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Research on agricultural research

Rates of return to agricultural research in Sweden

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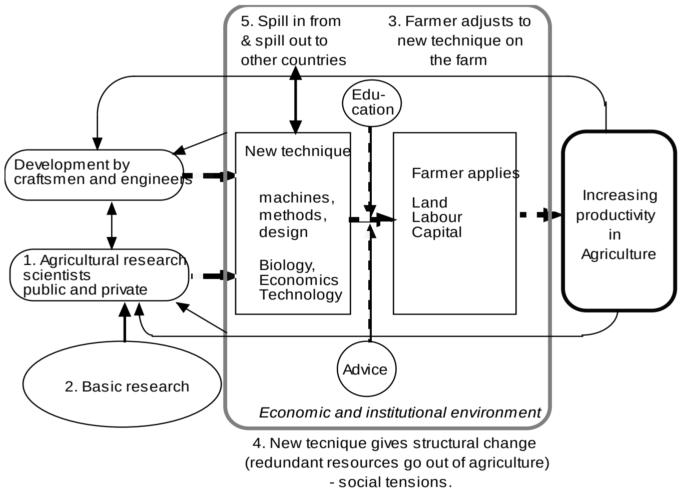

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Abstract

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A Cobb-Douglas type production function is estimated for the Swedish agricultural sector over the period 1944/45 - 1986/87. Total production of the sector is the dependent variable. Public research and advisory services are introduced as independent variables together with labour, land, variable capital and inputs bought from other sectors and a yield variable. Research is introduced with lags from 6 to 24 years from research inputs to effects on the total sector production. Research lags of 14-18 years give best estimation quality. **Elasticities** of total production per farm related to public research are estimated to lie between **0,06 and 0, 10** for the total period. Production elasticities related to advisory services give too uncertain results to be closer analyzed. Marginal value products, **MVP**, related to research are calculated to 7**-12** as an average for the period. **IRR**, Internal rates of return to public research reach **13 to 17** per cent per year above price level change over the lag period of 16-18 years. These MVP:s and internal rates of return are calculated for total production at national prices, "as the farmers see them". Approximate estimates of these values for production at world market prices give MVP:s of 4-8 and IRR of 10 to 14 per cent over price level change.

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*) The author is indebted to university lecturer Sven-Olov Larsson, professors Anders Ågren, Yves Surry and Bo Öhlmér all Uppsala and professor Kurt Brännäs, Umeå for Valuable comments on early drafts of this report.

Research on agricultural research
Rates of return to agricultural research in Sweden*

Aim of this study

The hope has been to be able to say something on the effect of public research inputs on total production of the agricultural sector in Sweden during some forty years after WWII. The hope has also been to shed some light on the length of time between inputs of agricultural research and its effects on the total agricultural production. As the research problem is stated nothing, however, can be said about the length of time this effect is lasting.

Conclusions

1. Public investment in agricultural research in Sweden gave an average yearly marginal return of 13-17 per cent above price level changes during the time period 1944/45 to 1986/87.
2. This return was counted in national agricultural product prices. An approximate calculation in "world market" prices gave an average marginal return of 10-14 per cent above price level changes during the period.
3. These returns are based on estimates indicating that an additional 1 million SEK invested in public research costs gave a marginal increase of research benefits of some 7 to 12 million SEK national (4-8 million SEK in "world market" prices).
4. The investigation also shows that research costs one year gave these benefits some 16-18 years later. The returns in points 1 and 2 above are the average marginal returns over the whole period.
5. The nature of the estimation methods used make these figures subject to uncertainty. This stems from model simplifications, econometric quality, lag structure used and techniques to overcome common trends and correlations in the material. However, the many experiments analyzed here and in an earlier report have shown a surprising stability around these results.

Data

6. **Available data are** research inputs 1931/32 to 1986/87 and volumes of total agricultural production and inputs of means of production during the years 1944/45 to 1986/87.
7. The research effects are the results of all public agricultural research in Sweden during the time period studied. Both successful and less successful projects are included. We are painting an image of a small part of the world of successes and failures, of trials and errors that constitute every scientific culture.

8. Data later than 1986/87 are not included. The obvious reason is that the project was started by the end of the 1980ies. Also, the tudy covers a time period with approximately one clear goal, productivity gain in the sector. During the period thereafter two goals exist for agricultural research productivity gain and environment protection in Sweden. This requires other models than the one here used.

Model

9. The image of the agricultural sector is a production function for the average farm formed bty all inputs and outputs in the sector. A Cobb-Douglas production function is used to connect research and other inputs to total agricultural production. The production function is estimated in logarithmic linear form. This approach gives direct estimations of the relevant elasticities, i.e. the relation between the marginal change of total agricultural production to the marginal change of individual inputs.
10. The inputs are labour, land, machine and animal capital, bought production to the marginal change of individual inputs.inputs all expressed per farm, a yield (weather) variable, public research and public advisory services expressed for the whole country.
11. The picture where research (and advice) influence the agricultural sector expressed as a simple production function, is a clear simplification of how new technology influences agricultural production. See figure on page 9.
12. The research inputs for the years 1931/32 to 1986/87 are giving research benefits – effects on total agricultural production –during each of the years 1944/45 to 1986/87. It is the relation between these two streames of total costs and benefits in this "going concern" of research efforts, in principle constructed like the total sums of costs and production in the hypothetical example on pages 11 and 12, which are compared in the model. .
13. In all experiments research inputs are lagged 6,12,14,16,18, 20, 22 and 24 years. The aim being to test which of these lags best relates the variation in research inputs to the ariation of total agricultural production
14. The estimations of the production functions have been made with ordinary least squares,OLS.. The quality of the estimations are tested with R-squares values, Durbin- Watson tests, t-statistics and desired sums of elasticities. In some experiments stability test with Ridge Regression are made.
15. In experiments 1 to 7 the log values of all variables are usedin the calculations. In experiments 8 to 14, log values of differences

between two consecutive moving, weighted sums of three, four and five years are used.

Experiments 1 to 7

16. These seven experiments are analyzed in the unpublished Working paper **Research on agricultural research I.** In these experiments variations were made of time periods studied and of variable specifications. The effects of all these experiments gave a good knowledge of the data material used. However, they all showed R-square values close to 95-99 per cent indicating possible effects of common trends in the data series. The best results were reached in experiment 2 where the Land variable was measured in hectares per farm with more than 2 hectares of land.

17. In all experiments 2 to 7 the alternatives with time lags of 14, 16 and 18 years showed better quality than alternatives with shorter and longer lags.

18. In e**xperiment 2** lags shorter han 12 and longer than 18 years show no or negative effects of public research on total production per farm. Equations for lags 12-18 years show acceptable t-statistics and good Durbin-Watson test values.The sums of elasticity coefficients are, however, too high to Be accepted as good estimations of Cobb-Douglas production functions. Even with these shortcomings in quality of the elasticities of production related to public research the stimates show promising values with reasonable stability over these lags The production elasticities related to research are 0,06 and 0,09 for lags of 16 to 8 years with good t-values 1,6 - 2,5.

Experiments 8 to 14

19. In these experiments the model is changed in two ways. To decrease common trends in the material differences between consecutive years of output and inputs are used. In experiments 8,14 and 13 research inputs are expressed as moving weighted sums of three, four and five years inputs expressed as same differences. The five years are given weights from equal for all to a low inverted V-shape.

20. The best quality of the estimations are reached in experiments13. This estimations with 18 years lag give elasticities of production related to research of b= 0,07 to 0,12. They give the best quality with R-squares at 72 per cent and sums of elasticities b = 1.3. The t-statistics indicates that these estimations are uncertain.

Summary of Results

21. The effects of **public research** in Swedish agricultureduring the time period 944/45 to 1986/87, based on all here reported experiments are **that** a cautious estimation of production elasticities related to public research is centered around 0,06 and 0,10; **that** most probable lag period are centered around 18 years, i.e research effects on production 16 to 18 years after research inputs and:**that** t-statistics meets requirements in experiment 2 but not in experiment 13. The results give effects in practical terms indicated in points 1 to 5 above.
22. The estimations of production elasticities related to **advice** are too unstable for us to make any guesses of the general effect of this variable at this point.

1. Introduction

This is a report on the continuation of a research project on productivity of Swedish agricultural research 1945-1985 financed by Formas, the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning, (project J 151). It was financed 1984/85-1986/87 by the forerunners of Formas and by the Swedish University of Agricultural Sciences.

The aim of the project is to estimate the effect of agricultural research on total production of Swedish agriculture during the time period 1945-1985. A Cobb-Douglas production function is used in the study to connect research and other inputs to agricultural output. This approach gives direct estimates of the relevant elasticities, i.e. the relation between the marginal change of output to the marginal change of the research and other inputs. The marginal value product, MVP, and internal rates of return, IRR, to agricultural research are determined. Estimates of MVP of research are based on total production at national prices. A calculation of the approximate effects on total production at world market prices is also made.

The hope is thus that the study to be reported here can say something on the magnitude of the effect on total production of the agricultural sector that can be related to research inputs. The hope is also that it can shed some light on the length of time between inputs of agricultural research show effects on the total agricultural production. As the research problem is stated nothing, however, can be said about the length of time this effect is lasting.

The question asked is: How is yearly total agricultural production per farm determined by total inputs of this research and by advice as a production factor together with inputs per farm of labour, land, capital in machines and animals and bought inputs in the production function of agriculture for each of the years during the time period mentioned?

A number of experiments were originally made, with research inputs one year giving an effect on total production after a lag of six years, with estimating elasticities of agricultural production and of net productivity related to public research, of research inputs treated as a moving stock of 15 or 20 years and no lag, of research represented by two variables, public national and imported research. The low quality of most of these estimations made me (in 1992) give up the hope to get results of interest to publish.

The scene changed when some articles were published pointing out that the lags between research inputs and resulting effects on agricultural production may well be much longer and last longer than earlier research had assumed. Information in the international literature of lag lengths, effects on production and productivity, and acceptable empirical estimates of these lengths and effects of agricultural research are still very uncertain. This was indicated for example by Chavas and Cox in 1992 and by Alston and Pardey in 2001. These articles made me restart - in the fall of 2005 for other reasons - the Formas research project J 151. It is this new part of this project that will be reported here.

Three questions have been asked to this material:
a) Is it possible to identify the marginal value that agricultural research has contributed to total agricultural production during the period 1945/46 to 1986/87?
b) Is it possible to identify a time period from the yearly input of research resources into the public research organizations to the effects of total production in the Swedish agricultural sector?
c) Is the total production function of acceptable quality in the cases where we find acceptable answers to questions a) and b)?

The picture via a simple production function, which expresses the influence of research on the agricultural sector, is a clear simplification of how new technology influences agricultural production. We also have the effects of private research, of advisory services, of "practical" technical development and the possible better education of the farmers. These factors may well be "picked up" by the elasticities we are trying to estimate. Thus the effects of public research may be overestimated in the studies reported here.

The search for an answer to question b) has resulted in developing a research plan with 8 lags from 6 to 24 years after the research inputs are made.

The research effects here reported are the results of all public agricultural research - basic and applied - in Sweden during the time period studied. This means that both successful and less successful projects are included. We are thus close to painting an image of a small part of the world of successes and failures, of trials and errors that constitutes every scientific culture.

Data later than 1986/87 are not included. The obvious reason is that we are reporting a project planned and worked on by the end of the 1980ies. Also this final date was chosen due to the fact that the public research shifted character to a more environment protecting goal structure by the end of the 1980ies. Our studies indicate (Renborg 1989) that by the mid 1980ies some 6-12 per cent of the research at the Swedish University of Agricultural Sciences - and a continually increasing relative amount, was directed towards this field. We wanted to concentrate the study to a time period where one goal, the effects of research on total production from the sector within the existing institutional setting, dominated the research. The data material contains time series of some 40 years of inputs of public research and advisory services as production factors together with inputs per farm of labour, land, capital in machines and animals and bought inputs and their effects on total production per farm.

Seven different experiments have been made and are reported in an hitherto unpublished report aimed for the Working paper series at the Department of Economics, The Swedish University of Agricultural Sciences: **Research on agricultural research I. Rates of return to agricultural research in Sweden.**

In experiment 1 estimations of capital in land and buildings per farm was used as the land variable with a not acceptable effect. In experiment 2 this variable was replaced by land in hectares per farm with good effects. In experiment 3 farms with more than 2 hectares of land were replaced by farms with more than 5 hectares of land in an effort to come closer to the size groups which stand for the major part of the total production. This had little effect on the estimated equations. In experiment 4 the data material was divided in two groups 1945/46-1965/66 and 1966/67-1986/87. The reason was the observation made, that the production functions may differ between the two periods. In experiments 5 and 6 the yield variable was simplified from 13 to 2 values. Only small effects were observed with this change. In experiment 7, finally, the effect of excluding the yield variable was studied. This exclusion had very little effect on the resulting elasticities. Experiment 2 will be analyzed further on in this report.

The effect of all these experiments gave a good knowledge of the data material used. In this respect they were a success. However, probably due to common trends in the material, the ensuing parameter estimates were unreliable. Also in some cases the ridge regression analysis had not given stable elasticities. These are the reasons why new experiments have been made, where the common trends in the material are counteracted by using annual differences in inputs and outputs when estimating the elasticities of production. It is in these experiments also possible to observe the time lags that we are asking for is approximatively indicated already in the first 7 experiments.

2. The model

The production function used is a Cobb-Douglas function. With all its limitations this function directly gives the production elasticities we are looking for. Also, it is so often used in the studies met in the literature, that it gives a good basis for comparisons with other similar studies.The following equation is estimated:

$$y = aX^b$$

where $y = Y/n$ denotes value of total output*(Y)*/farm*(n),*

a is a constant

$X = (x_i)$ denotes different kinds of inputs/farm,

and $b = (b_i)$ denotes exponents to the inputs (production elasticities),

where $(i = 1...8)$ and where all values are in 1985/86 prices.

The inputs x_i are:

x_1 = total public research

x_2 = labour/farm

x_{31} = land and buildings/farm

or

x_{32} = land on all farms > 2 ha / all farms > 2 ha

or

x_{33} = land on all farms > 2 ha / all farms > 5 ha

x_4 = machine and animal capital/farm

x_5 = bought inputs/farm

x_6 = a yield or weather index

x_7 = total public advice inputs

x_8 = total private research inputs

All estimations are performed in log form i.e.

$$\log y = \log a + \sum_1^8 b_i \log x_i$$

x_1 *and* x_8 are subject to lag effects. When all other variables are given for year t,

x_1 *and* x_8 are given for years $t - l$ where

l for x_1 are a set of earlier years, and

$x_8 = 0$ in this version of the investigation.

In all experiments lags with l = 6,12,14,16,18,20,22,24 years have been tested.

The estimations of the production functions have been made with ordinary least squares - OLS -. The quality of the estimations is tested with R-squares values, Durbin –Watson tests at the 5 % significance level 1,2-1,8, t-tests of the estimated parameters over 1,6, and desired sums of elasticities 1,0-1,1.

<u>On the influence of research and advice on the total production of the agricultural sector</u>

We have to be aware of the fact that the picture where research (and advice) influence the agricultural sector expressed as a simple production function, is a clear simplification of how new technology influences agricultural production.

In the agricultural economics literature Schultz(1953) and Griliches (1964) were the first to give a picture on how new technique is introduced into this sector. They imagined that research produced new technique, which through education and advice was transferred to the farmers and caused improved production/productivity. Hayami and Ruttan (1971) proposed that new technique was induced and developed as an answer to changing economic and institutional conditions. This new technique is developed by entrepreneurs in agriculture and associated industry, as well as by researchers and stimulated by politicians who want to encourage a good development.

Rosenberg (1982)- working in the telecommunication industry –means that new technique, is developed by technicians, who know that these new methods and machines work in the production before they know why. v. Wright (1986) points out that "The origin of the historic development of our techniques are our craftsmen rather than our scientists." Let me add that much of this development and adjustment of new techniques to the individual farm level is in this way made by the farmers themselves. Today research and technical development is more and more integrated, research alone is not the only contributor to new techniques.

The picture on the following page may give an idea of some features of the technical development environment in agriculture where we are trying to estimate the effects of research inputs on production in the sector via the simple production function approach. Its appearance in this study indicates that we are aware of our oversimplification.

The consequences of these viewpoints for the simple production function to be used in the research efforts following here is the awareness that the effect of this "practical" technical development and the possible better education of the farmers may well be "picked up" by the elasticities we are trying to estimate. Also, in this version of our study, we are concentrating the estimations around the effect of public research. To this should be added the effects of the private research. The costs of this industry research are here assumed to be included in the input prices.

Figure 1. Research and Agriculture

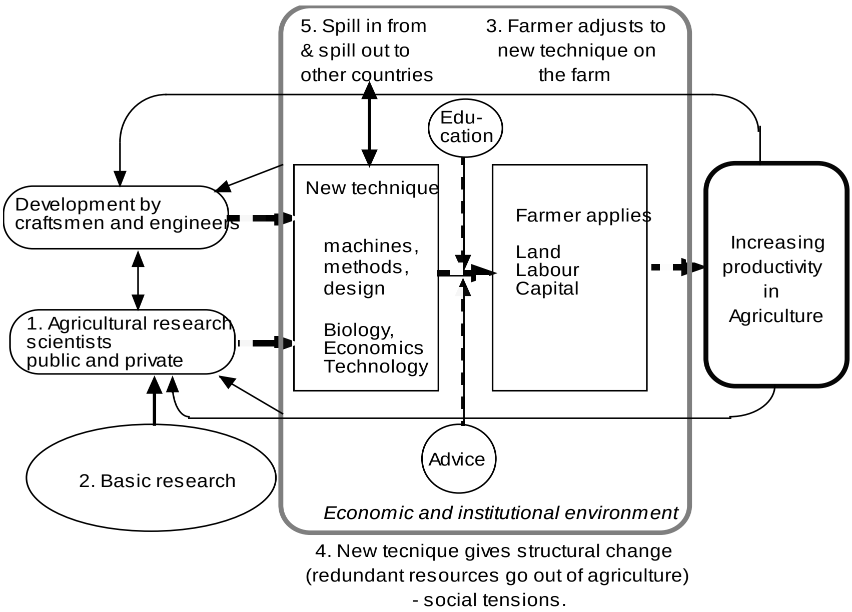


Figure by Sven-Olov Larsson after design Ulf Renborg

<u>On the time lag between research inputs and its effect on the total production i agriculture.</u>

Robert Evenson (1967, p 1421-1422) discusses the distribution over time of the utility of agricultural research. He states that this distribution is influenced by three factors, (a) the time between inputs of research funding and the product of the research, (b) the time for adoption of the research product in the sector and (c) the time elapsing until the effect of the research product is fading away. These three factors constitute a lag problem, which has to be handled when the effects of research on production and productivity within a sector are estimated. Using different ideas on the shape of the distribution over the lag period Evenson estimates the length of this period to 6-7 years for US agriculture 1938-1963 using USDA input indexes. How long this lag period is has been discussed in many papers since the 1960ies. See for example in Davis (1981), Pardey and Craig (1989), Chavas and Cox (1992), and Alston, Chan-Kang, Marra, Pardey, Wyatt (2000), in a "Meta-Analysis ..", Alston and Pardey (2001) in an extensive review of the whole lag problem, and Evenson (2001), in Huffman and Evenson (2006). The general view of this lag discussion seems to be that these scientists now think in rather long lag periods - up to 30 years or longer - for the whole period (a)+(b)+(c) as expressed by Evenson above. How it has to be successfully handled in the case of all research inputs in a sector seems however still to be an open question.

Alston and Pardey (2001, p146) state that "There are lags of several years, typically, between when an expenditure is made on research and when the resulting innovation or increment to knowledge begins to be adopted and to affect production and productivity. The effects of a particular investment today can persist over many production periods, perhaps forever. The effects of other R&D investments may be short-lived or nonexistent. Estimating the parameters that characterise this overall dynamic research-development-adoption-disadoption process is the most challenging empirical problem in evaluating R&D." Their paper also shows that lag lengths, effects of production and productivity, and good empirical estimations of these lengths and production/productivity effects still are very uncertain.

In this study I am using an approach mentioned by Alston et al (2000, p 18) in their Meta Analysis of Rates of Return to Agricultural R&D. They distinguish between one set of problem where the effects of ***one particular project*** is studied, a project for which the flows of resources, benefits and costs may be anticipated or estimated. Another set of problems relate to "for example, ***a research program or portfolio of projects*** (my accentuation) and programs within an institution or across all the institutions that make up a country´s national agricultural research system". In this type of analysis "information of the average lag profile across the entire inventory of projects and programs within the portfolio being assessed" is developed. "The essential distinction is that it is easier to know the lag structure for some types of research than for others."
My approach is the last mentioned by Alston et al (2000 p 18). Let me continue the exemplification of the arguments for use of this approach in

this study. We do not only have projects with differences in lag structure. We are also handling a portfolio with projects in different stages of development - just started, well under way, ready to leave research, already out and applied by few users or by all - , projects with different length of lag periods, projects that will never be finished, or that were aimed at "inventing the wheel again" or developed around impossible ideas. Research is a trial and error business.

In the table and figure on the following pages an effort has been made to illustrate the development of the model of research costs and research benefits for single projects to the model of the sums of research costs and research benefits for a group of projects. In this hypothetical illustration, with assumed values of costs and benefits of each project, benefits follow the generally assumed inverted V-shape of research benefits for individual projects (Alston et al 2000 p 17). In the example nine projects are assumed to be carried out one after another in three research institutes. Cost and benefits are summarized for the whole group of projects. The inverted V-shaped total research benefits shown in the figure are not an effect of the shape of benefits of the assumed individual projects. It only shows that we in the hypothetical model have allowed the first project in each "institute" to start in year 2. In a "going concern" the benefits of a set of earlier projects would have filled up the increasing first part of the inverted V-shaped curve of benefits and later started projects the decreasing last part of this curve.

A consequence of this discussion is that it is not possible to say a priori anything on the shape over time of the total benefits of the portfolio of projects in such a "going concern" of research as the total Swedish public agricultural research.

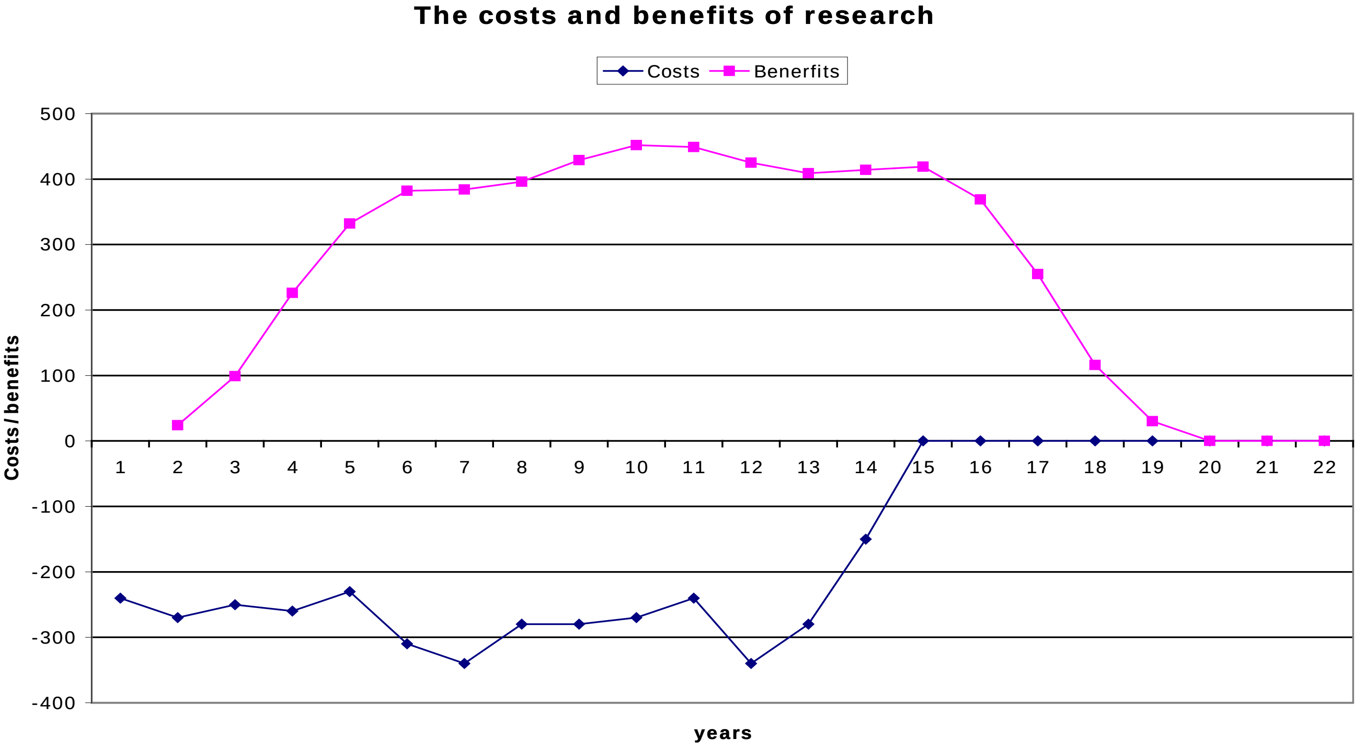
In our study the research costs for the years 1931/32 to 1986/87 are giving research benefits during each of the years 1944/45 to 1986/87. It is the relation between these two streams of total costs and benefits in this "going concern" of research efforts, in principle constructed like in our hypothetical example, which is investigated in the model used in the study here reported. As is seen from the model specification on page 7 the stream of research costs is in every experiment lagged 6,12,14,16,18,20,22 and 24 years. The effects on the production elasticities related to research and all other inputs are compared between lags.
An interesting feature of the average productivity of a whole national agricultural research system is that it shows the results of the "everyday" type research efforts to increase the productivity of a sector. Does it really

pay? What does it pay in relation to other of a country´s public investments? How good is it in relation to the highest prestige research? This type of studies even open up new questions: How can we improve the research organizations studied? How productive are they compared to more prestigious research efforts?

The effects in the experiments reported here are of the total public Swedish agricultural research 1931/32-1986/87 on the total production of the agricultural sector in Sweden during the time period 1944/45-1986/87. Of interest to note is that these are the effects of **all** public agricultural research both successful and less successful and even all research efforts that turned out to be total failures.

Figure 2. A model of the sums of research costs and benefits for a bundle of projects. An hypothetical illustration.

	Institute 1						**Insttitute 2**						**Institute 3**						**Sum of all projects**	
	Proj	1	Proj	5	Proj	9	Proj	2	Proj	4	Proj	8	Proj	3	Proj	6	Proj	7		
Year	x1	y1	x5	y5	x9	y9	x2	y2	x4	y4	x8	y8	x3	y3	X6	y6	x7	y7	X	Y
1	-100						-90						-50						-240	
2	-110	10					-100	9					-60	5					-270	24
3	-100	41					-80	37					-70	21					-250	99
4	0	93	-90				-90	83					-80	50					-260	226
5	0	125	-100	9			0	119	-110				-20	79					-230	332
6	0	114	-110	37			0	125	-120	11			0	95	-80				-310	382
7	0	62	-120	86			0	97	-130	45			0	86	-90	8			-340	384
8	0	20	-110	131			0	52	0	104	-80		0	56	-90	33			-280	396
9	0	0	0	160	-90		0	18	0	143	-90	8	0	24	-100	76			-280	429
10	0	0	0	157	-90	9	0	0	0	135	-100	33	0	4	-80	114			-270	452
11	0	0	0	125	-90	36	0	0	0	76	-110	77	0	0	-40	135			-240	449
12	0	0	0	68	-100	81	0	0	0	26	-120	118	0	0	0	132	-120		-340	425
13	0	0	0	22	-60	118	0	0	0	0	-100	147	0	0	0	110	-120	12	-280	409
14	0	0	0	0	-40	135	0	0	0	0	0	159	0	0	0	72	-110	48	-150	414
15	0	0	0	0	0	126	0	0	0	0	0	154	0	0	0	32	0	107	0	419
16	0	0	0	0	0	100	0	0	0	0	0	120	0	0	0	8	0	141	0	369
17	0	0	0	0	0	64	0	0	0	0	0	64	0	0	0	0	0	127	0	255
18	0	0	0	0	0	28	0	0	0	0	0	20	0	0	0	0	0	68	0	116
19	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	22	0	30
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
22	0	0			0	0			0	0	0	0			0		0	0	0	0
Sum	-310	465	-530	795	-470	705	-360	540	-360	540	-600	900	-280	420	-480	720	-350	525	-3740	5610


The costs and benefits of research
Costs
Benerfits
500
400
300
200
100
0
-100
-200
-300
-400
Costs/benefits
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
years

3. Data base

The data used in this study are described in the working paper mentioned earlier. The **"total production value"** for the years 1944/45-1986/87 is the volumes of all deliveries out of the sector expressed as values of production and each input in 1985/86 prices with relevant indexes for individual series.

The volume of **"public research"** in the agricultural sector is yearly current values of direct public grants and external contributions to public research universities and institutes for agricultural and veterinary research for the years 1931/32-1986/87.They include costs for education to doctor´s level of agronomists and veterinarians. These costs – approximately 10-20 per cent of total grants during the period - are not possible to separate from other public grants to the agricultural university during the period studied. A specifically constructed index based on wage statistics (Renborg 1992) has been used.

Inputs of **"labour"** are given in millions of working hours by farmers, their families and hired hands. The estimates are yearly transformed to the total agricultural sector in the official accounts of the national agricultural policy.

"Farm land" is the yearly cultivated hectares of arable land plus 0,3 times hectares of pasture. Figures are from the official agricultural surveys. Yearly figures between 1944 and 1968 have been estimated as linear interpolations between survey years. For 1968 and later yearly surveys are used. The **number of agricultural holdings** with more than 2 hectares of arable land are taken from the same statistical sources as for farmland and calculated in a similar fashion.

"Machines and animals" are the sum of capital in animals, machinery, stored stocks and growing crops, all in principle evaluated at market prices in existing condition.

"Bought Inputs" are the total value of inputs and services bought from other sectors, such as fuel, fertilizers, feed, electricity, and services like freights, control fees, trading costs, accounting and veterinary services etc.

The yearly **"yield or weather index"** is measured with the subjective estimates of the yield level for every crop made in October each year, i.e. when the harvest was known. These are subjective measures based on yield estimates for every crop in small regions over the whole country and summarized for the country as a whole with the regional acreages of each crop as weights. This variable is assumed mainly to capture the weather variations between years.

4. The basic production function

In our study the model of the agricultural sector is the production function for the average farm formed by inputs and outputs of all these available data. This model is shown in this section without introduction of research inputs. It is given in the form used in Experiment 2, where the variable "Capital in land and buildings per farm" is replaced by variable "Land as hectares per farm", since this gave the best quality in our estimations. The hope is that studies of the basic production function based on "Swedish agriculture looked upon as an average farm" will give some idea of the quality of the production data, on which the influence of research and advisory services will be studied.

The basic characteristics of the resulting functions are summarized in the table on the following page. With the required quality of the estimated models the first conclusion to be drawn from this table is that the result is of a good quality only in a few cases. Wide variations, however, exist.

In the estimations where effects of the existing multicollinearities between explanatory variables are limited using the ridge regression technique we observe that the elasticities of production show a certain stability over all equations and a good stability for the best equations within each group of data material. For the best equations also the DW-tests and the *sumbnw* values show reasonably good qualities of the data material. Here and in all following tables the *sumbnw* values means the sum of all elasticities estimated except for the yield and weather index. This means that we assume that the weather index variable is a correction of the estimated production y and that the *sumbnw* is the one we expect to be equal to 1.0-1,1 for good quality of the production function.

Production functions for the average farm. OLS estimates. Production Elasticities and t-statistics. Data 1944/45-1986/87

Estim. Nbr.	Labour /farm	LAND1 Hect/f	Machin +anim/f	Bought Input/f	Yield Index	DW Test	*Sumb nw*	Rsq
601	0,586	0,712	0,230	0,440	-----			
t-st	2,9	4,0	1,6	4,3		1,5	*2,0*	99,4
602	-----	0,600	0,469	0,154	-----			
t-st		3,2	3,7	4,2		1,2	*1,2*	
603	0,528	0,634	0,274	0,418	0,221			
t-st	2,9	3,9	2,1	4,5	3,1	1,1	*1,9*	99,5
604	-----	0,527	0,491	0,160	0,242			
t-st		3,1	4,3	4,9	3,1	0,9	*1,2*	

Elasticities of Production in Ridge regression models.

Estim. Nbr.	Ridg parm	Labour /farm	LAND1 Hect/f	Machin +anim/f	Bought Input/f	Yield Index	DW Test	*Sumb nw*
601								
Rdg	0,02	0,083	0,631	0,399	0,209	-----	1,2	*1,3*
	0,1	-0,164	0,582	0,362	0,167	-----	0,8	*1,0*
602								
Rdg	0,02	-----	0,632	0,408	0,178	-----	1,2	*1,2*
	0,1	-----	0,593	0,367	0,204	-----	1,0	*1,2*
603								
Rdg	0,02	0,063	0,597	0,400	0,206	0,249	0,8	*1,3*
	0,1	-0,176	0,560	0,356	0,165	0,295	0,5	*0,9*
604								
Rdg	0,02	-----	0,598	0,407	0,183	0,252	0,8	*1,2*
	0,1	-----	0,573	0,361	0,205	0,286	0,6	*1,1*

A pervading characteristic of the estimations is that those containing hours of labour per farm result in an unrealistic production function with a sum of elasticities on this farm level approaching 2. This table also indicates that the labour variable rapidly approaches zero and has a tendency to become negative. This is a tendency that has been stable over all estimations made in the study as a whole. This is not surprising in the situation studied. The forty years after the Second World War was a period where farm sizes, bought inputs and machine investments increased but rarely in a pace that gave the originally available labour inputs full employment. This development finds support in a cross section study from 1961, which shows low or very low marginal products for the affluent available labour on farms of average size (Sandqvist 1961 and in SOU 1963:66, p.72).

With few exceptions the t-statistics in these estimations vary from being very good to acceptable, as is true also for most of the Durbin-Watson tests even if, in some cases, they show that autocorrelations still distort the estimates.

As a whole we are accepting this study of the farm as a basis for closer studies of the effects of public research and - to some extent of advisory services - on production in agriculture.

5. Experiment 2. Total production per farm explained by farm inputs per farm plus country inputs of agricultural research and advisory services.

The experiment results are shown in appendix table 1 for all lag lengths from research inputs to effects on production per farm tested. The appendix tables indicate that lags shorter than 12 and longer than 18 years show no or negative effects of public research on total production per farm. With some variation between equations tested the best quality and positive effects of total public research are show by estimations with a lag between 12 and 18 years. Estimation results with these lags are shown in the following table.

Results Experiments 2
OLS LAND1 replacing land & buildings as independent.variables
Original Yield variable. Series 1 1944/45-1986/8. With labour
Best estimations of all shown in the appendix

YRS LAG	PUB-RES	LAB-OUR	LAND1	MACH &ANIM	BOUGH INPUTS	YIELD INDEX	ADVC	DW	R-sq	*SUM bnw*
6 variables										
14	0,049	0,540	0,772	0,152	0,391	0,391	-----		99,5	
t-v	1,0	3,0	4,4	1,1	4,3	3,0		1,1		*1,9*
16	0,087	0,512	1,100	0,007	0,265	0,287	-----		99,7	
t-v	2,3	3,4	6,7	0,1	3,4	5,0		1,4		*2,0*
18	0,080	0,344	1,230	0,095	0,116	0,245	-----		99,8	
t-v	2,1	2,0	7,6	0,8	1,0	4,7		1,6		*1,9*
7 variables										
12	0,061	0,378	0,737	0,417	0,119	0,173	0,168		99,6	
t-v	1,3	2,3	5,0	3,4	1,0	2,6	3,5	1,4		*1,9*
14	0,089	0,458	0,777	0,325	0,182	0,166	0,162		99,6	
t-v	2,1	2,9	2,4	5,0	1,5	2,6	3,3	1,5		*2,0*
16	0,091	0,494	1,040	0,100	0,224	0,263	0,062		99,7	
t-v	2,5	3,3	6,0	0,7	2,3	4,3	1,2	1,5		*2,0*
18	0,087	0,366	1,190	0,112	0,114	0,242	0,024		99,8	
t-v	2,0	2,0	6,6	0,9	1,0	4,5	0,4	1,7		*1,9*

Original Yield variable. Series 1 1944/45-1986/8. Without labour
Best estimations of all shown in the appendix

YRS LAG	PUB-RES	LAB-OUR	LAND1	MACH &ANIM	BOUGH INPUTS	YIELD INDEX	ADVC	DW	R-sq	*SUM bnw*
6 variables										
14	0,033	-----	0,672	0,387	0,131	0,243	-----		99,3	
t-v	0,7		3,5	2,9	3,5	3,1		0,,9		*1,2*
16	0,062	-----	1,050	0,226	0,028	0,310	-----		99,5	
t-v	1,5		5,5	1,9	0,7	4,7		1,2		*1,4*
18	0,037	-----	1,290	0,267	-0,100	0,234	-----		99,7	
t-v	1,1		7,9	2,9	-2,4	4,3		1,6		*1,5*
7 variables										
12	0,088	-----	0,675	0,575	-0,109	0,172	0,196		99,5	
t-v	1,8		4,4	5,5	-1,5	2,5	4,1	1,4		1,4
14	0,081	-----	0,695	0,543	-0,084	0,181	0,184		99,5	
t-v	1,8		4,1	4,4	-1,2	2,6	3,5	1,4		1,4
16	0,069	-----	0,979	0,336	-0,039	0,278	0,081		99,5	
t-v	1,7		5,0	2,3	-0,6	4,0	1,3	1,4		1,4
18	0,035	-----	1,310	0,255	-0,093	0,236	-0,011		99,7	
t-v	1,0		7,2	2,2	-1,6	4,2	-0,2	1,6		1,5

The equations in this table show acceptable t-statistics and good Durbin-Watson test values. The high R-square values indicate that there probably exist common trends in the material. The sums of elasticity coefficients are, however, too high to be accepted as good estimations of Cobb-Douglas production functions. Even with these shortcomings in quality of the estimations for the total production functions **the elasticities of production related to public research show promising values with reasonable stability of between 0.06-0,09** over the **lags of 14-18 years**. The corresponding elasticities related to advisory services are not very stable.

These results have led to further experiments.

6. Experiment 13. Efforts to overcome common trends and correlations in the material.

The model

In this experiment a model is used, which differs from the earlier experiments on two points. **First** it is built up of differences from year to year of all inputs relevant in a model and the resulting difference in output. The reason for this is that, in time series, yearly differences in inputs and outputs are usually less correlated than are yearly inputs and outputs. **Second** the research input is the floating sum of five consecutive years change in research funding and its effect on the production of one future year. This approach induces a research input with possible larger differences in inputs over the years than when only research effects of one year are used as in our earlier estimations. It also decreases the serial correlation effects from this variable, as our studies show that the most important serial correlations occur between the first three to four years in these time series. The alternative to base the estimations of production elasticities on the series of yearly differences in inputs of the independent variables is explained for example by Maddala (1977, p 192):

$$y_t = \alpha + \beta_1 x_{1t} + \beta_2 x_{2t} + u_t$$

Changing t to t-1, we get

$$y_{t-1} = \alpha + \beta_1 x_{1,t-1} + \beta_2 x_{2,t-1} + u_{t-1}$$

By subtraction we get

$$\Delta y_t = \beta_1 \Delta x_{1t} + \beta_2 \Delta x_{2t} + \Delta u_t$$

We will introduce this technique of working with differences when estimating the elasticities, here named β, in our time series analysis. This is made even with the relatively small risk that other statistical problems - with heteroscedasticity - may threaten the estimations (Maddala pp 193, 259-260). This is so because we are more interested in approximate estimates of the elasticities than estimates of the variance of these elasticities.

The data material we use is constructed in the following way

1. The available material is expressed as yearly output y_t and inputs x_t per farm for the farm variables and as total yearly effects to the sector for yield index and advice and as research inputs with anticipated effects this year.

2.The differences Δy and Δx are calculated as differences in logarithms of the variables based on the assumption that

$$\frac{y_t - y_{t-1}}{y_{t-1}} \approx \Delta \log y_t$$

which is valid under the assumption that Δy_t is small in relation to y_t. This is true for our variables.

3. In this experiment 13 the available material is arranged as follows

- Research inputs with anticipated effects a specific year is a moving and weighted sum of five years logarithm differences, The effects of following weighted sums are estimated. The five years are indicated a,b,c,d,e:

  Exp 13-1 0,2a+0,2b+0,2c+0,2d+0,2e
  13-2 0,1a+0,2b+0,4c+0,2d+0,1e
  13-3 0,15a+0,2b+0,3c+0,2d+0,15e
  13-4 0,1a+0,25b+0,3c+0,25d+0,1e
  13-5 0,05a+0,25b+0,4c+0,25d+0,05e

  The five years are summarized to the fifth of the five years, year e. This is also the year to which the lag periods are related.
- the logarithms of output and all inputs but research are calculated for each year as well as the differences of logarithm values between years.

Research inputs with anticipated effects a specific year are in each experiment a floating sum of logarithms differences in research inputs (*t-l*) years earlier expressed in 1985/86 years value. The estimations of research effects are given for the alternative lagged periods for research of *l* years earlier.

It is important to remember that the estimation of a specific situation where say an 18 years research lag, (*t-18*) is tested on a data material covering n years containing n observations of years where - for each year - the output per farm is related to a set of yearly inputs of which the research input is the 18 years earlier occurred five years added change of research inputs, as indicated above.

The estimations

The whole material 1931/32-1986/87 is used as inputs for each one of the lag alternatives. In each of the experiments a dummy variable is introduced, a 1 for the first subset of data, 1945/46-1965/66, and a 0 for the second, 1966/67-1986/87. The aim has been to investigate if the y-intercept of the regression line differs between the two subsets. As is seen from the tables the difference between the intercepts is not significant for the estimations.

Here the analysis can concentrate on the differences in the observed individual elasticities for the whole period.
The experiment results are shown in appendix table 2 for all lag lengths. The estimations show higher R-squares than in two earlier experiments where floating average of research inputs were summarized over three and four years.

The low R-square values (60-70) is probably an effect of the removal of a common trend component in the time series used as compared to the model used in experiments 2. The equations show acceptable t-statistics for the bulk of the farm level variables and good Durbin-Watson test values for all equations. However, A disturbing and unexplained feature is the negative sign of the elasticity related to investment in machinery and animals.

The estimations for all lag periods of experiments 13-2 and 13-3 are given in Appendix 2. The t-statistics never reaches the required 1.6 but show best values of 0,5 to 0,9 for lag periods of 16-18 years. Estimations with lags lower than 14 and over 18 years show negative or zero effects of research on total production per farm.
The **Table on next page** summarizes estimations for six variables at lags 14,16 and 18 for experiments13-2 and 13-3. Experiments 13-3 and 13-4 give results which can well be represented by 13-2 and 13-3. **Estimations with 16to18 years lag give elasticities of production related to research of b= 0,07 to 0,12.** They give the best quality with R-squares at 72 per cent and sums of elasticities b = 1.3. The t-statistics never reaches the required 1.6 but show best values of 0,5 to 0,9 for lag periods of 16-18 years.

Corresponding elasticities related to advisory services approach zero.

In our material there still remains important correlations between some of the explanatory variables even as expressed by differences between two consecutive years. In an effort to study the effects of decreasing these correlations Ridge Regression is applied. Results are also given in the table on page 21. The ridge parameter is kept at 0,4 where the main effects of the correlations are counteracted. The table shows that the R-squares and the elasticities related to research decrease and the sum of elasticities b improves to 1,2. The negative elasticities related to machinery and animals changes to the more expected positive.

A fair summary of these four experiments are that the elasticity of production related to Swedish agricultural research during the time period 1944/45-1986/87 lies somewhere between 0.07 and 0.12.

Estimations for six variables at lags 14,16 and 18 for experim:s13-2 and 13-3

	PUBRES	LABOUR	LAND	MACHIN ANIM	BOUGHT INPUTS	YIELD	R-sq	DW	Sum Bnw
Exp 13-2 6 variables									
LAG 14									
OLS	0,064	0,237	1,180	-0,006	0,117	0,278	66,2	2,5	1,6
RR	0,020	0,228	0,817	0,142	0,041	0,185	50,5	2,5	1,3
LAG 16									
OLS	0,127	0,318	1,110	-0,024	0,219	0,289	68,0	2,5	1,8
RR	0,070	0,252	0,805	0,141	0,083	0,190	51,0	2,5	1,4
LAG 18									
OLS	**0,071**	**0,149**	**0,765**	**-0,041**	**0,312**	**0,386**	**71,8**	**2,4**	**1,3**
RR	0,039	0,198	0,714	0,133	0,111	0,209	53,3	2,5	1,2
Exp 13-3 6 variables									
LAG 14									
OLS	0,095	0,251	1,190	-0,007	0,114	0,276	66,4	2,5	1,6
RR	0,049	0,234	0,825	0,140	0,039	0,185	50,6	2,5	1,3
LAG 16									
OLS	0,125	0,308	1,100	-0,026	0,209	0,293	67,7	2,5	1,7
RR	0,052	0,242	0,797	0,142	0,082	0,191	50,8	2,5	1,3
LAG 18									
OLS	**0,118**	**0,161**	**0,728**	**-0,041**	**0,317**	**0,336**	**72,2**	**2,4**	**1,3**
RR	0,075	0,203	0,692	0,133	0,113	0,209	53,6	2,5	1,2

For the total data material over all forty years the estimated elasticities for the farm and weather specific inputs are surprisingly stable over the various lag periods. This is a positive sign of stability in the basic material as we also know that over the estimations there always exists a variation in the number of years analysed. This variation in number of years is due to the fact that available number of years with data on research inputs - allowed to move through the rest of the material - is smaller than the data material of all the other variables.

The estimations of **elasticities of production related to public research** for the total time period 1944/45-1986/87 in experiment 2 where yearly differences are studied show elasticities between **0,06 and 0,09** with acceptable t-values. Experiments 13 indicate best elasticities of **0,07 to 0,12**. The t-statistics never reaches the required 1.6 but show best values of 0,5 to 0,9 for lag periods of 16 and18 years. **These elasticities**

are reached at a lag of 18 years. The five years floating average means a weighted average of research inputs for the years with 14 to 18 years lag. The lag years 15 to17 carries 70-80 per cent of the weights. This is the time span that we – in this experiment – have observed that the major effects of public research on total agricultural production is shown.

The estimations of production elasticities related to advice are too unstable for us to make any guesses of the general effect of this variable at this point.

Experiment 13-2. Elasticities of production from inputs based on differences in logged values for two consecutive years. 1945/46-1986/87 EFFECTS OF 5 YEARS FLOATING SUMS OF DIFF:S IN RESEARCH INPUTS ON PRODUCTION/FARM AND FARM INPUTS ALL AS SINGLE YEARS

Exp 13-2	PUBRES as 5 yrs floating val. 0,1a+0,2b+0,4c+0,2d+0,1e sum to e										
YRS LAG	PUB RES	LABR	LAND1	MACH ANIM	BOUG INPU	YIELD	ADV	DUM MY	R-sq	DW	Sum bnw
6 variables											
14	0,064	0,237	1,180	-0,006	0,117	0,278	---	-0,002			
tv	0,5	0,7	2,6	0,0	0,8	5,1		-0,3	66,2	2,5	1,6
16	0,127	0,318	1,110	-0,024	0,219	0,289	---	-0,002			
tv	0,9	0,9	2,3	-0,1	1,4	5,2		-0,2	68,0	2,5	1,8
18	**0,071**	**0,149**	**0,765**	**-0,041**	**0,312**	**0,336**	**---**	**-0,004**			
tv	**0,5**	**0,5**	**1,5**	**-0,2**	**1,9**	**5,8**		**-0,7**	**71,8**	**2,4**	**1,3**
7 variables											
14	0,069	0,208	1,230	-0,003	0,118	0,281	-0,035	-0,002			
tv	0,5	0,6	2,6	0,0	0,8	5,0	-0,5	-0,2	66,4	2,5	1,6
16	0,122	0,293	1,120	-0,019	0,219	0,291	-0,019	-0,002			
tv	0,9	0,8	2,3	-0,1	1,3	5,1	-0,2	-0,2	68,2	2,5	1,7
18	**0,071**	**0,135**	**0,792**	**-0,038**	**0,310**	**0,336**	**-0,019**	**-0,004**			
tv	**0,5**	**0,4**	**1,5**	**-0,2**	**1,9**	**5,7**	**-0,2**	**-0,6**	**71,9**	**2,4**	**1,3**

Experiment 13-3. Elasticities of production from inputs based on differences in logged values for two consecutive years. 1945/46-1986/87 EFFECTS OF 5 YEARS FLOATING SUMS OF DIFF:S IN RESEARCH INPUTS ON PRODUCTION/FARM AND FARM INPUTS ALL AS SINGLE YEARS

Exp 13-3	PUBRES as 5 yrs floating val. 0,15a+0,2b+0,3c+0,2d+0,15e sum to e										
YRS LAG	PUB- RES	LABR	LAND	MACH ANIM	BOUH INPUT	YIELD Index	ADV	DUM MY	R-sq	DW	SUM Bnw
6 variables											
14	0,095	0,251	1,190	-0,007	0,114	0,276	---	-0,002			
tv	0,7	0,8	2,6	0,0	0,8	5,0		-0,2	66,4	2,5	1,6
16	0,125	0,308	1,100	-0,026	0,219	0,298	---	-0,002			
tv	0,8	0,9	2,3	-0,1	1,4	5,2		-0,3	67,7	2,5	1,7
18	**0,118**	**0,161**	**0,728**	**-0,041**	**0,317**	**0,336**	**---**	**-0,004**			
tv	**0,8**	**0,5**	**1,5**	**-0,2**	**2,0**	**5,9**		**-0,6**	**72,2**	**2,4**	**1,3**
7 variables											
14	0,098	0,222	1,240	-0,004	0,115	0,278	-0,034	-0,001			
tv	0,7	0,7	2,6	0,0	0,8	5,0	-0,5	-0,2	66,3	2,5	1,7
16	0,120	0,279	1,110	-0,020	0,218	0,295	-0,023	-0,002			
tv	0,8	0,8	2,2	-0,1	1,3	5,2	-0,3	-0,2	67,8	2,5	1,7
18	**0,118**	**0,149**	**0,754**	**-0,038**	**0,315**	**0,336**	**-0,017**	**-0,004**			
tv	**0,7**	**0,4**	**1,5**	**-0,2**	**1,9**	**5,7**	**-0,2**	**-0,5**	**72,2**	**2,4**	**1,1**

7. MVP and IRR to public research based on Experiments 2, 8 and 12

A: Estimations of Marginal value products, MVP

Taking into account the above given quality discussion, I propose that these estimations will be based on the cautious conclusion that **the elasticities of total production per farm related to inputs of public research according to this study tentatively may be set to 0,06-0,10 in Swedish agriculture during the forty years 1945-1985.** The division of the material in two parts give elasticities that are too uncertain to base a general conclusion on.

From page 6 in the earlier report we have the following relations.
The marginal value product per farm, mvp, of a variable *i* in the Cobb-Douglas production function $y = aX^b$ is

$$mvp_i = dy/dx_i = b_i a x_i^{b_i - 1} = b_i y/x_i$$

The total marginal value product, $MVP_i = n \times mvp_i$, of total public research thus is:

$$mvp_1 = dy/dx_1 = b_1 a x_1^{b_1 - 1} = b_1 y/x_1$$

Since $y = Y/n$, the total marginal value product is

$$MVP_1 = n \times mvp_1 = nb_1 y/x_1$$

If there exists a lag of say *l* years between the research inputs should be measured earlier, we have to add a time index t = output year and $l = 0,1,2,...$ = time lag . Then we can rewrite the *MVP* formula above:

$$mvp_{1l} = dy_l / dx_{1l-t} = b_{1l} y$$

$$mvp_{1l} = dy_l / dx_{1l-1} = b_{1l} a x_{1l-1}^{b_{1l-1}} = b_{1l} y_l / x_{1l-1} \text{ and}$$

$$MVP_{1l} = n \times b_{1l} y_l / x_{1l-1}$$

Thus the contribution of public research can be calculated by relating the production of the agricultural sector to the input of public research a number of years earlier in the following way.

Elasticities of production related to research for the lag periods of 18 years of 0,06 - 0,10 for the whole period 1944/45-1986/87.

Average of $^{10}\log$(production/farm) for the whole period is 5,01=
= 102.300 kr/farm.
Year 1966/67 gave
91.716 kr production/farm and total production of 17.756 MSEK.
Year 1967/68 gave
110.569 kr production/farm and total production of 19.947 MSEK.
Year 1968/69 gave
119.195 kr production/farm and total production of 20.359 MSEK.

The average of 102.300 SEK production/farm equals a total production of 18.983 MSEK or approx. 19.000 MSEK. for the years 1966/67-1968/69.
For 14-18 earlier years 1949/50-1953/54 with
experiment 13-2 weights give research inputs of 158 SEK
experiment 13-3 weights give research inputs of 160 MSEK
an approx. estimation of MVP

for b = 0,06 is 0,06*19000/158 = 7,2
and 0,06*19000/160 = 7,1
for b = 0,10 is 0,10*19000/158 = 12,0
and 0,10*19000/160 = 11,9

This means that 1 MSEK increase of total public research gave an approximate increase of total Swedish agricultural production of around 7-12 MSEK 14-18 years later.

B. The internal rate of return - IRR - to public research in Swedish agriculture based on Experiments 2 and 13.

The calculations above give an internal rate of return of
13-17 per cent over price level change during the total period studied.

C. MVP and IRR at world market prices based on Experiments 2 and 13.

The approximations above are made on the assumption that the value of total agricultural production is measured in national Swedish producer prices. As such the estimated internal rates of return are those realized by the Swedish farmers at their farm gates.

The national Swedish producer prices include a support to the farmers via a national agricultural policy. A better approach to estimations of internal rates of returns of research is to find methods to estimate the macroeconomic value of the total Swedish agricultural production. This is a value lower than the value at national producer prices, and difficult to determine empirically. In theory we are looking for the value of the total production measured at the economic shadow prices of the factors used in the production. An alternative we are groping for is the total value of this production sold on a world market, the character and size of which it is difficult to visualise. With this background I am looking for some competent guesses on how many per cent reduction of the value in national prices of the total Swedish agricultural production is necessary to reach a probable world market price level. The approximation may well be indicated as a possible price span.

To get the necessary information I have turned to knowledgeable sources within the agricultural economics academic world in Sweden. Here Olof Bolin, retired professor of the Economy of the agricultural sector and international trade at the SLU has been my advicer. He is also a co-author of a book on the political economy of the food sector in Sweden (Bolin, Meyerson, Ståhl, 1984). He bases his recommendations on the findings published in this book.

After discussions with Bolin and consultations with knowledgeable persons in the Swedish Board of Agriculture - Statens Jordbruksverk - I am proposing a per cent span with which to reduce the total production value of Swedish agriculture to approximate the level within which its world market value lies. I have used a reduction of total agricultural production measured in national Swedish producer prices with 30-50 per cent to approximate the limits within which this estimated world market value lies. The calculations are shown in the table below.

D. Calculation of MVP and IRR at approximate world market prices at a production elasticity related to public research of 0,06-0,09.

Average values of total Swedish agricultural production at

national prices 1944/45 -1986/87		100 %	70%	50%
Production value pr year				
at middle of the period	MSEK	19000	13.300	9.500
	MVP	7-12	5-8	4-6
	IRR %	13-17	11-14	10-12

The table shows that MVP and IRR of national public research reach profitable values even when total agricultural production value is calculated at approximate world market prices. IRR is calculated over price level changes.

8. Final observations and conclusions

All resulting figures show a considerable uncertainty. This is not due to the data material used, which is of good quality. Part of the uncertainty results from the drastic simplification in a Cobb-Douglas production function of the complex relations between factors which explain the total production of agriculture. Uncertainties are also shown in the quality of the econometric analysis, in the lag structure used, and in the choice of techniques to overcome the effects of existing common trends and autocorrelations in the time series.

A simple way to indicate this uncertainty is to give areas within which the resulting Production Elasticities related to public research, Marginal Value Products, MVP:s, and Internal Rates of Return, IRR, may be found. When specifying these areas results of all estimation experiments are used. This means that I am assuming that the majority of these experiments with various techniques include some valuable information of the relationship searched for, even if the individual approach can be criticized for various reasons.

The conclusions of this study of research effects in Swedish agriculture during the time period 1944/45 to 1986/87 are that

- Production elasticities related to public research is 0,04-0,13 centering around 0,06 to 0,10 with best statistical quality.
- Most probable lag period varies between 16 and 20 years centering around 18 years with best statistical quality. This means best effects of public research after a period of 16-18 years. Resulting MVP is 7-12
- Resulting IRR is 13-17 per cent over price level change.

Even when total agricultural production is calculated at approximate world market values public research reach profitable values, for IRR only three to four index units lower. A practical way to summarize these results is:

Swedish public agricultural research contributed during the period 1944/45 – 1986/87 for each additional 1 million SEK research costs an increase of total agricultural production value of 7-12 millions SEK some 16-18 years later. This means that research costs during the period gave an interest rate of 13-17 per cent a year over price level change.

Irrespective of how we vary the estimations of the production elasticities based on these data series the majority of our experiments show a surprising stability around these results.

The estimations of production elasticities related to advice are too unstable for us to make any guesses of the general effect of this variable at this point.

9. Future research

It is important to point out that future research in this area probably would gain very much from introduction of another type of research efforts than the continuation of econometric studies of research for countries or sectors. It is time for down to earth empirical case studies of different R&D chains of realized and observed lags, of research inputs and "resulting innovations or increments to knowledge" and their effects in realized production for single projects and groups of projects. This is a necessary complement to statistical studies of large entities as countries and sectors. The aim would be to develop hypotheses and more efficient models for later studies of the macro relations.

References

Alston, J.M., Chan-Kang, C., Marra, M.C., Pardey, P.G., Wyatt, T.J., 2000. A Meta-Analysis of Rates of Return to Agricultural R&D. International Food Policy Research Institute. Washington, DC.

Alston, J.M. and Pardey, P.G., 2001. Attribution and other problems in assessing the returns to agricultural R&D. Agr. Econ. 25, 141-152.

Anderson, Å., 1997. Staten och jordbruket - en studie med utgångspunkt i rationaliseringspolitiken för jordbruket i Sverige, dess födelse, uppgång och fall åren 1940-1990. Dept of Economics Report, 112. Swedish University or Agricultural Sciences.

Bolin, O., Meyerson, P-M., Stål, I., 1984. Makten över maten. SNS.

Chavas, J-P., and Cox, T.L., 1992. A Nonparametric Analysis of the influence of Research on Agricultural Productivity. Amer. J. Agr. Econ. 74, 583-591.

Davis, J., 1981. A Comparison of Procedures for Estimating Returns to Research using Production Functions. Australian J. Agr. Econ. 25, 60-72.

Evenson, R.E., 1967. The contribution of Agricultural Research to Production. Am. J. farm econ. 49, 1415-1425.

Evenson, R.E., 2001. Economic Impacts of Agricultural Research and Extension. In: Gardner, B.L., and Rausser, G., eds. Handbook of Agricultural Economics Vol 1A, 574-628. North-Holland, New York.

Griliches, Z., 1964. Research Expenditures, Ewducation and the Aggregate Agricultural Production Function. Amer. Econ. Rev.

Hayami, Y. and Ruttan, V.W., 1971. Agricultural Development. An International Perspective. Johns Hopkins, Baltimore.

Huffman, W.E. and Evenson, R.E., 2006. Do formula or competitive grant funds have greater impacts on state agricultural productivity? Amer. J. Agr. Econ. 88(4), 783-798.

Heady, E.O. and Dillon, J.L., 1961. Agricultural Production Functions. Iowa State University Press, Ames Iowa.
Hjelm, L., 1977. Från kungsladugård till lantbruksuniversitet. Sveriges Lantbruksuniversitet.
Holmberg, M., 1988. Företagens FoU-arbete inom primärproduktionen i svenskt jordbruk. Ex.arbete nr 9. Inst.för ekonomi. Sveriges Lantbruksuniversitet
Huffman, W.E. and Evenson, R.E., 1992. Contributions of of public and private science and technology to US agricultural productivity. Amer. J. Agr. Econ. 74, 752-756.
Maddala, G.S., 1977. Econometrics. McGraw-Hill.
Maddala, G.S., 1992. Introduction to Econometrics. Macmillan.
Pardey, P.G. and Craig, B., 1989. Causal Relationships between Public Sector Agricultural Research Expenditures and Output. Amer. J. Agr. Econ. Febr.1989, 9-19.
Renborg, U., 1989. The possibilities to estimate efficiency of agricultural research - Examples Finland and Sweden. In: Neuere Forschungskonzepte und methoden in den Wirtschafts- und Sozialwissenschaften des Landbaues. Landwirtschaftsverlag GmbH, Münster-Hiltrup.
Renborg, U., 1989. Jordbruksforskningen 1945-1985 - lönsamhet och förändrad inriktning. Några preliminära resultat. Småskriftsserien nr 24, Institutionen för ekonomi. Sveriges Lantbruksuniversitet.
Renborg, U.,1992. Jordbruksforskningen 1945-1986 - index för deflatering av FoU-insatser. Småskriftsserien nr 63. Institutionen för ekonomi. Sveriges lasntbruksuniversitet
Renborg, U., Croon, I., 1993. Jordbruksforskningen 1945-1987. Den offentliga forskningens omfattning och utveckling 1944/45-1986/87. Småskriftsserien nr 74. Institutionen för ekonomi. Sveriges Lantbruksuniversitet
Rosenberg, N., 1982. Inside the Black Box: Technology and Economics. Cambridge Univ. Press, Cambridge.
Schultz, T.W., 1953. The economic Organization of Agriculture. McGraw-Hill New York.
Sumelius, J., 1987. The returns to investment in agricultural research in Finland 1950-1984. In: Journal of Agricultural Science in Finland Vol 59, 251-354. Helsinki.
Wright, G.H.v., 1986. Vetenskapen och förnuftet. Borgå.

Appendix 1a Table Exp 2 With Labour.
OLS LAND1 replacing land&buildings as indep.variables
Original Yield variable. Series 1:(1931-32)-1944/45-1986/8

Year Lags	PUBRES	LABOUR	LAND1	MACH ANIM	BOUGH INPUTS	YIELD INDEX	ADVICE	R-sq	DW	SUM *bnw*
6 varbl										
6	-0,170	0,345	0,878	0,193	0,490	0,233	-----	99,7		
t-v	-3,9	2,2	5,8	1,7	6,0	3,9			1,6	1,7
12	-0,015	0,537	0,643	0,281	0,427	0,227	-----	99,5		
t-v	-0,3	2,9	3,9	2,1	4,3	3,1			1,1	1,9
14	**0,049**	**0,540**	**0,772**	**0,152**	**0,391**	**0,216**	**-----**	**99,5**		
t-v	**1,0**	**3,0**	**4,4**	**1,1**	**4,3**	**3,0**			**1,1**	**1,9**
16	**0,087**	**0,512**	**1,100**	**0,007**	**0,265**	**0,287**	**-----**	**99,7**		
t-v	**2,3**	**3,4**	**6,7**	**0,1**	**3,4**	**5,0**			**1,4**	**2,0**
18	**0,080**	**0,344**	**1,230**	**0,095**	**0,116**	**0,245**	**-----**	**99,8**		
t-v	**2,1**	**2,0**	**7,6**	**0,8**	**1,0**	**4,7**			**1,6**	**1,9**
20	-0,003	0,143	1,270	0,268	-0,005	0,226	-----	99,7		
t-v	-0,1	0,8	5,6	2,1	-0,0	3,7			1,5	1,7
22	-0,041	0,117	1,180	0,318	0,039	0,227	-----	99,7		
t-v	-0,7	0,7	3,8	2,9	0,4	4,1			1,8	1,7
24	-0,042	0,152	1,030	0,345	0,105	0,225	-----	99,7		
t-v	0,8	0,7	4,0	3,0	1,0	4,0			1,7	1,6

Appendix 1a continued

Year Lags	PUBRES	LABOUR	LAND1	MACH ANIM	BOUGH INPUTS	YIELD INDEX	ADVICE	R-sq	DW	*SUM bnw*
7 varbl										
6	-0,136	0,320	0,912	0,311	0,322	0,215	0,100	99,2		
t-v	-0,2	2,1	6,4	2,7	3,1	3,8	2,5		1,6	1,8
12	**0,061**	**0,378**	**0,737**	**0,417**	**0,119**	**0,173**	**0,168**	**99,6**		
t-v	**1,3**	**2,3**	**5,0**	**3,4**	**1,0**	**2,6**	**3,5**		**1,4**	**1,9**
14	**0,089**	**0,458**	**0,777**	**0,325**	**0,182**	**0,166**	**0,162**	**99,6**		
t-v	**2,1**	**2,9**	**5,0**	**2,4**	**1,5**	**2,6**	**3,3**		**1,5**	**2,0**
16	**0,091**	**0,494**	**1,040**	**0,100**	**0,224**	**0,263**	**0,062**	**99,7**		
t-v	**2,5**	**3,3**	**6,0**	**0,7**	**2,3**	**4,3**	**1,2**		**1,5**	**2,0**
18	**0,087**	**0,366**	**1,190**	**0,112**	**0,114**	**0,242**	**0,024**	**99,8**		
t-v	**2,0**	**2,0**	**6,6**	**0,9**	**1,0**	**4,5**	**0,4**		**1,7**	**1,9**
20	-0,010	0,123	1,320	0,233	0,005	0,230	-0,036	99,7		
t-v	-0,2	0,6	5,4	1,7	0,0	3,7	-0,6		1,5	1,7
22	-0,062	0,130	1,320	0,247	0,053	0,233	-0,050	99,7		
t-v	-0,9	0,7	3,7	1,7	0,5	4,2	-0,8		1,8	1,6
24	-0,065	0,174	1,170	0,232	0,162	0,238	-0,084	99,7		
t-v	-1,2	0,8	4,3	1,6	1,4	4,2	-1,3		1,8	1,7

Appendix 1b Table Exp 2 . Without Labour
OLS LAND1 replacing land&buildings as indep.variables
Original Yield variable Series 1:(1931-32)-1944/45-1986/87

Year Lags	PUBRES	LABOUR	LAND1	MACH ANIM	BOUGH INPUTS	YIELD INDEX	ADVICE	R-sq	DW	SUM *bnw*
6 varbl										
6	-0,196	-----	0,850	0,315	0,341	0,247	-----	99,4		
t-v	-4,5		5,4	3,1	7,0	3,4			1,3	1,3
12	0,006	-----	0,524	0,487	0,157	0,240	-----	99,3		
t-v	0,1		3,0	4,0	4,1	3,0			0,9	1,2
14	**0,033**	**----**	**0,672**	**0,387**	**0,131**	**0,243**	**----**	**99,3**		
t-v	**0,7**		**3,5**	**2,9**	**3,5**	**3,1**			**0,9**	**1,2**
16	**0,062**	**----**	**1,050**	**0,226**	**0,028**	**0,310**	**----**	**99,5**		
t-v	**1,5**		**5,5**	**1,9**	**0,7**	**4,7**			**1,2**	**1,4**
18	**0,037**	**----**	**1,290**	**0,267**	**-0,100**	**0,234**	**----**	**99,7**		
t-v	**1,1**		**7,9**	**2,9**	**-2,4**	**4,3**			**1,6**	**1,5**
20	-0,017	-----	1,300	0,332	-0,091	0,217	-----	99,6		
t-v	-0,4		5,8	3,6	-1,5	3,6			1,6	1,5
22	-0,028	-----	1,110	0,366	-0,004	0,229	-----	99,7		
t-v	-0,5		3,9	4,2	-0,0	4,3			1,8	1,4
24	-0,019	-----	0,457	0,386	0,055	0,218	-----	99,7		
t-v	-0,5		4,2	3,9	0,7	4,0			1,8	1,4

Appendix 1b continued

Year Lags	PUBRES	LABOUR	LAND1	MACH ANIM	BOUGH INPUTS	YIELD INDEX	ADVICE	R-sq	DW	*SUM bnw*
7 varbl										
6	-0,157	-----	0,890	0,429	0,176	0,226	0,108	99,6		
t-v	-3,6		6,0	4,1	2,2	3,8	2,6		1,4	1,4
12	**0,088**	**----**	**0,675**	**0,575**	**-0,109**	**0,172**	**0,196**	**99,5**		
t-v	**1,8**		**4,4**	**5,5**	**-1,5**	**2,5**	**4,1**		**1,4**	**1,4**
14	**0,081**	**----**	**0,695**	**0,543**	**-0,084**	**0,181**	**0,184**	**99,5**		
t-v	**1,8**		**4,1**	**4,4**	**-1,2**	**2,6**	**3,5**		**1,4**	**1,4**
16	**0,069**	**----**	**0,979**	**0,336**	**-0,039**	**0,278**	**0,081**	**99,5**		
t-v	**1,7**		**5,0**	**2,3**	**-0,6**	**4,0**	**1,3**		**1,4**	**1,4**
18	**0,035**	**----**	**1,310**	**0,255**	**-0,093**	**0,236**	**-0,011**	**99,7**		
t-v	**1,0**		**7,2**	**2,2**	**-1,6**	**4,2**	**-0,2**		**1,6**	**1,5**
20	-0,023	-----	1,350	0,279	-0,064	0,224	-0,043	**99,6**		
t -v	-0,5		5,7	2,3	-0,9	3,6	-0,7		1,5	1,5
22	-0,045	-----	1,230	0,307	0,005	0,235	-0,046	99,7		
t-v	-0,7		3,7	2,6	0,1	4,3	-0,8		1,8	1,5
24	-0,038	-----	1,080	0,285	0,102	0,230	-0,079	99,7		
t-v	-0,9		4,3	2,2	1,1	4,1	-1,2		1,8	1,4

Appendix 2a Experiment 13-2.
Elasticities of production from inputs based on differences in logged values for two consecutive years.
Period 1945/46-1986/87 Effects of 5 years moving sums of research inputs

Exp 13-2	PUBRES as 5 yrs floating val. 0,1a+0,2b+0,4c+0,2d+0,1e sum to e										
YERS LAG	PUBR	LABR	LAND1	MACH ANIM	BOUGH INPUTS	YIELD Index	ADV	DMM	Rsq	DW	SUM Bnw
6 variables											
6	-0,063	0,177	0,725	0,072	0,201	0,261	---	-0,001			
tv	-0,5	0,5	1,6	0,5	1,6	4,9		-0,1	56,8	2,3	1,1
12	0,009	0,340	0,939	-0,120	0,275	0,303	---	-0,003			
tv	0,1	1	2,1	-0,7	2,2	5,9		-0,5	64,2	2,4	1,4
14	0,064	0,237	1,180	-0,006	0,117	0,278	---	-0,002			
tv	0,5	0,7	2,6	0,0	0,8	5,1		-0,3	66,2	2,5	1,6
16	0,127	0,318	1,110	-0,024	0,219	0,289	---	-0,002			
tv	0,9	0,9	2,3	-0,1	1,4	5,2		-0,2	68,0	2,5	1,8
18	**0,071**	**0,149**	**0,765**	**-0,041**	**0,312**	**0,336**	**---**	**-0,004**			
tv	**0,5**	**0,5**	**1,5**	**-0,2**	**1,9**	**5,8**		**-0,7**	**71,8**	**2,4**	**1,3**
20	-0,030	0,027	0,620	0,026	0,387	0,337	---	-0,007			
tv	-0,2	0,1	0,9	0,1	2,0	5,6		-1,0	68,4	2,4	1,0
22	-0,245	0,410	0,770	-0,194	0,565	0,340	---	-0,011			
tv	-1,6	1,0	1,4	-0,8	2,6	5,8		-1,5	72,8	2,6	1,3
24	-0,010	0,096	0,637	0,034	0,400	0,324	---	-0,006			
tv	0,0	0,2	1,0	0,1	1,3	4,9		-0,7	69,4	2,4	1,2
7 variables											
6	-0,049	0,197	0,707	0,112	0,179	0,297	0,057	-0,002			
tv	-0,4	0,6	1,5	0,7	1,4	4,6	1,2	-0,3	58,5	2,5	1,2
12	0,011	0,341	0,927	-0,106	0,268	0,298	0,011	-0,003			
tv	0,1	1,0	2,0	-0,6	2,0	5,3	0,2	-0,5	64,3	2,4	1,5
14	0,069	0,208	1,230	-0,003	0,118	0,281	-0,035	-0,002			
tv	0,5	0,6	2,6	0,0	0,8	5,0	-0,5	-0,2	66,4	2,5	1,6
16	0,122	0,293	1,120	-0,019	0,219	0,291	-0,019	-0,002			
tv	0,9	0,8	2,3	-0,1	1,3	5,1	-0,2	-0,2	68,2	2,5	1,7
18	**0,071**	**0,135**	**0,792**	**-0,038**	**0,310**	**0,336**	**-0,019**	**-0,004**			
tv	**0,5**	**0,4**	**1,5**	**-0,2**	**1,9**	**5,7**	**-0,2**	**-0,6**	**71,9**	**2,4**	**1,3**
20	-0,028	0,005	0,629	0,031	0,388	0,327	-0,020	-0,006			
tv	-0,1	0,0	0,9	0,1	2,0	5,5	0,0	-0,9	68,5	2,4	1,0
22	-0,249	0,406	0,775	-0,194	0,565	0,340	-0,004	-0,011			
tv	-1,5	0,9	1,3	-0,7	2,5	5,7	-0,1	-1,5	72,8	2,6	1,3
24	-0,006	0,093	0,626	0,043	0,388	0,334	0,011	-0,006			
tv	0,0	0,2	1,0	0,1	1,1	4,7	0,1	-0,7	69,4	2,4	1,2

Appendix 2b Experiment 13-3.
Elasticities of production from inputs based on differences in logged values for two consecutive years.
Per.1945/46-1986/87 Effects of 5 years moving sums of research inputs

Exp
13-3 PUBRES as 5 yrs floating val. 0,15a+0,2b+0,3c+0,2d+0,15e sum to e

YRS LAG	PUB RES	LAB OUR	LAND1	MACH ANIM	BOUG INPUT	YIELD Index	ADV	DMM	Rsq	DW	SUM Bnw
6 variables											
6	-0,097	0,176	0,766	0,075	0,200	0,259	---	0,000			
tv	-0,7	0,5	1,7	0,5	1,6	4,9		-0,1	57,1	2,3	1,1
12	0,017	0,335	0,937	-0,121	0,275	0,303	---	-0,003			
tv	0,1	1,0	2,1	-0,7	2,2	5,9		-0,5	64,2	2,4	1,4
14	0,095	0,251	1,190	-0,007	0,114	0,276	---	-0,002			
tv	0,7	0,8	2,6	0,0	0,8	5,0		-0,2	66,4	2,5	1,6
16	0,125	0,308	1,100	-0,026	0,219	0,298	---	-0,002			
tv	0,8	0,9	2,3	-0,1	1,4	5,2		-0,3	67,7	2,5	1,7
18	**0,118**	**0,161**	**0,728**	**-0,041**	**0,317**	**0,336**	**--**	**-0,004**			
tv	**0,8**	**0,5**	**1,5**	**-0,2**	**2,0**	**5,9**		**-0,6**	**72,2**	**2,4**	**1,3**
20	-0,144	0,080	0,860	-0,020	0,354	0,332	---	-0,008			
tv	-0,6	0,2	1,2	-0,1	1,8	5,5		-1,1	68,9	2,4	0,8
22	-0,272	0,468	0,825	-0,208	0,559	0,338	---	-0,010			
tv	-1,5	1,0	1,5	-0,8	2,5	5,8		-1,5	72,3	2,6	1,4
24	-0,010	0,093	0,636	0,034	0,400	0,324	---	-0,006			
tv	0,0	0,2	1,0	0,1	1,3	4,9		-0,7	69,4	2,4	1,2
7 variables											
6	-0,089	0,195	0,755	0,117	0,177	0,244	0,058	-0,001			
tv	-0,6	0,6	1,6	0,7	1,4	4,5	1,2	-0,2	58,9	2,5	1,2
12	0,019	0,336	0,925	-0,107	0,268	0,299	0,011	-0,003			
tv	0,1	1,0	2,0	-0,6	2,0	5,3	0,2	-0,5	64,3	2,4	1,5
14	0,098	0,222	1,240	-0,004	0,115	0,278	-0,034	-0,001			
tv	0,7	0,7	2,6	0,0	0,8	5,0	-0,5	-0,2	66,3	2,5	1,7
16	0,120	0,279	1,110	-0,020	0,218	0,295	-0,023	-0,002			
tv	0,8	0,8	2,2	-0,1	1,3	5,2	-0,3	-0,2	67,8	2,5	1,7
18	**0,118**	**0,149**	**0,754**	**-0,038**	**0,315**	**0,336**	**-0,017**	**-0,004**			
tv	**0,7**	**0,4**	**1,5**	**-0,2**	**1,9**	**5,7**	**-0,2**	**-0,5**	**72,2**	**2,4**	**1,1**
20	-0,139	0,065	0,864	-0,016	0,255	0,332	-0,013	-0,008			
tv	-0,6	0,2	1,1	-0,1	1,8	5,4	-0,1	-1,1	69,0	2,4	1,1
22	-0,271	0,465	0,828	-0,207	0,559	0,338	-0,002	-0,010			
tv	-1,4	1,0	1,4	-0,8	2,5	5,6	0,0	-1,4	72,3	2,6	1,4
24	-0,007	0,092	0,626	0,043	0,388	0,324	0,011	-0,006			
tv	0,0	0,2	1,0	0,1	1,1	4,8	0,1	-0,7	69,4	2,8	1,2

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