	0.28709 (0.25036)	0.02003 (0.00522)	0.80721
Fruits	56 619.5 (6 677.1)	0.05 (-)	0.01356 (0.00144)	0.94193
Fish	7 546.8 (1 838.6)	0.05 (-)	0.01274 (0.00151)	0.92209
Coffee	17 807.4 (4 342.3)	0.84415 (0.04372)	0.00001 (-)	0.89320
Tea, cacao	1 649.3 (603.5)	0.05 (-)	0.01550 (0.00123)	0.96859
Alcoholic beverages	1 754.8 (-)	0.09144 (0.22977)	0.06519 (0.01521)	0.96265
Clothing fibers	151.3 (-)	0.95341 (0.00736)	0.00001 (-)	0.66104
Industrial raw materials	1 339 226.0 (1 085 077.0)	0.69023 (0.27541)	0.00738 (0.02376)	0.95302
Rest of the economy	7 430 651.0 (2 482 206.0)	0.05 (-)	0.81597 (0.01566)	0.99961

[a] (-) indicates that the parameter value is equal to an upper or a lower limit.

TA consists of two parts: a compensation component for increased production costs and an income parity component:

$$TA = \frac{\Delta P_{19}}{P_{19}} \times CINT_{19} + (\Delta\, WNA - \mu) \times TLA \tag{2.45}$$

$CINT_{19}$ = volume of agricultural inputs bought from the nonagricultural sector

$\Delta\, WNA$ = growth rate of labor income in nonagriculture

TLA = agricultural labor input (hired labor excluded)
μ = deduction for productivity growth in agricultural production.

$\bar{Sh}_i$, the normalized share of commodity i in TA, is calculated in the following way:

$$\bar{Sh}_i = \frac{Sh_i}{\sum_{i=1}^{n} Sh_i} \tag{2.46}$$

where each Sh_i is determined by equations (2.47) and (2.48) as follows:

Plant commodities:

$$Sh_i = \alpha_i \left[\frac{X_i \times P_i}{\sum_{j=1}^{n} X_j \times P_i} \right] + \beta_i (P_i - P_i^w) \tag{2.47}$$

Livestock commodities:

$$Sh_i = \alpha_i \left[\frac{X_i \times P_i}{\sum_{j=1}^{n} X_j \times P_j} \right] + \beta_i (SSR_i - SSR_i^*) \tag{2.48}$$

SSR and SSR^* are actual and desired levels of self-sufficiency ratios, respectively. P^w is the world market price, and P_i is the domestic price.

The second terms in equations (2.47) and (2.48) can be seen as corrections. In the case of plant commodities, the correction is dependent upon the difference between the domestic and the world market price. In the case of livestock commodities, the correction is based on the discrepancy between the actual and the desired level of self-sufficiency.

Equations (2.47) and (2.48) have been estimated for the Swedish model. All the αs are significant. As far as the βs are concerned, the signs are as expected, but some are not significant. It is, of course, difficult to explain the full outcome of the annual negotiations with a system of equations because other important factors cannot be readily formalized. The explanatory model is, consequently, rather tentative. However, using the equation system for the simulation of an endogenously determined policy in the model generates (after some tuning) quite satisfactory results in replicating past policy development.

2.8. Validation

The model and its results have been discussed with many people, from scientists to politicians, over time. These discussions have proved useful in developing the model, but they have also added to its complexity. As a result, the model's details and procedures are clear to only a very small group of experts, which is a problem in determining its validity.

The validity of this (or any) model should be judged on such grounds as:

(1) Descriptive realism.
(2) Mode reproduction ability.
(3) Transparency.
(4) Relevance.
(5) Fertility.
(6) Formal correspondence with data.
(7) Ease of enrichment.
(8) Point predictive ability.
(9) Insight-generating capacity.

The strength of the current model is its holistic approach toward describing the interaction among different subsystems. This may yield insights into the functioning of the system and a fertile basis for policymaking in different areas. The price for these advantages is partly a simplified description of some rather complex subsystems and partly a complicated computer language. As the model grows in size and complexity, it becomes more difficult to enrich its parameters. At the same time, it is hoped that these enrichments increase the model's relevance and descriptive realism. In estimating relationships and simulating historic behavior, the formal correspondence with data and the mode reproduction ability have been of decisive importance.

In *Figures 4–24*, results are compared to actual figures for some central variables in the model during the 1970–1984 period. Note that the modeled production variables are not influenced by the actual weather, which partly explains differences between modeled and actual figures.

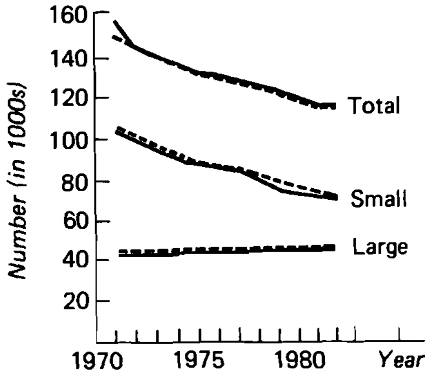

Figure 4. Number of farms: model run results compared with actual data, 1970–1984.

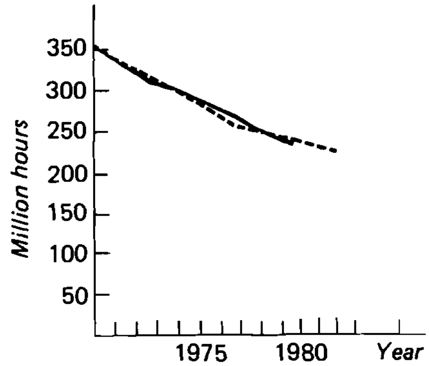

Figure 5. Agricultural labor input: model run results compared with actual data, 1970–1984.

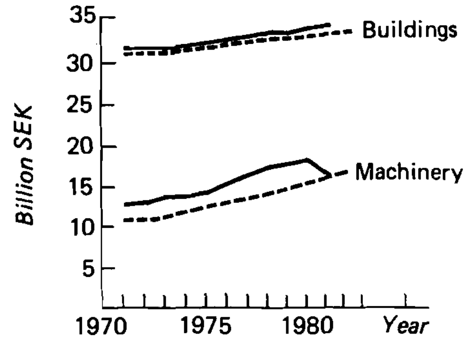

Figure 6. Agricultural capital stocks (buildings and machinery): model run results compared with actual data, 1970–1984.

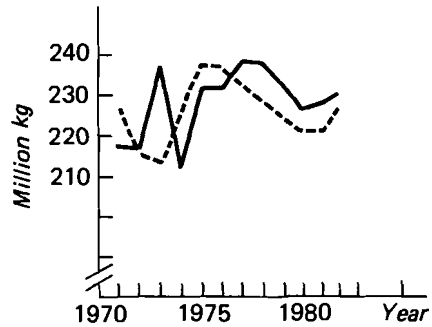

Figure 7. Fertilizer input: model run results compared with actual data, 1970–1984.

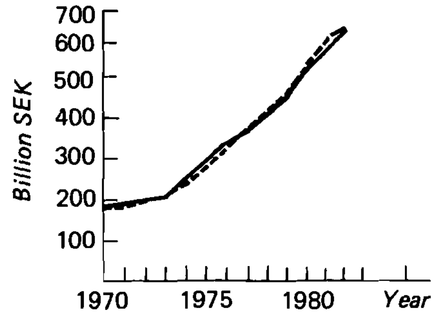

Figure 8. Gross domestic product: model run results compared with actual data, 1970–1984.

Legend: ——— Actual data
------ Model results

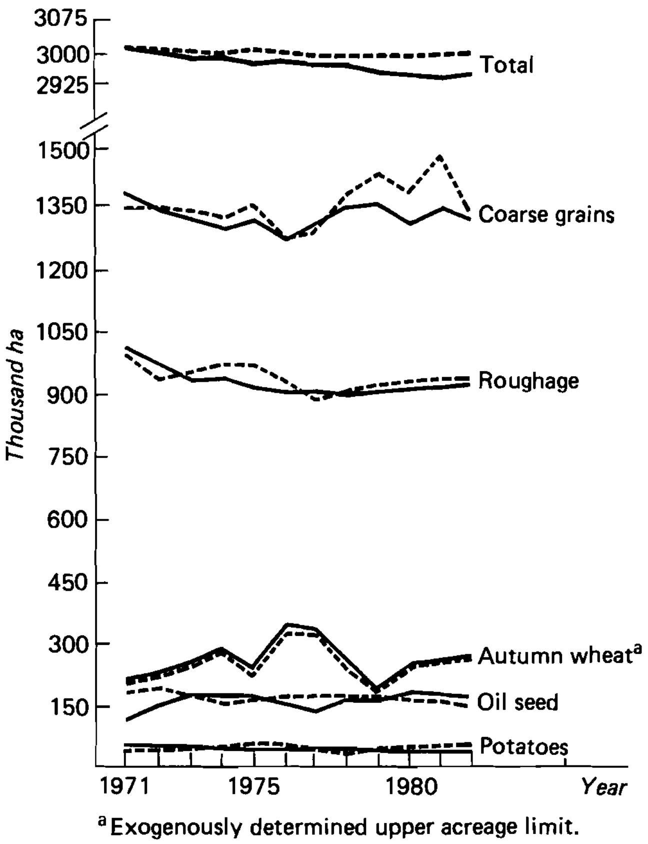

Figure 9. Distribution of arable land: model run results compared with actual data, 1971–1984.

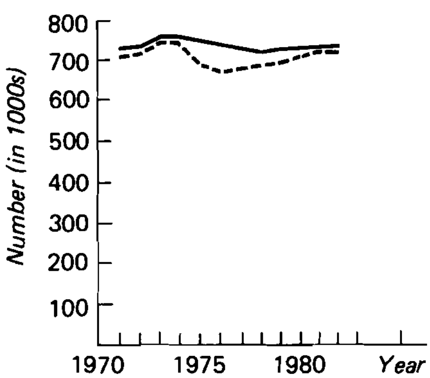

Figure 10. Bovine production: model run results compared with actual data, 1970–1984.

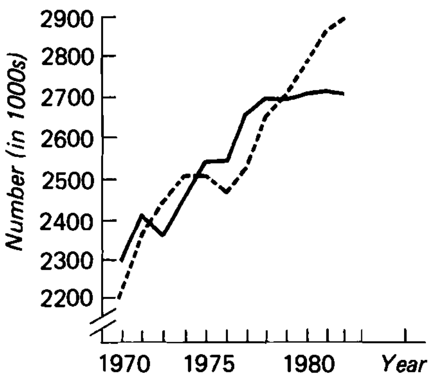

Figure 11. Hog production: model run results compared with actual data, 1970–1984.

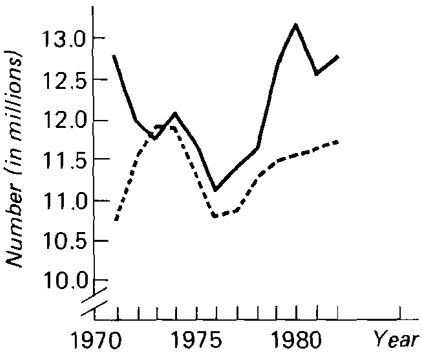

Figure 12. Poultry production: model run results compared with actual data, 1970–1984.

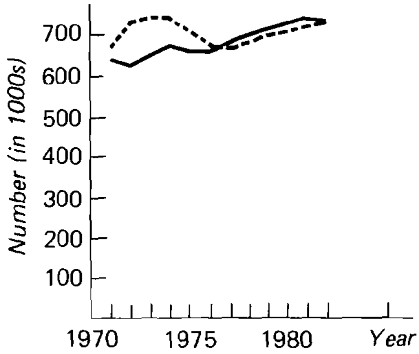

Figure 13. Production of other bovine animals: model run results compared with actual data, 1970–1984.

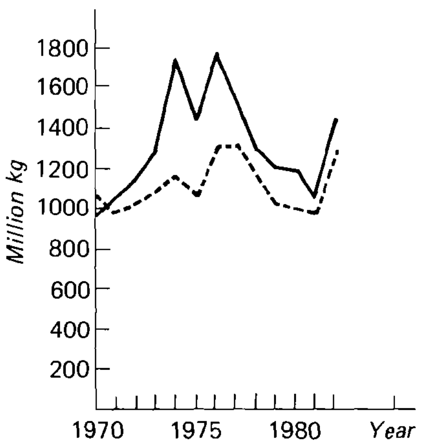

Figure 14. Wheat production: model run results compared with actual data, 1970–1984.

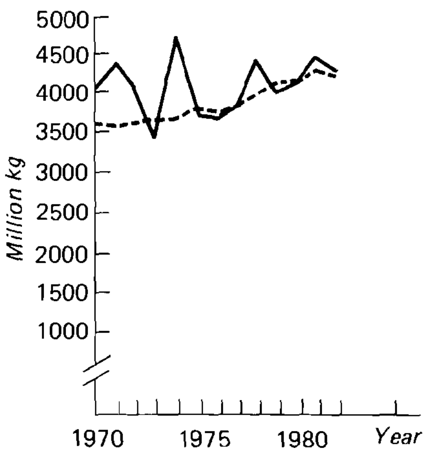

Figure 15. Coarse grain production: model run results compared with actual data, 1970–1984.

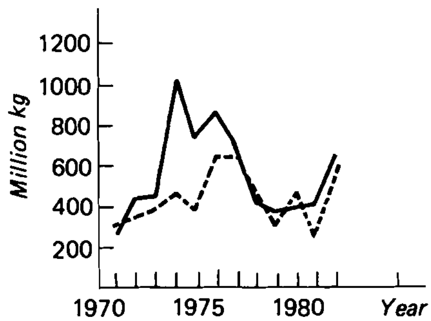

Figure 16. Wheat exports: model run results compared with actual data, 1970–1984.

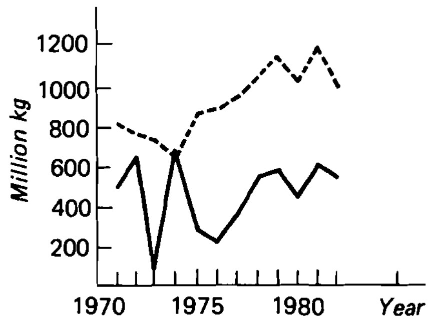

Figure 17. Coarse grains exports: model run results results compared with actual data, 1970–1984.

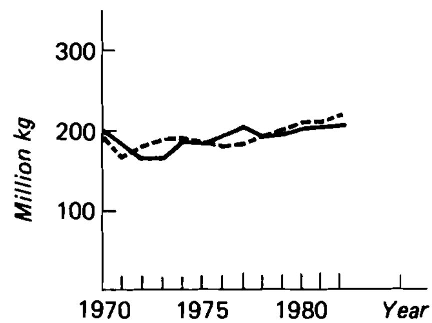

Figure 18. Beef production: model run results results compared with actual data, 1970–1984.

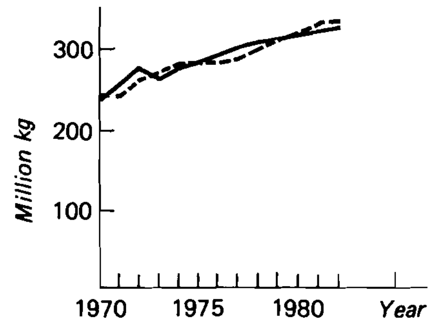

Figure 19. Pork production: model run results results compared with actual data, 1970–1984.

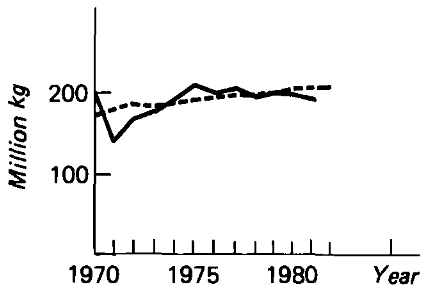

Figure 20. Beef consumption: model run results results compared with actual data, 1970–1984.

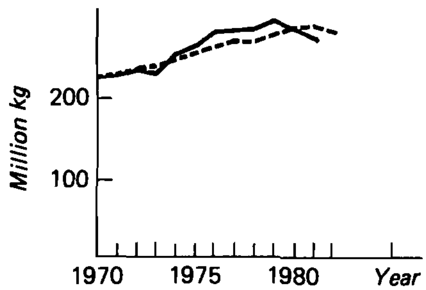

Figure 21. Pork consumption: model run results results compared with actual data, 1970–1984.

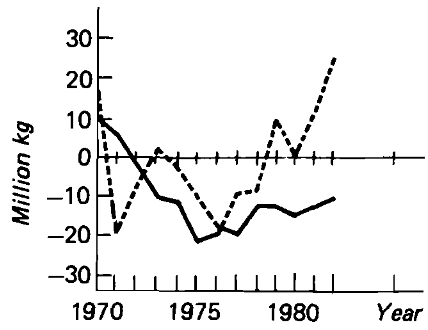

Figure 22. Beef exports: model run results results compared with actual data, 1970–1984.

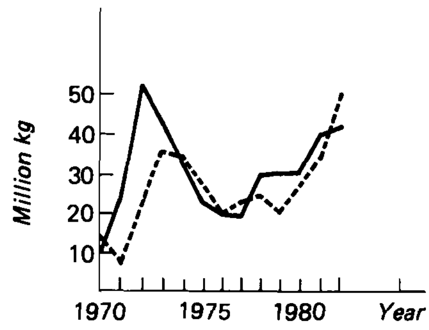

Figure 23. Pork exports: model run results results compared with actual data, 1970–1984.

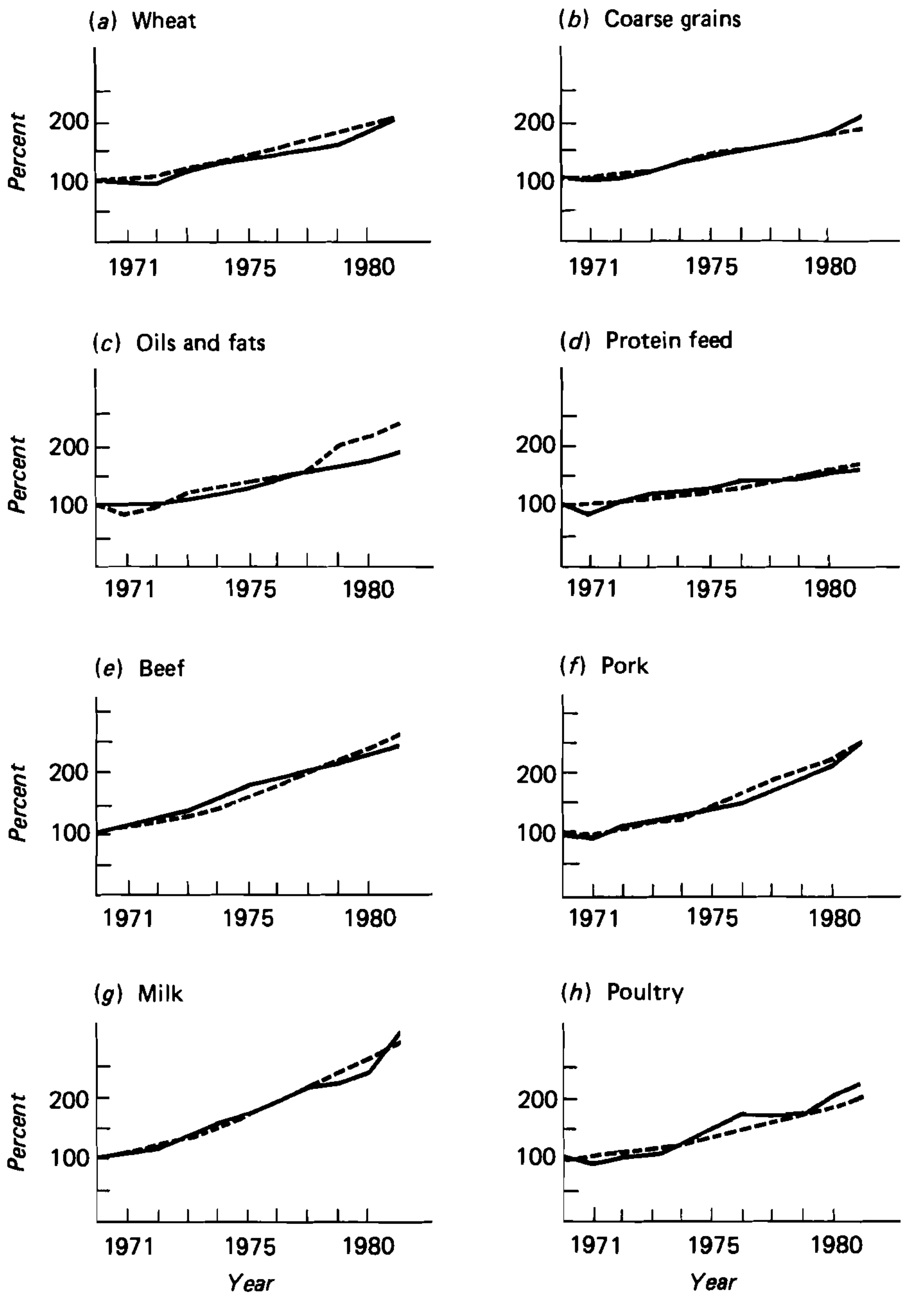

Figure 24. Percentage price increases for key commodities: model run results results compared with actual data, 1970–1984.

PART 3

Reference Run, 1982–2001

3.1. Resources

The total inputs of land, labor, machinery, and buildings, according to the base-run simulation, will develop as shown in *Table 13*, where we also show the breakdown in terms of small- and large-farm sectors.

The total labor input will drop more (by 62%) in animal production than in plant production (-24%).

Table 13. Change (%) in resource supply, 1982–2001, by resource category and farm-size category.

Resource category	*Small farms*	*Large farms*	*Total*
Arable land	-38	9	- 1
Agricultural labor	-55	-36	-44
Farm machinery	- 2	62	47
Farm buildings	- 6	50	29
Fertilizers	-50	19	10

3.2. Production and Consumption

Total output and consumption will change during the period 1982–2001 in the base-run scenario as shown in *Table 14*.

Again, the situation will change differently in the two farm sectors. The gross domestic product of small farms will drop by 5%, while that of large farms will increase by 43%.

Both caloric intake and protein consumption will increase by 7% per capita, and fat intake will grow by 10%.

These production and consumption changes will raise demand for energy inputs in both agriculture (16%) and processing (17%). The food sector as a whole will require 16% higher energy input by the end of the 1982–2001 period.

Table 14. Change (%) in production, human consumption, and feed, 1982–2001, by commodity.

Commodity	*Production*	*Human consumption*	*Feed*
Wheat	34	27	–10
Rice	–	50	
Coarse grains	28	17	–14
Oils, fats	– 2	18	
Protein feed	21	–	5
Sugar	6	3	–16
Meat	– 6	8	
Pork	– 2	7	
Poultry	–19	9	
Milk	19	19	–15
Vegetables	85	9	– 9
Fruits, nuts	0	10	
Fish	–41	13	
Coffee	–	2	
Cacao, tea	–	52	
Beverages	– 1	20	
Clothing fibers	9	–20	
Nonfood	–	59	
Nonagriculture	61	18	

3.3. Productivity

In plant production, *Table 15* displays the expected changes in yields, fertilizer use, and cultivation costs per hectare. As gross revenues in plant production rise by 84% and costs by less than 40%, the net profitability is calculated to increase drastically during the period.

In animal production, *Table 16* shows the gross margins (revenues minus feed costs), capital and labor requirements, and yields per unit developed in the reference run.

Table 15. Change (%) in yields, nitrogen use, and cultivation costs in plant production, 1982–2001, by crop.

Crop	*Yields*	*Use of nitrogen*	*Cultivation costs (1982 prices)*
Winter wheat	26	13	41
Spring wheat	18	10	41
Coarse grains	22	12	44
Rapeseed	26	20	41
Sugar beets	6	–14	13

Table 16. Change (%) in numbers, yield, inputs, and gross margins in animal production, 1982–2001, by activity.

Activity	*Numbers*	*Yield/unit*	*Labor/unit*	*Capital/unit*	*Gross margin*
Milk cows	-13	37	-56	62	98
Pigs	-13	12	-46	80	105
Poultry	-36	26	-57	42	63
Bovine animals	-27	28	-54	27	34

3.4. Prices

All prices are expressed relative to 1982 price levels. Prices for agricultural commodities are based on changes in production costs, income level gap between agriculture and nonagriculture, and the degree of self-sufficiency in certain commodities.

Maintaining the existing policy for the period will result in a 14% real increase in agricultural prices, but the impact on the nonagriculture sector would be nil.

Agricultural price policy will raise food prices even if the inflation rate in the rest of the economy is zero. Price changes at producer and consumer levels are shown in *Table 17*, along with modeled changes in price elasticities for the major domestically produced agricultural commodities.

Table 17. Changes (%) in producer and consumer prices and price elasticities, 1982–2001, by commodity.

Commodity	*Producer prices*	*Consumer prices*	*Price elasticities*[a]
Wheat	3	0	– 6
Coarse grains	1	0	2
Oils, fats	4	1	0
Protein feed	4	4	0
Sugar	6	2	13
Meat	7	4	6
Pork	34	12	0
Poultry	7	3	6
Milk	5	3	– 3

[a] A negative sign means a reduced price elasticity.

As a consequence of the price, resource use, and productivity changes detailed above, labor remuneration will increase in all categories. Over the 1982–2001 period, the wage rate per hour on small farms will grow by 167%; on large farms, by 242%; for hired labor in agriculture, by 70%; and in nonagriculture, by 67%.

Shadow prices in animal production, over the period 1982–2000, will change as follows: capital for small farms will grow by 116%; for large farms, by 381%. At the same time, labor's shadow price for small farms will drop by 62%, and for large farms, by 61%.

In plant production, shadow prices calculated for land will increase by 115%; for fertilizer use, by 90%.

Data Sources

For this Research Report, the data are mainly FAO national-specific figures for Sweden aggregated to the 10- or 19-commodity list devised by IIASA. These IIASA lists largely reflect produced and consumed quantities and their corresponding prices. Data on resource inputs, structural conditions, nonagricultural economic variables, and agricultural policy were collected from national official accounts, mainly "Nationalräkenskaperna" and "Lantbrukets företagsregister". Some figures have been developed within the project, such as the distribution of production between two agricultural sectors: small and large farms.