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THE FIRST GREEN REVOLUTION

The growth of production and productivity in European agriculture 1870-1914

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1.Introduction

The years after 1870 were a major turning point in the history of the agriculture of Western Europe. Until then, agricultural growth had almost taken a single course. As the population grew and land became scarcer, labour intensity of agricultural production was increased to raise the output per hectare. After 1750 this process of Boserup-like agricultural growth had been very much stimulated by rapidly rising cereal prices and an accelerating rate of population growth. ([1]) In large parts of Western Europe the classical two and three field rotation systems had given way to much more labour intensive modes of agricultural production, in which the fallow was replaced by legumes, potatoes and sugar beet. The increased supply of nitrogen resulted in large advances in agricultural productivity. (2)

The economic rationale of this agricultural revolution is clear; until about 1850 real wages of agricultural labourers, expressed in quantities of wheat or rye, showed a declining trend in most Western European countries. This trend was only interrupted by the agricultural depression of 1818-1835. Britain seems to be the major exception, the deepest 'trough' in the real wage level being in the Napoleonic Wars. (3) The rental value of agricultural land increased even more than cereal prices and this long term trend continued well into the third quarter of the nineteenth century. (4)

All this meant that farmers were strongly induced to increase production per hectare by using more wage labour and family labour. After 1870 this changed. The process of 'modern economic growth', which had begun in most countries of Western Europe in the first half of the nineteenth century and which accelerated after 1850, in the long run caused labour to become increasingly scarce. When the rise of cereal prices came to a halt in the 1870s and the agricultural depression set in, nominal wages continued to rise as an increasing share of the labour force left the countryside for the rapidly growing cities. Real wages of agricultural laborers in kilograms of wheat doubled in almost all European countries between 1870 and 1910; only in Russia did real wages increase much less, by about 25 percent between 1881/83 and 1910. (5)
The change in the price of land varied from country to country, from a sharp decline in Britain to a modest rise in Denmark, Germany and the Netherlands, but land prices in all cases increased much less than wage costs, which made the continuation of the course of agricultural growth followed before 1870 impossible. (6)

New ways had to be found to increase production and productivity in the agriculture of Western Europe. In an economy in which labour costs were rising rapidly, a gradual mechanization of the production process seemed to be the most obvious solution. As costly machines could only be purchased by rich farmers, and as the use of them would have strongly enlarged the economics of large-scale production, a rapid mechanization of the production process would have given large farmers important cost advantages over smaller ones. The outcome might have been an increased polarization of the structure of farm holdings, comparable to the trend in many branches of industry in this period; small-scale producers would have been forced to became wage workers and large-scale producers would have dominated the agriculture. The face of European agriculture would have changed radically.

In fact, as is well known, precisely the opposite happened. After 1870 the definite rise of the small family farm, which in some countries (France, Belgium) had already begun in the third quarter of the century, set in and large-scale farming, based on wage work, gradually disappeared from the agricultural scene in a large number of regions. (7)
As will be shown, in those countries which adapted best to the changing circumstances, the further intensification of agricultural production went together with a rapid growth of labour productivity. The innovations that were adopted by farmers in those countries, i.e. chemical fertilizers and purchased feed stuffs (maize and oilseed cakes), were typically land saving. (8) But these innovations proved to be extremely important for the growth of agricultural production by freeing it from its most important bottle-neck, the scarcity of land.

Beginning with an analysis of agricultural productivity in Europe in 1870, in this article I have tried to explain this first 'green revolution'; why did some countries fully participate in these changes and why did others, especially Britain, whose prospects seemed so good in the 1870's, remain behind?

The analysis is based on a detailed data base covering about 60 agricultural and economic variables for 16 countries. This data base and the method for estimating international differences in agricultural productivity are described first. Then follows a cross-section analysis of international differences in agricultural productivity in 1870. Finally an attempt has been made to explain productivity growth during the period 1870-1910.

2. The data-base and the method for comparing levels of agricultural productivity.

In the course of the nineteenth century, almost all European governments began the systematic collection of statistics on the inputs and the outputs of agriculture. About 1870, almost all governments published detailed figures on the area under cultivation, on the production of cereals and other arable crops, and on livestock. (9)
The exceptions were Britain, where statistics on cereal production were not collected until the eighties, some Balkan countries and Spain and Portugal. In fact, agriculture is probably the sector for which historical data on production and productivity are most abundant in almost all European countries. Of course, judged by modern standards, these statistics were not very accurate. Generally speaking they probably underestimated the true values as they were often collected for tax purposes. As government bureaucracy grew and the level of intervention in local affairs increased, the statistics became more accurate. (10) Therefore studies based on these statistics may tend to overestimate the growth of agricultural production.

Apart from the official statistics, such studies were the second main source of data. Many gaps in the information given by the official statistics, for example the lack of data on meat production and the milk yield per cow, had to be filled in by historical-statistical studies on the development of agriculture in individual countries. Fortunately many such studies have been published in the last two or three decades, sometimes within the framework of an analysis of the growth of the economy as a whole.

Much less research has been done on the analysis of international differences in agricultural productivity. The major problem in this type of research has been the difficulties caused by the existence of national currencies, for which the rates of exchange may vary enormously over time and which were often out of line with real differences in purchasing power. The much debated study by P.K. O'Brien and C. Keyder on the comparison of levels of productivity between the United Kingdom and France, used an indirect method (through recalculated rates of exchange based on purchasing-power parity) to tackle this problem. (11)
C. van der Meer and H.H.van Ark adopted a different indirect approach when comparing levels of agricultural productivity between five European countries in the period 1850-1980. They converted real output and input series, taken from a number of country studies, into U.S. dollars using 1975 purchasing power ratios. (12)
The major drawbacks to these indirect approaches are that the exchange rates so calculated remain rather rough, especially in the O'Brien-Keyder case, and not very well suited to the analysis of differences in productivity between the agricultural sectors in the economies studied. Moreover, in the Van der Meer approach, the biases of the time-series of the individual countries, all of which are calculated in different ways, tend to accumulate over time; as a result margins of error increase sharply as the year of comparison is farther away from the one bench-mark year (1975) which is used.
An alternative approach, which is also proposed in this study, is a direct comparison, in which all agricultural outputs (and inputs) are converted into one 'constant' numerator, for example wheat units or calories. (13) Apart from the arbitrariness of some numerators, such as why a tonne of sugar beet, which contains many calories, should be more valuable than a tonne of flax, which contains almost no calories - their constancy is also a problem when long-term changes are analyzed and relative prices of outputs and inputs change. So a somewhat modified direct method is used in the analysis, in which all inputs and outputs are converted in 'wheat units' using current world market price relatives.

In more detail the adopted method is as follows. For 15 European countries the average annual output of the 25 main agricultural products is estimated for the years 1865/74 (1870) and 1905/13 (1910). For Spain this was only possible for 1905/13. The total area under cultivation, the agricultural population and the livestock are also estimated for these years.

The total agricultural output is the sum of the output of these 25 agricultural products, using two sets of world market prices, again for 1865/74 and 1905/13. In these sets the price of a tonne of wheat is the numerator (Table 1). These world market prices are taken from a large number of published price data for the individual countries, most relative prices in the countries of Western Europe not diverging very much. (14) Only the relative prices of some products, especially olive oil, rice, wine and, to a lesser extent, flax, potatoes and milk, varied significantly. In those cases the 'world market prices' were taken from price data of the most important centres of production, for example in the case of subtropical products Italy and France. Apart from those countries where the protection of agriculture changed relative prices in a substantial way, these price relatives more or less reflect the relative prices faced by most farmers.

Table 1. Estimated relative 'world market' prices of the most important agricultural products, 1865/74 and 1903/13.

	unit	1865/74	1905/13
wheat	tonne	1.00	1.00
rye	"	.75	.80
barley	"	.72	.80
oats	"	.68	.75
rice (unhusked)	"	.63	.84
potatoes	"	.24	.35
flax (linen)	"	6.00	7.00
wine	hl	.12	.13
olive oil	tonne	4.10	4.60
milk	tonne	.40	.50
beef	"	5.00	6.00
pork	"	4.80	5.50
wool	"	10.00	10.00

Source: Appendix.

The estimates of the total area under cultivation were in some cases rather crude. This was especially true for the extent to which estimates for rough grazing, particularly important in mountainous regions, were included in the official statistics. For example in Norway, where rough grazing was important for the dominant livestock sector, these estimates were excluded from the official statistics for the cultivated area. (15) As this would only have been possible after detailed research into soil types and geographical structures of all 16 countries, a re-estimation of the official figures has not been attempted. But as is shown in Section 3, there is some indirect evidence that differences in the average quality of the soil were not very large between eight of the countries, which probably means that in most cases the area under cultivation is defined in about the same way.

Estimates for the agricultural labour force were much more problematic. Firstly, in some countries like Poland and Russia, no reliable occupational censuses were held until the end of the nineteenth century. Secondly, the definition of the agricultural labour force, particularly whether it included married women and children who worked on family farms, varied widely. Some countries such as the Netherlands, Britain and Norway, hardly counted them; others like Germany, Austria and Denmark, counted them generously. (16)

Perhaps some part of the difference in method may be attributed to actual differences in the participation of women and children in agricultural work. There are some indications that as real incomes rose, working in the household increasingly became the primary occupation of married women, and children were going to school more regularly instead of working in the field. (17) But the prejudices of the men who were responsible for the occupational censuses seem to have been more important; at least this is true of the Netherlands and Belgium. (18)
It proved impossible to compare the concepts of agricultural labour force used in the official statistics, and therefore another concept had to be used: the agricultural population, i.e. all persons living from agriculture. This was estimated by multiplying the share of the male labour force working in agriculture by the total population. In this way the problem of the estimation of the female labour force was avoided. (19)

A third problem raised by there figures was that in most publications of census results, agriculture, fishing and forestry were taken together and more detailed statistics were not available. In most countries fishing and forestry were rather unimportant; only in two countries did these occupations contribute more than 5 per cent of the total value added in the primary sector (but again figures for Poland, Russia, Italy and Spain are missing). Only in these two cases, not surprisingly Sweden and Norway, both heavy exporters of wood, was the agricultural population corrected for the large part played by those other primary activities.

Estimates for the quantities of other inputs were much harder to collect. Only the quantities of seed used could in almost all countries be estimated on the basis of the sown or harvested area and statistics of the average quantity of seed used per hectare. Statistics for the consumption of artificial fertilizers were only available for most countries for the years after about 1900. In a number of countries regular statistics on the number of agricultural machines were published, but for other important countries like

the United Kingdom, Russia and Denmark no comparable statistics were available. Most deficient were statistics on the consumption of purchased feed stuffs and of the part of the arable crop fed to the livestock. As only a few countries published reliable estimates for these inputs, international comparison of the level of net production (gross production minus seeds, feed stuffs, fertilizers and depreciation of machinery) was very difficult. I decided to make the comparison primarily in terms of gross output. In the appendix, which contains an overview of the sources used and the main figures of the data base, some attention is also paid to the biases that are introduced in this way.

The third and least complete part of the data base are statistics on the prices of the main inputs land, labour, fertilizer and concentrated feeds. Only for eight countries could complete sets of estimates of average daily wages of agricultural laborers and of average prices or rents per hectare be collected. Fertilizer prices were even more scarce, but as these were traded almost completely free of duty, it was assumed that price trends were almost the same in the countries of Western Europe. For feed stuffs, where the price was strongly related to the price of cereals, a similar assumption was made.

3.Agricultural productivity in Europe in 1870.

In the nineteenth century the economic landscape of Europe was characterized by large differences in the level of development of the economic structure of society. The relatively modern economies of Western Europe, at about 1870 still headed by Britain, differed in almost all aspects from the backward regions in Eastern and Southern Europe. According to estimates made by A.Maddison, G.D.P. per head in Russia was only about a third of the British level; the rest of Europe varying between these extremes. (20)

In the 15 countries studied in this section, 55 percent of a population of 265 million was still working in the primary section in 1870, a percentage that fell to 46 percent in 1910. Only in Britain, Belgium, and the Netherlands did more than 50 per cent work outside agriculture. The level of agricultural productivity was still of fundamental importance for the prosperity of the European population.

Table 2 gives some of the direct statistics that were collected. These figures illustrate very well the large differences in production per hectare and per cow. For example the milk yield per cow in Eastern Europe was only about 30 to 40 percent the level of that of the Netherlands. Cereal yields per hectare also varied accordingly. Of course, such statistics give only a very partial picture of real differences in agricultural productivity as, for instance, the use of other inputs like labour is not taken into account.

In the analysis three variables were used to measure the overall level of productivity: gross output per head of the agricultural population, gross output per hectare of land under cultivation and a measure of total productivity, based on a Cobb-Douglas production function, in which land, labour and livestock are weighted as 0.35, 0.50 and 0.15. (21)
The variables so calculated for the 15 countries in 1870 are presented in

Table 2. Yield per hectare of arable land of wheat and rye and the milk yield per cow in fifteen European countries, 1865/74 (in tonnes).

	yield per hectare		yield
	wheat	rye	per cow
Denmark	2.1	1.6	1.4
Britain	2.1	1.4	1.9
Netherlands	1.6	1.3	2.5
Belgium	1.6	1.5	1.5
France	1.1	1.0	1.2
Ireland	1.6	-	1.7
Norway	1.6	1.6	1.1
Sweden	1.4	1.3	1.0
Germany	1.2	1.0	1.8
Switzerland	1.5	1.4	2.1
Italy	0.8	1.0	0.8
Poland	-	-	0.7
Russia	0.5	0.6	0.8
Hungary	0.8	0.8	0.7
Austria	1.0	0.9	1.0

Source: Appendix.

Table 3. Agricultural productivity in 1870 (in wheat units[a] and prices of 1870).

	production per head	production per hectare	total productivity[c]
Denmark	2.49	0.85	1.54
Britain	2.34	1.01	1.59
Netherlands	1.89	1.32	1.58
Belgium	1.54	1.56	1.55
France	1.82	0.91	1.41
Ireland	1.61	0.57	1.03
Norway	1.05	1.13	1.01
Sweden	1.40	0.87	1.14
Germany	1.32	0.83	1.11
Switzerland	1.10	0.70	0.96
Italy	0.91	0.78	1.03
Poland	0.90	0.46	0.69
Russia	1.08	0.41	0.77
Hungary	0.81	0.49	0.69
Austria	0.72	0.54	0.69
Europe[b]	1.21	0.62	0.96

a - one wheat unit is the equivalent of one tonne of wheat, using relative world market prices of 1865/74

b - 15 countries

c - calculated with the formula

$$\text{Production} = (\text{Labour})^{0.5}.(\text{Land})^{0.35}.(\text{Livestock})^{0.15}.(\text{Total Productivity})$$

Source: Appendix.

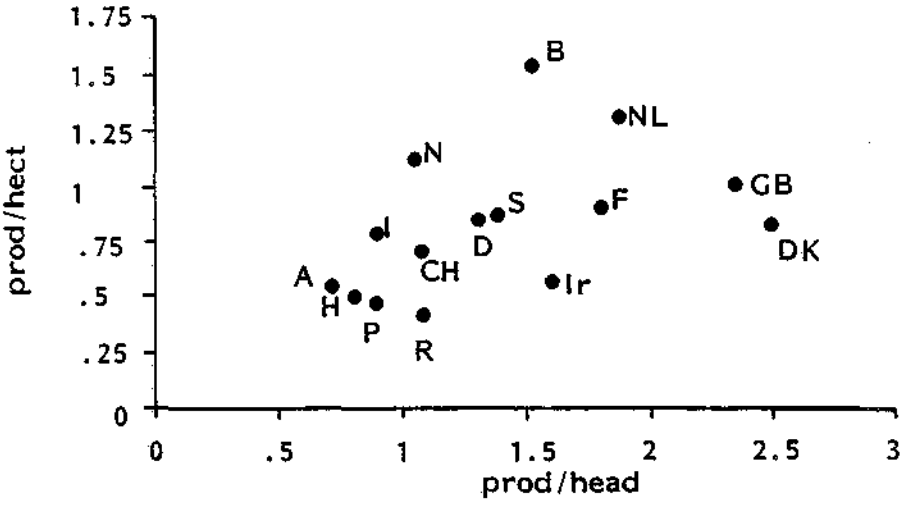
Table 3.

On the basis of the variable of total productivity three regions can be discerned in Europe. (22) The first region, here called the core, was made up of countries with a highly productive agriculture. It is the region where the "agricultural revolution" of the period 1750-1880 originated (i.e. in the Low Countries) and had spread. (23) It formed a nucleus of labour-intensive and land-intensive agriculture.
The second group of countries, characterized by medium levels of productivity, lay in a circle around the core. In these semi-peripheral countries the variable of total productivity was about one, or a third smaller than in the first region. In Eastern Europe, the third region, this variable again falls by a third to about 0.70. In this third region labour productivity was, with the exception of Russia, well below 1.0, or less than the equivalent of 1000 kg of wheat produced per head of the agricultural population, and land productivity was about 0.5, or 500 kg wheat per hectare. If data were available for the Iberian peninsula, Spain and Portugal would also be classified in the third group, as data for Spain in 1910 show. The same probably holds true for the Balkan countries. (24)

Of course this classification hides important regional differences in agricultural productivity within countries. Probably only the northern part of France belongs to the first group, as in all likelihood does some part of Western Germany. What is called Austria in this article is the Austrian part of the Habsburg Empire, properly called Cisleithania, which covered relatively modern regions like present day Austria and Bohemia, but also Galicia and Slovakia. Here the agriculture was very backward. (25) Even in so small a country as the Netherlands, there existed large differences in labour productivity between the coastal provinces, with a modern, capital intensive agriculture, and the inland provinces, which resembled much more the neighbouring parts of Germany. But the main pattern in clear: a core of very intensive and highly productive agriculture on the borders of the North Sea (and within this core parts of the Low Countries and probably England with an even higher level of productivity), a circle of countries with medium productivity consisting of most of the rest of present day Western Europe, including Italy, and the 'periphery' of countries with low productivity in Eastern and Southern Europe.

The explanation for there large differences in agricultural productivity may start from Figure 1, which visualizes the figures of Table 3. Figure 1 shows that four countries, Belgium, the Netherlands, Britain and Denmark, were on the 'efficiency' frontier in 1870. With their specific resource combinations, these countries realized the highest levels of production per hectare and per head of the agricultural population. All other countries had a lower level of productivity, the four Eastern European countries being on what perhaps may be called an 'efficiency bottom'.

Two questions can now be raised. Firstly, why did countries have different positions on these 'productivity curves'? Why for example did Denmark excel in labour productivity and Belgium in land productivity? Secondly, why were there such large differences in the level of total productivity? Why are some countries able to produce much more with the same combination of resources than other countries? Translated in terms of Figure 1, the first question is about the tangent of the line between the dot of country x and zero, the



A-Austria	DK-Denmark	H-Hungary	NL-Netherlands
B-Belgium	E-Spain	I-Italy	P-Polen
CH-Switserland	F-France	Ir-Ireland	R-Russia
D-Germany	GB-Great Britain	N-Norway	S-Sweden

Figure 1.

Agricultural Productivity in 1870; Production per head of the Agriculturel Population and Production per hectare of cultivated land in wheat units.

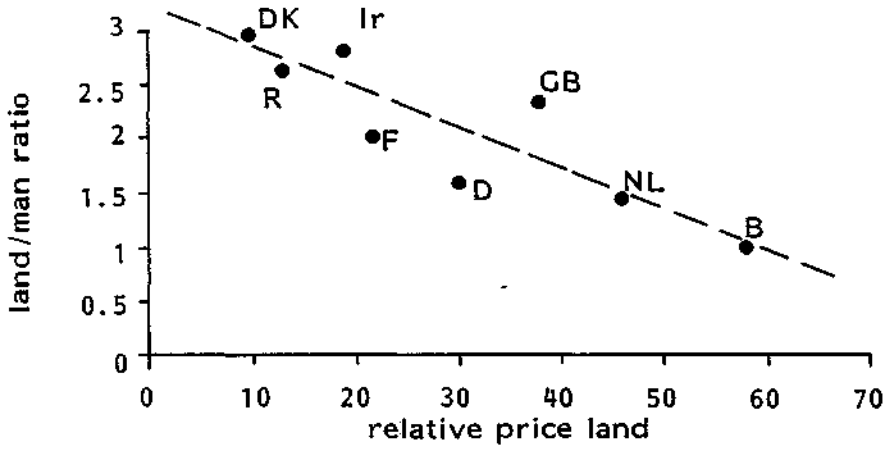


Figure 2.

Relative Factor Endowments and the Relative Price of Land versus Labour, 1870.

second question relates to the distance between this dot and zero.

There existed large differences in relative factor endowments especially in the core region. In Belgium, only one hectare of cultivated land was available per head of the agricultural population; in Denmark, the other extreme case, this was almost three hectares.

The different factor endowments resulted in large differences in relative factor prices (see Figure 2). In Belgium an agricultural labourer had to work almost 60 days to rent a hectare of land, in Britain this ratio was 38 and in Denmark only 10. Figure 2 shows that there existed a clear relationship between the relative price of land and the land-man ratio for the eight countries for which these figures are available. Only the dots for Britain and Ireland are somewhat above the line of regression, which may be explained by the better quality of the land in the United Kingdom, but probably has also to do with the fact that land prices were extremely high there because of the (political) prestige and power of landownership. (26)
That such a clear relationship between relative factor prices and the land-man ratio is not self evident, is shown by comparable data for the agriculture in the provinces of the Netherlands in 1880 (see Figure 3). The two agrarian regions of the country, the coastal and the inland provinces, had different relationships between factor endowments and relative factor prices, which was caused mainly by the much better quality of the land in the coastal provinces. (27)

Through the relative factor prices faced by farmers, different factor endowments should have resulted in different product mixes. For example in a country with a very low land-man ratio farmers should concentrate on those products which use much labour and little land. To test this hypothesis an index of the labour intensity of the product mix was constructed. It is well known that some crops demanded a much higher labour input per hectare than others. On the basis of data collected by F. Dovring it was established that potatoes, sugar beet, flax, hemp, wine and olive oil were the most typical labour intensive arable products, for which the labour input per hectare was at least four times as high as the labour input for cereals. (28) The share of these products in total arable output was one component of the index. Comparable evidence of the labour intensity of livestock farming is much less convincing. What is clear is that the production of pork was relatively labour intensive, and that sheep-breeding was often labour extensive. So the proportion of pigs in the total livestock, measured in livestock units, was taken as the second element of the index, which was made up of the multiplication of both variables.

In Figure 4 this labour intensity index is set out against the land-man ratio. With the exception of Ireland and Norway, Figure 4 shows a considerable relationship between the labour intensity of the product mix and the available quantity of cultivated land per head of the agricultural population. Without Norway and Ireland the correlation coefficient is $r = -.72$, which is significant at the 1 percent level. Denmark on the one hand and Italy and Belgium on the other hand are extremes in relative factor endowments and in product mix. The figures for Norway are probably caused by deficient data on the land under cultivation land as extensive rough grazings were not included in the statistics. (29) The figure for Ireland suggests that the adoption of labour intensive crops may to same extent be a

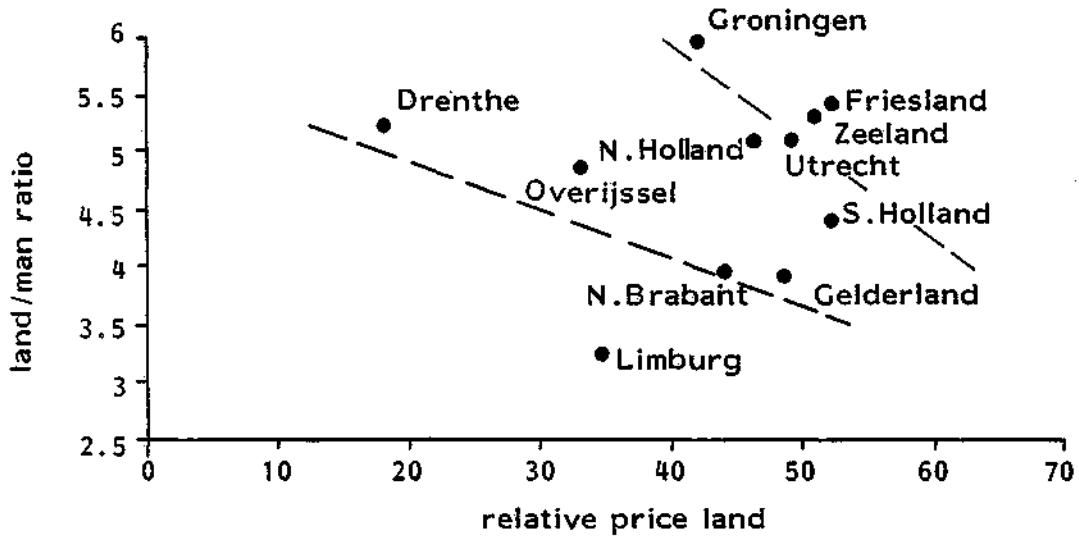


Figure 3

Relative Factor Endowments and the relative price of land versus labour in the provinces of the Netherlands, 1880.

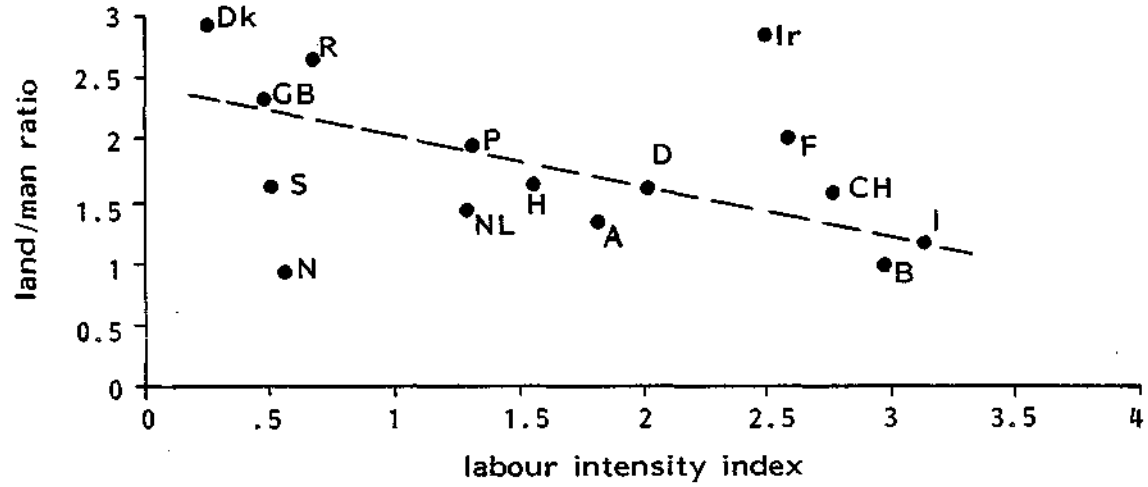


Figure 4.

Relative Factor Endowments and the Labour Intensity of the Product Mix, 1870.

one way process. The high score for this country is the result of the important role played by the cultivation of potatoes and flax in its agrarian economy, which dated back to the years of sharply increasing population pressure before 1845. After the potato blight the land-man ratio improved again as a result of massive emigration, but these crops remained of great although somewhat declining importance in the agriculture. The extensification of Irish agriculture after 1850 took the form of a strong increase in livestock farming at the expense of arable farming. (30)

It is also clear from Figure 4 that productivity was almost independent from product mix. Britain had about the same product mix as Russia, Hungary compares well in this respect with the Netherlands, and Italy and Belgium also score about the same on the labour intensity index. Highly productive regions produced similar crops to low productive ones, but in a different way. There was only a weak tendency for livestock farming to be more important in countries with high productivity. In Eastern Europe livestock farming contributed not more than 20 to 30 percent of total gross output. In some core countries this was much more, up to 64 percent in the Netherlands and 48 percent in Denmark. But in Belgium and France this percentage was also low, about 30 percent, and in semi-peripheral countries like Switzerland, Ireland and Norway it was again more than 50 percent. To a large extent these differences should be attributed to natural conditions (in the Netherlands, Norway and Switzerland much of the land was unsuitable for arable farming) and to differences in the composition of the demand for agricultural products.

In conclusion, it is possible to establish systematic relationships between resource endowments, relative factor prices and (the degree of labour intensity) of the product mix adopted by the European farmers. In other words, through the adoption of more labour intensive crops and induced by changing relative factor prices, these farmers were able to adapt to changing resource endowments - in most cases, growing population pressure.

An explanation for the large differences in the level of agricultural productivity is much less easy to give. Two hypotheses may be derived from the current literature on the economics of agricultural development. The first explains changes in the level of productivity as the result of increasing use of purchased inputs. These inputs are needed to solve bottlenecks in the production process. When land is relatively scarce, inputs are purchased to increase the productivity of the land (eg. fertilizers), or to substitute for land (eg. concentrated feeds). When labour is the most important bottleneck, inputs like agricultural machinery are bought to substitute for this factor of production. In this theory rising productivity is the result of the development of increasingly efficient and profitable inputs and their adoption by farmers. (31)

A second hypothesis may be derived from the classical theory of economic growth. In this theory, low productivity is the result of a low level of commercialization and specialization. As sufficient market outlets are missing, farmers devote much of their time to inefficient subsistence production or other forms of underemployment. A low level of production for the market necessarily leads to structural shortages of working capital and large-scale indebtedness to outside creditors. Only a sharp increase of production for the market, induced by improvements in the rural infrastructure, will reduce

Table 4. Consumption of chemical fertilizers and oilseed cakes is 1870 and 1880 is some core countries.

	fertilizers (kg per hectare)		oilseed cakes (kg per livestock unit)	
	1870	1880	1870	1880
Denmark	0	1	-	40[a]
United Kingdom	5	7	41	52
Netherlands	0	1	-	48
Belgium	-	9	20	28
France	2	2	.[b]	.[b]
Germany	-	4	-	10

a - all concentrated feeds

b - probably insignificant

Sources: W.W. Wade, Institutional determinants of technical change and agricultural productivity growth (New York, 1981) appendices, Centre for European agricultural Studies, The development of agriculture in Germany and the U.K.; 3. Comparative time series 1870-1975. (Kent, 1979). G. Bublot, La production agricole Belge (Louvain, 1957). J.L. van Zanden, De economische ontwikkeling van de Nederlandse landbouw in de negentiende eeuw 1800-1914 (Wageningen, 1985).

the level of underemployment and stimulate a process of specialization and commercialization on the countryside. (32)

As far as the first hypothesis is concerned, there are clear indications that the countries of highest productivity also took the lead in the introduction of new inputs. In Belgium, especially Flanders, there was a very long tradition of the use of purchased fertilizers, particularly garbage from the cities. In the nineteenth century British farmers increasingly followed this example and Britain began to play a leading role in the adoption of new fertilizers like guano and nitrate imported from Latin America, in the years of high farming after 1850. (33) The farmers in the coastal provinces of the Netherlands had, since the seventeenth century, supplemented the winter feed of their livestock with purchased oilseed cakes, and again this practice was adopted widely by British farmers in the nineteenth century. (34) In the same way the development and spread of new agricultural machinery was increasingly concentrated in the Britain in the period before 1870. (35)

There is some doubt whether these innovations were already of great importance by 1870 and if they played a large role in raising productivity. The main reason for this is the on average still relatively low level of adoption of the new inputs in about 1870. Only in the Low Countries and the United Kingdom had chemical fertilizers already become of any importance, and the same is probably true for concentrated feeds (see table 4). France and Denmark, both countries of high productivity, used almost no fertilizers and purchased feeds. Different levels of adoption of new inputs can in any case not explain the large differences in productivity between the semi-peripheral countries of Western Europe and Eastern Europe, as neither region used them. The same applies to the use of agricultural machinery. With the possible exception of Britain, machines played only a marginal role in the agriculture of Europe in 1870. In many cases these machines were more a matter of scientific interest for wealthy landowners than of practical use for farmers. (36) This is developed in the next section.

It may be added that in large parts of the Low Countries the high level of productivity in 1870 had already been attained at the beginning of the century, well before the introduction of new fertilizers and many new machines, and before the consumption of oilseed cakes became important. In the Netherlands, labour productivity hardly increased at all between 1810 and 1870 - it in fact fell in the first half of the century - and the same is probably true for large parts of Belgium. (37)

The second hypothesis seems to offer a better explanation for international differences in agricultural productivity in about 1870. To test the hypothesis, the following variables were correlated with the estimated levels of labour productivity and total productivity, taken from Table 3.

1. To measure the level of specialization and of urban demand for agricultural products, the share of the non-agricultural population was taken as a proxy. For eleven countries estimates of G.D.P. per capita, derived from the work of A. Maddison, were also introduced as a variable. (38)
2. Another measure of the demand for agricultural products was the level of meat consumption per capita, which could be estimated for 10 countries (see Table 6). As meat was a luxury product, the variable probably measures fairly well the overall level of consumption.

Table 5. The explanation of international differences in the level of agricultural productivity in 1870 (equations that proved statistically significant at the 5 percent level).

	R^2	F
Total Productivity		
var 1 = 0.340 C + 0.018 var 3	.72	17.7*
(1.53) (4.21)		
var 1 = 0.530 C + 0.0011 var 7	.60	10.3**
(2.27) (3.20)		
var 1 = 0.498 C + 1.083 var 5	.48	7.4**
(1.87) (2.72)		
Labour Productivity		
var 2 = 0.147 C + 0.026 var 3	.72	17.9*
(0.45) (4.23)		
var 2 = 0.080 C + 0.016 var 3 + 0.564 var 6	.86	19.0*
(0.32) (2.53) (2.52)		
var 2 = 0.488 C + 0.940 var 6	.72	17.8*
(1.93) (4.21)		
var 2 = 0.681 C + 0.031 var 4	.51	7.3**
(2.13) (2.71		

* - significant at the 1 per cent level

** - significant at the 5 per cent level

C - constant

var 1 - estimated total productivity

var 2 - estimated labour productivity

var 3 - share of non-agricultural employment in total labour force

var 4 - meat consumption per capita

var 5 - livestock units per hectare

var 6 - livestock units per head of the agricultural population

var 7 - G.D.P. per capita (after A. Maddison)

variables 8 and 9 (the labour intensity index and the land-man ratio) did not correlate significantly with one of the variables.

3. To measure a hypothesized lack of working capital in low productivity agriculture, the density of the livestock, usually the most important part of the farmers' capital apart from land and buildings, was taken as a proxy; livestock per hectare of cultivated land and livestock per head of the agricultural population were used as variables which indicate the level of capital intensity.
4. To check if the land-man ratio and the product mix influenced productivity, both variables were also introduced into the equation.

The multiple regression analysis was severely handicapped by a large degree of multicollinearity between the independent variables. As a result almost all equations with more than one independent variable proved to be inferior to equations with only one variable, the more so as one variable, the share of the non-agricultural population, correlated very well with both measures of agricultural productivity.

Table 5 presents the statistically significant relationships between the estimates of productivity and the other variables mentioned. The share of the non-agricultural population correlated highly with labour productivity and total productivity and explains more than 70 percent of the variance of these variables. Only the addition of variable 6, the livestock density per head, improves the explanation of labour productivity (i.e. the F-value). Total productivity was also positively correlated with G.D.P. per capita and livestock density per hectare.

What is surprising is that production per head of the agricultural population did not correlate well with G.D.P. per capita. Variables 8 and 9 were also independent of the estimates of productivity, which confirms the previous conclusion.

Figure 5 shows that the relationship between the share of the non-agricultural population and the level of total agricultural productivity was indeed very strong. In the countries of Eastern Europe only about 30 percent of the population worked outside the agriculture and in the semi-peripheral countries this percentage was 40 to 50. Only in the core region did a larger variance occur, mainly between the countries of specialized export-oriented agriculture like Denmark and the Netherlands and the main importer of agricultural products, Britain. If these countries were to be treated as one economic entity, the correlation would be almost perfect.

It may be concluded that by 1870 the level of agricultural productivity was highly dependent on the level of structural transformation of the economy, and that low productivity agriculture was mainly caused by the lack of (urban) demand and of working capital.

4.The first green revolution 1870-1914.

During the 1870's the economic tide for European agriculture changed. The prices of cereals, which had reached a peak in the fifties and again in the early seventies, started to decline as a result of the sharply increasing exports of wheat and maize from the American continent. Unfavourable weather in the late seventies added to the difficulties by causing a succession of crop failures. In the eighties cereal prices dropped very rapidly, and this continued until 1896, when the prices of most cereals were

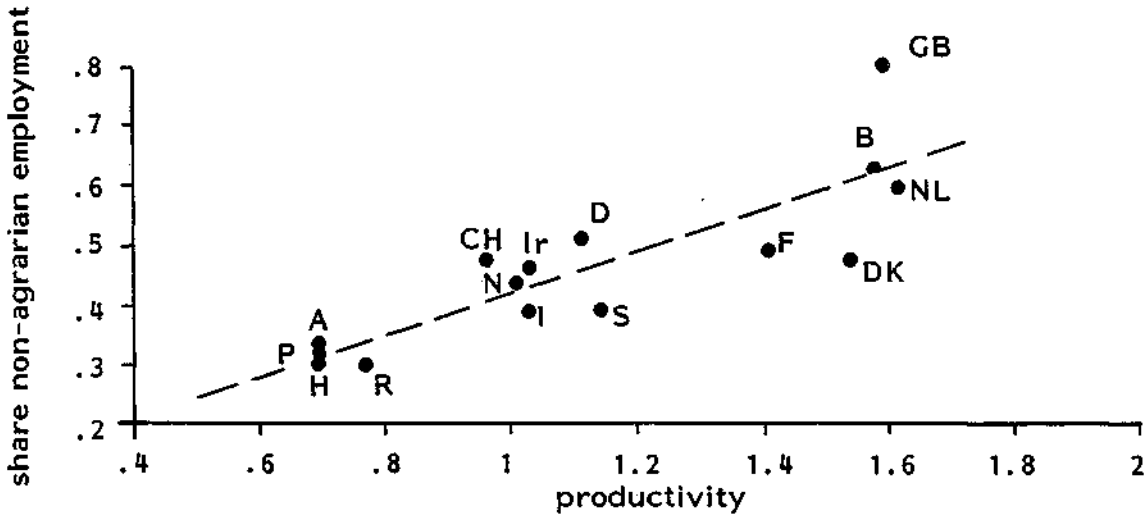


Figure 5

Agricultural Productivity and the share of non-agrarian employment in the total Labour Force, 1870.

less than half those of the early seventies. After 1896 prices began to rise again, but before the war they remained at a rather low level.
In a number of countries like Germany, Italy and France, where governments tried to protect farmers against the worst consequences of the depression by raising the import duties on imported grains, cereal prices dropped much less than on the world market. For instance in Germany, average wheat prices dropped only by 10 percent between 1865/74 and 1905/13, and in France this decline was 17 percent, compared to about 40 per cent in countries without protection for cereal farmers like Britain and Denmark (Appendix, Table A.2).

On the input side of the production process a number of rather unfavourable developments for European farmers also occurred. Nominal wages for agricultural labourers rose almost continually in most countries as a result of the rapid economic growth of the economies of continental Europe. Real wages rose by 80 percent or more in almost all countries between 1870 and 1910, Russia and France being the main exceptions (Table 6). As agriculture was very labour intensive, labour costs accounting for 30 to 50 percent of total expenses, farmers faced great difficulties in keeping their costs down. (39)
As at the same time the price of the other fundamental factor of production, land, was also rising, farmers had to radically change their mode of production radically to meet the twin processes of rising costs and rapidly falling output prices.

Rising real wages resulting in rising living standards were, in another way, more favourable to the agricultural sector, as it meant that consumption of agricultural products per capita rose rather rapidly almost eveywhere. The demand for relatively luxury items of consumption like most livestock products especially rose rather fast, as did the demand for horticultural products in the core countries (Table 6). Only in Russia did the level of meat consumption not increase, in spite of some rise in real wages, which probably testifies to the marginal character of the rural labour market in the Russian peasant economy. (40)
As a result of the sharply rising demand for livestock products and the less intense international competition in this field, in comparison with the prices of cereals the prices of livestock products rose (Table 1). Specialization on livestock farming could be one of the ways in which farmers managed to meet the challenge of the agrarian depression.

In spite of these generally unfavourable circumstances for a rapid development of agriculture, farmers in many countries succeeded in increasing production and productivity rather rapidly. As Table 7 shows, European agricultural output increased by more than one percent a year, which was only marginally higher than the growth rate of the European population (41), and productivity increased by 0.65 percent a year. As the area under cultivation hardly increased, the growth of land productivity was almost as high as the increase of output; the rise of labour productivity was less high.

These European averages conceal large international differences. In Eastern Europe the growth of output was relatively rapid and, apart from Russia, productivity also increased more rapidly than the European average. Most surprisingly are the diverging paths of development in the core countries:

Table 6. Real wages of agricultural labourers and meat consumption per capita in Europe, 1870-1910

	Real wages (in kg wheat)		Cons. of meat (in kg)	
	1870	1910	1870	1910
Denmark	6.2	20.3	-	-
Britain	9.6	20.8	41	44
Netherlands	7.3[c]	13.6	31	43
Belgium	6.1	13.0	18	32
France	7.5	11.8	33	48
Ireland	5.2	12.6	-	-
Norway	7.5	17.7	-	-
Sweden	6.3	16.7	23	35
Germany	5.4	10.0	28	46
Switzerland	8.1	16.9	35	51
Italy	4.8	8.3	11	14
Poland	-	9.6	14	21
Russia	8.9[b]	11.2	11.5	10
Europe	-	-	24[a]	30[a]

a - production of meat per capita

b - 1881/83

c - 1880

Sources: Appendix Table A.2 and on meat consumptions C. van den Broeke, 'Kwantitatieve en kwalitatieve aspecten van het vleesverbruik in Vlaanderen', Tijdschrift voor sociale geschiedenis, IX (1983) 221-258 G. Helling, 'Berechnung vergleichbarer Indizes der Agrarproduktion entwickelter kapitalistischer länder im 19. Jahrhundert', Jahrbuch für Wirtschaftsgeschichte (1968), III 277-341. J.L. van Zanden, Economische ontwikkeling, 139. E. Lindahl, E. Dahlgren, K. Kock, National income in Sweden 1861-1930, London, 1937. H. Brugger, Die Schweizerische Landwirtschaft 1850-1914, Biel/Zurich. Statistiche storiche dell' Italia 1861-1975, Roma,1976. J. Sobczak, Przelom w konsumpcji spozywczej w krolestwie Polskum w XIX wieku, Wroclaw, 1968. R.W. Goldsmith, 'The economic growth of Tsarist Russia 1860-1913', Economic development and cultural change, IX (1961) 452.

agricultural production in the United Kingdom hardly grew at all, whereas Denmark, Germany, the Netherlands and, to a lesser extent, Belgium realized high growth rates of production and productivity.

In Western Europe the growth of output was largely the result of growth in productivity. Only in Italy, the Netherlands and Denmark did the growth of inputs like land, labour and livestock play some role. In Eastern Europe, especially in the regions of low population pressure in Russia, Hungary and Poland, the agricultural population and the cultivated area still increased significantly. The growth of these inputs accounted for more than two-thirds of the rise of agricultural production in Russia, where labour productivity did not increase at all. The international productivity gap between Russia and the rest of Europe widened.

Figures 6 and 7 give a graphical presentation of these developments. The 'efficiency frontier' was clearly pushed forward by the three small core countries in this period. Again it is clear that Britain fell behind and that Germany moved rapidly forward. These four continental countries, Germany, Belgium, Denmark and the Netherlands seem to have been most successful in adapting to the changing circumstances.
In Figure 6 the position of Spain is also given, which shows the very low level of productivity of agriculture ; labour productivity and land productivity here were even lower than in Eastern Europe. (42)

The explanation for these developments has to begin with a survey of the main changes in agricultural technology. According to the theory developed by Y.Hayami and V.W.Ruttan, two kinds of technologies can be distinguished: land-saving and labour-saving ones. Both will be dealt with in brief. (43)

Land saving technology developed very rapidly in the years after 1870. Foremost was the spread of the use of chemical fertilizers, which resulted from a massive increase in the supply of these fertilizers, caused by a number of unrelated innovations in fertilizer production and the advancing knowledge of soil chemistry. As a result fertilizer prices fell dramatically in the years after 1880. In the Netherlands, where a very competitive market for fertilizers came into existence, average prices for nitrogen and potash dropped by 40 to 45 percent and for phosphate even by two-third between 1880 and 1900, after which they remained almost stationary. This contrasted sharply with the period before 1880, when fertilizer prices rose.(44) The fall in fertilizer prices seems to have been general. They fell by an average 55 percent in Germany between 1880 and 1905/13, by 42 percent in Switzerland between 1882 and 1910 and by 47 percent in Britain between 1870 and 1910. (45) As importing countries highly profited from the low level of fertilizer prices, high import duties were not imposed and the trade in fertilizers remained almost completely free.

This resulted in a rapid increase in fertilizer consumption, especially after 1896 when agricultural prices started to rise again. Compared to the relatively low level about 1880, it more than quadrupled in Germany, France, Belgium and Denmark and it doubled in the United Kingdom (Table 8 and Table 4). In most other countries it rose from virtually nothing to the level estimated in Table 8.
About 1910 these levels of fertilizer consumption differed enormously from

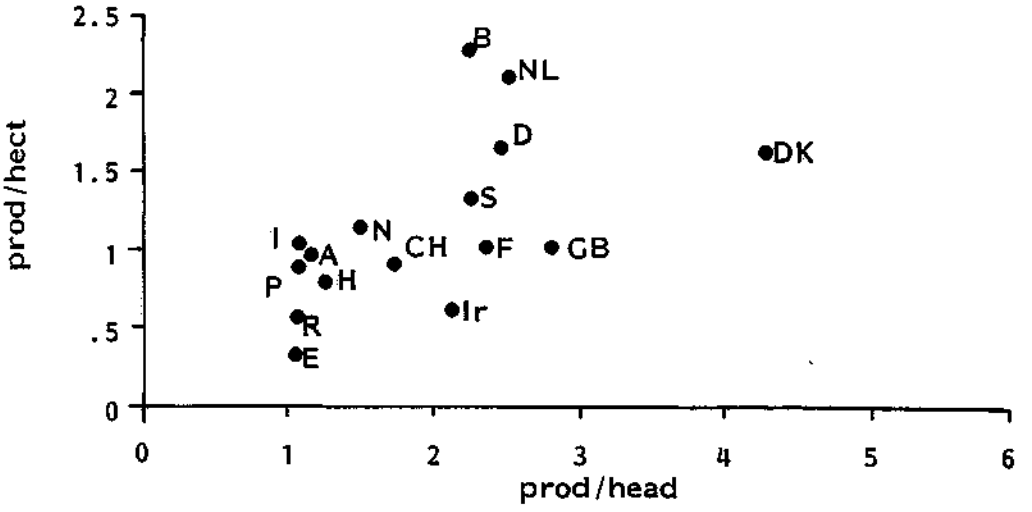


Figure 6

Agricultural Productivity in1910 (in wheat units and prices of 1870).

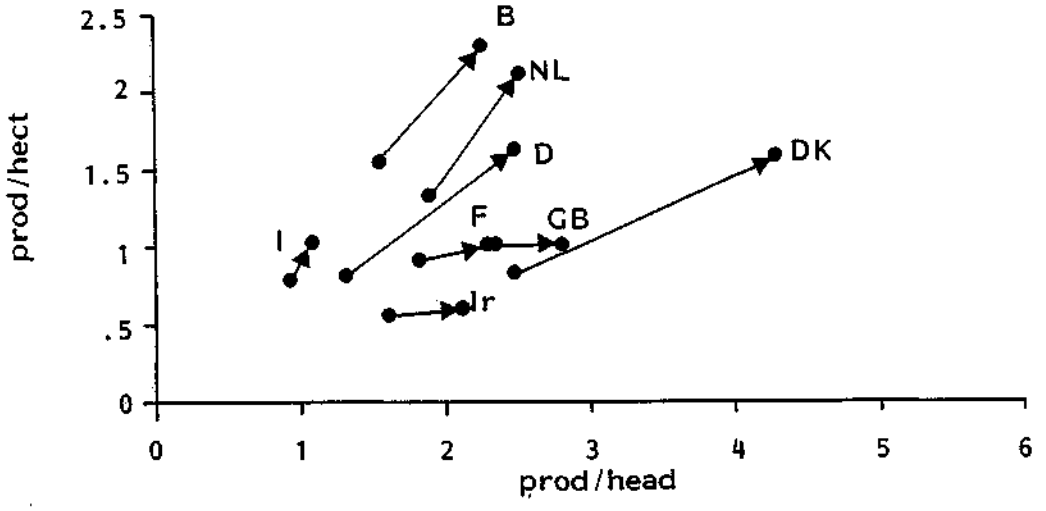


Figure 7

The Growth of Agricultural Productivity in Eight Countries of Western Europe, 1870-1910 (in wheat units and prices of 1870).

Table 7. The average annual growth rates of agricultural output and productivity, 1870-1910 (in wheat units and prices of 1870)

	gross output	production per head	production per hectare	total productivity
Denmark	1.78	1.37	1.62	1.31
Britain	0.15	0.46	0.01	0.19
Netherlands	1.29	0.72	1.17	0.82
Belgium	0.97	0.96	0.94	0.83
France	0.37	0.66	0.30	0.46
Ireland	0.15	0.69	0.14	0.36
Norway	0.52	0.88	0.00	0.48
Sweden	1.29	1.20	1.03	1.03
Germany	1.68	1.58	1.72	1.53
Switzerland	0.80	1.15	0.63	0.78
Italy	0.86	0.46	0.64	0.37
Poland	1.93	0.49	1.61	0.90
Russia	1.06	0.00	0.86	0.34
Hungary	1.61	1.08	1.18	1.11
Austria	1.42	1.17	1.43	1.21
Europe[a]	1.06	0.57	0.90	0.65

a - fifteen countries

Source: Appendix Table A.1

almost negligible quantities per hectare in Eastern Europe to 30 kg per hectare or more in Germany, Belgium and the Netherlands. (46) Denmark, which had followed a less labour-intensive growth path as a result of its much more favourable land-man ratio, and the United Kingdom and France all lagged behind and shared levels of average fertilizer consumption of about 10 kg per hectare with the semi-peripheral countries.

In the countries of high fertilizer consumption this meant an important break through in the technology of production. The costs of producing additional manure, or of buying garbage from the cities, in order to increase arable yields, had been rising rapidly before 1880. These costs were made up of the use of land to grow cattle fodder, and of the huge labour input to feed the cattle, collect the manure and spread it on the arable land. Especially in the region of very intensive mixed farming in Belgium and the Netherlands where the 'Flemish agriculture' was practised, a large part of the available labour was used in the production of manure. (47) Chemical fertilizers reduced these costs dramatically. In the region of 'Flemish agriculture' this type of mixed farming, which dated back to the Middle Ages, was suddenly abolished during the 20 years after 1895. (48)

In regions of high population pressure, chemical fertilizers soon became very important. For seven countries the correlation between the level of fertilizer consumption and the relative price of land versus labour in 1910 was calculated and proved to be very high ($r = .96$). The correlation with absolute land prices was somewhat lower ($r = .93$), but still significant at the 1 percent level (data taken from Table 8 and Table A.2). Figure 8 shows the relation between population pressure and the level of fertilizer consumption in 1910. The line between Belgium, Germany and the United Kingdom probably reflects some kind of 'consumption frontier' under different land-man ratio's. In Eastern Europe, and to a lesser extent in the semi-peripheral countries (except Germany), consumption is very much below this standard, which reflects a sub-optimal adoption of the innovation.
This may partially be explained by the somewhat higher prices for fertilizers in these regions, as most of it had to be imported from Western Europe (especially Germany) and Latin America. Other factors, like the lack of working capital to buy fertilizers and the lack of market outlets for the extra production, were also at work. The already highly developed agriculture in the core countries therefore profited most from the revolution in chemical fertilizers, and German agriculture seems to have made a decisive break through thanks to it. However the peripheral countries of Eastern Europe remained very much behind in its adoption.(49)

The next most important development in land-saving technology was the rapid growth of the supply of concentrated feeds. Apart from wheat, maize was the main agricultural export product of the United States. Its price fell almost as rapidly as that of wheat. The second source of supply of concentrated feeds, oilseed cakes, also expanded rapidly during these years, mainly because of the enormous rise of the output of tropical oils, which were used in the production of margarine. The prices for oilseed cakes dropped almost as much as wheat prices did. (50) As the prices of livestock products dropped much less, it became more profitable to increase livestock production by purchasing concentrated feeds. Livestock farming could become much more land intensive, as land (which was scarce), on which cattle fodder was grown, was substituted by purchased feeds.

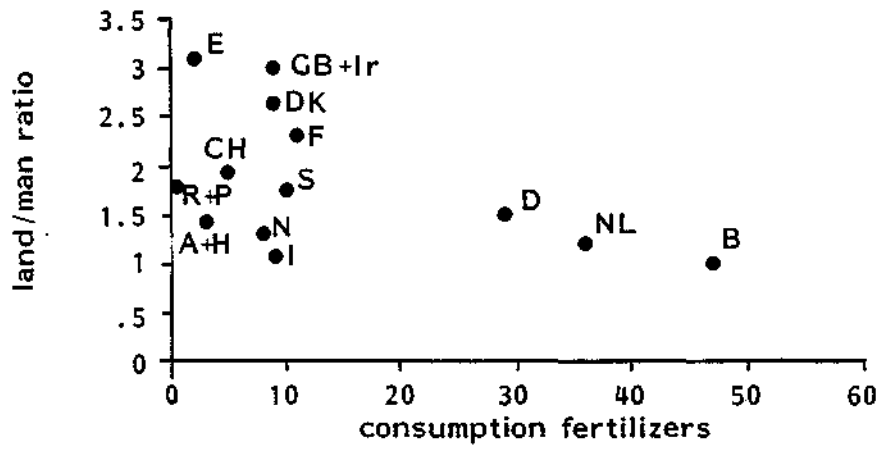


Figure 8

Relative Factor Endowments and Fertilizer Consumption (in kg per hectare) in 1910.

Table 8. Fertilizer consumption in 1910.

	(1) kg $N+P_2O_5+K_2O$ per hectare	(2) $N+P_2O_5+K_2O$ in grain units per hectare[a]	(3) column (2) as a percentage of gross production (prices 1910)
Denmark	9	20	1.1
United Kingdom[b]	9	23	2.3
Netherlands	36	133	5.2
Belgium	47	127	7.6
France	11	26	2.2
Norway	8	17	1.2
Sweden	10	20	1.7
Germany	29	72	3.6
Switzerland	5	9	0.8
Italy	9	16	1.4
Poland/Russia	0.5	1	0.1
Austria/Hungary	3	6	0.6
Spain	2	4	1.0
Europe[c]	7	16	1.7

a - 1 tonne N is estimated to value 7.5 wheat units, 1 tonne P_2O_5 1.35 and 1 tonne K_2O 1.5 wheat units (based on Dutch and German price data)

b - Britain and Ireland

c - including Spain

Source: International yearbook of agricultural statistics, 1915 (for data on fertilizer production and trade)
Appendix Table A.1

Only in a few countries did the consumption of these feeds become really important. Again the core countries were to the fore (Table 9). In the United Kingdom the level of consumption stagnated after 1880, following the rapid rise during the years of 'high farming' between 1850 and 1880.(51) In most (semi-)peripheral countries, imports of concentrated feeds remained unimportant: even in France this input was adopted on a very restricted scale.(52) Although data on the level of consumption of concentrated feeds are much less complete, it is clear that the spread of this innovation broadly speaking followed the same pattern as that of chemical fertilizers.

The development of land-saving technology was not restricted to chemical fertilizers and concentrated feeds. Some exchange of superior breeds of seed, which were more responsive to the increased application of fertilizers, began during this period. In a number of countries, particularly Germany and the Netherlands, this greatly was stimulated by extension services supported by or set up by the government.(53) Cattle breeds with superior milk or meat producing capacities were increasingly used to augment the quality of the livestock.(54) A glance at the data presented in Table 2 gives an idea of the rise in productivity that could be made in these ways.

The improvements in labour saving-technology seem to have been much less spectacular than the 'green revolution' caused by the adoption of fertilizers and concentrated feeds.

One of the fundamental changes was the gradual replacement of wooden parts of agricultural implements by iron and steel, which was caused by the secular fall in iron prices in the nineteeth century. The efficiency and durability of these implements was greatly enhanced by the change. (55) However, the main bottleneck in the development of labour-saving technology remained the supply of motive power. The steam engine, with which numerous experiments had been made in the course of the century, proved to be too heavy and manoeuverable for practical use and remained a curiosity for wealthy landowners. (56) As a result, rapid progress in mechanization was restricted to those parts of the production process which were concentrated in one place, such as threshing and butter making. The main agricultural activities remained dependent on horse power and human labour.(57)

For the dairy farmers the development of the centrifugal cream separator, which replaced much inefficient labour used in butter making, was a major breakthrough. Invented in Denmark in 1878, the continuous cream separator spread very quickly in most of the core countries - Denmark, the Netherlands, Germany, Belgium and France - but was hardly adopted at all in Britain, where dairy farmers increasingly specialized in the sale of liquid milk. (58) It effectively lowered the cost of butter making, especially for smaller farmers, and improved the quality of the butter. In the Netherlands small farmers could increase the revenue from dairy farming by 25 to 50 per cent by participating in cooperative factories. (59) As dairy farming was a relatively labour and land intensive occupation, this innovation, in contrast to much modern machinery, ameliorated the relative economic position of the small farmer.

Treshing machines, on the other hand, were mainly used by large farmers to

Table 9. The consumption of concentrated feeds[a] in six countries in about 1910.

	per head of livestock (in kg)	in wheat units[b] as a percentage of gross production
Denmark	265	13.7
United Kingdom	297	21.9
Netherlands	336	14.2
Belgium	304	12.9
Germany	121	4.9
Switzerland	116	7.1

a - oilseed cakes, maize and bran

b - one tonne of concentrated feeds is 0.9 wheat unit

Sources: Table 4 and Appendix Table A.1

H. Brugger, Landwirtschaft.

save wage labour. As a result of the rising wage level and gradual mechanical improvements, their importance increased after 1880. By 1907 they were used on about 30 percent of all holdings in Germany. In other countries for which more or less reliable statistics are available, about 5 percent of all holdings possessed one (Table 10), but only a minority of these machines was steam-driven; in Germany about 30 percent but in the Netherlands only 4 percent used steam power. (60)

The next most important 'new' machine, the mechanical reaper, was at this time always horse drawn. These reapers were introduced successfully, especially in regions of intensive cereal cultivation, where extreme peaks in the demand for labour in harvest time drove up see real wages, although their use was often handicapped by mechanical deficiencies. Although the data in Table 10 underestimate the importance of the new machines, as their share in the total cultivated area was higher than their share in the number of holdings, it is clear that they played no decisive role in the development of agriculture before 1914. (61)

The survey shows that technology progress in European agriculture in the period 1870-1914 was dominated by new-land saving technologies. This conclusion can be tested through the comparison of changes in relative factor prices and changes in relative factor endowments. If the land-man ratio declined, one would, in the absence of biases in the direction of technological change, expect that the relative price of land rose. In 1870 a rather high correlation was found between relative factor prices and the land-man ratio (Figure 2). Between 1870 and 1910 this correlation decreased sharply. In Belgium, the Netherlands, Germany, Denmark and Russia technological progress was clearly land-saving as both the relative price of land and the land-man ratio declined (Figure 9). In France, Ireland and Britain, countries which hardly adopted the new land-saving innovations, no clear bias in the direction of technological change is evident; these countries merely moved along the line of regression established in 1870 (Figure 9).

To test the hypothesis that the growth of agricultural productivity in the period 1870-1910 was highly connected with the adoption of land-saving technologies, resulting in an increase in the labour intensity of the product mix, the estimated growth rates of total productivity and labour productivity were correlated with a number of variables.
These variables were:

1. The growth rate of the labour-intensity index, which measures the labour intensity of the product mix, and the total increase in fertilizer consumption per hectare. (62)
2. The variables used to explain the international differences in agricultural productivity in 1870: the growth of non-agricultural employment (in absolute values and as a percentage of total employment), the growth of livestock density per head and per hectare.
3. To find out whether government policy, in particular the measures to protect agriculture against the cheap imports of American cereals, influenced the course of agricultural change, a very crude variable was introduced in the equation. For countries without protectionist policies like the United Kingdom, Denmark, and the Netherlands this variable was zero, for countries which erected high tariff walls for agricultural products like Germany, Italy, France, Sweden and Austria-Hungary it was two and for the intermediate cases like Belgium and Switzerland it was

Table 10. Percentage of holdings on which the farmer used his own or hired mechanical treshers, reapers or sowing machines at about 1905.

country	date	treshers	reapers	sowing machines
percentage of holdings where they were used				
Germany	1907	29.3	6.1	5.9
Switzerland	1905	20.8	13.9	1.7
Austria	1902	11.5	0.5	2.6
percentage of holdings where they were owned				
Netherlands	1904	5.0	2.0	2.7
Belgium	1910	6.2	5.1	3.2
France	1892	4.1	1.1	0.9
Norway	1907	-	19.9	2.8
Hungary	1895	5.3	0.4	4.1

Sources: F. Dovring, 'Transformation', 644; Brugger, Landwirtschaft, 56; Sandgruber, Agrarstatistik, 117; Van der Poel, Landbouwmechanisatie, 213; Katus, 'Growth', 96 and agricultural censuses published in statistical yearbooks for the total number of holdings.

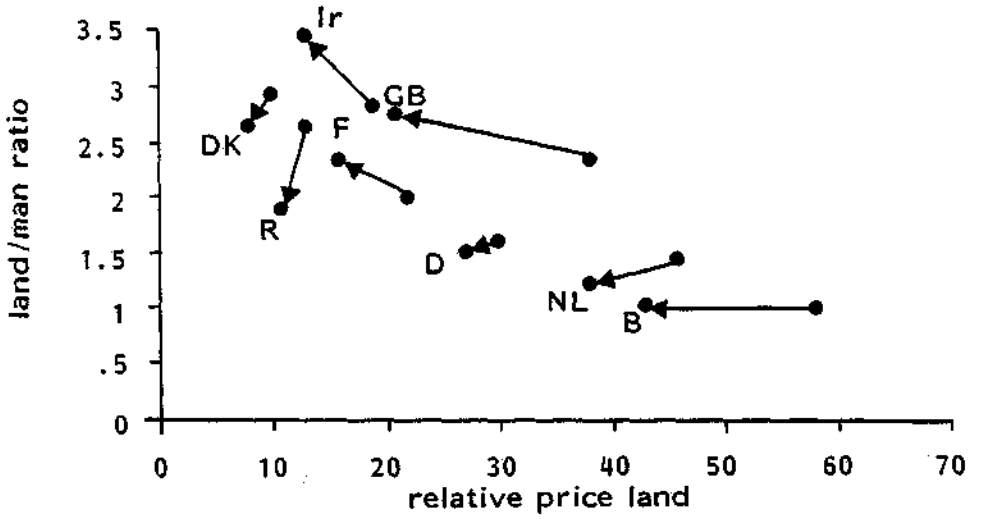


Figure 9

Relative Factor Endowments and the Relative Price of Land versus Labour, 1870-1910.

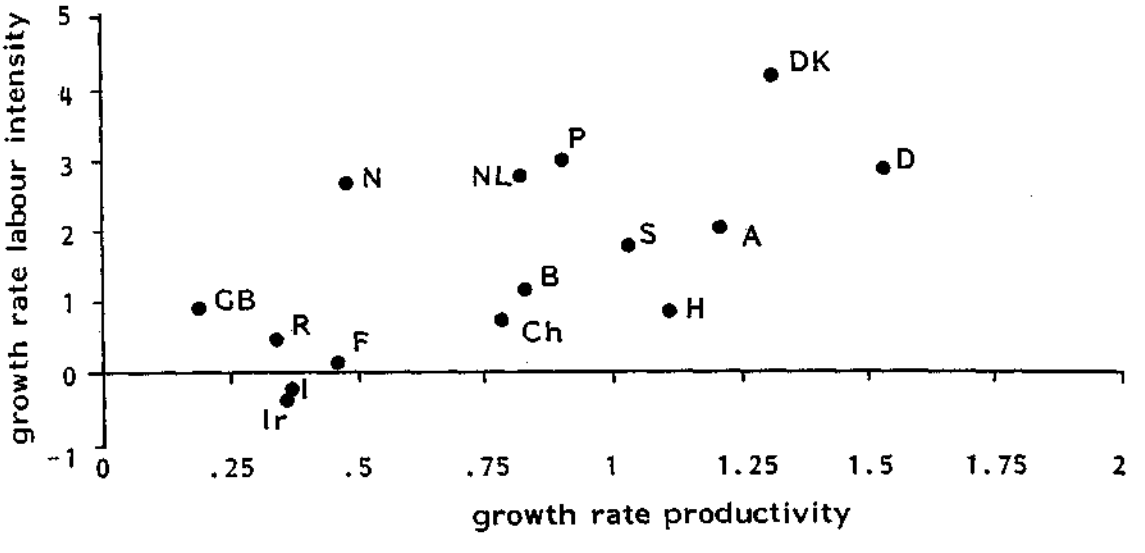


Figure 10

The Growth of Total Productivity and the Growth of the Labour Intensity of the Product Mix, 1870-1910.

one. (63)

Table 11 shows the statistically significant results of the multiple regression analysis. The growth rate of labour productivity and of total productivity is best explained by the combination of two variables, the growth rate of the labour intensity index and the proxy which 'measures' the direction of government policy. All other variables fail to explain the international differences in the growth of agricultural productivity: only the growth rate of the livestock density per head of the agricultural of the agricultural population is almost significantly correlated with the growth of labour productivity.
The relation between productivity growth and the increase of the labour-intensity index is indeed rather strong, as can be seen from Figure 10. This confirms the land-saving and labour-using bias in technological change. The fact that there is no clear correlation between the growth of fertilizer consumption and productivity growth results from the fact that in some countries of medium or low productivity high growth rates were still possible without the consumption of large quantities of fertilizer.

The significant positive correlation between protectionism and productivity growth is rather surprising. The inverse relation, that free trade stimulated rapid agricultural growth in Denmark and the Netherlands, and that protection hampered it in France and Italy, has received much more attention from economic historians. (64) But it seems that the positive effects of protection are underestimated in the prevailing view. On average countries with policies to protect the agriculture clearly did better than countries without them. (65)

All other variables hardly contributed to the explanation of international differences in productivity growth. The coefficients of the variables 4, 5 and 9 were consistent with theoretical expectations, but the regression results were not significant at the 5 percent level. The variables 3 and 10 clearly dominated the explanation of productivity growth.

Finally the question should be posed why some countries like the Ireland, Britain, France and Italy were unable to adopt the new land-saving innovations, whereas others were very successful in doing so. The analysis of this problem will be restricted to the poor performance of British agriculture in this period, which is certainly the most surprising development in European agriculture after 1870. Whereas the agriculture in Britain played a leading role in the transformation of European agriculture in the period 1750-1880, being the breeding ground of many innovations and the place where they were adopted on the largest scale, it suddenly lost its position in the forefront of change and stagnated for almost 60 years - until about 1930. (66)

A number of factors may help to explain the sudden change after 1870. As has been shown, the most important incentive for continental farmers to adopt the new land-saving inputs was the favourable development of the price of these inputs relative to the price of land. Whereas the price of land still increased on the continent, apart from France, after 1870, the prices of fertilizers and concentrated feeds fell by 40 percent or more. In the United Kingdom, land prices and rents were relatively high in 1870, fell almost continually afterwards until 1900, after when they increased slightly. In

Table 11. The explanation of international differences in the growth of total productivity and labour productivity, 1870-1910.

	R^2	F
Growth rate total productivity		
var 1 = 0.477 C + 0.201 var 3	.45	10.7*
(3.88) (3.27)		
var 1 = 0.179 C + 0.245 var 3 + 0.248 var 7	.78	20.7*
(1.64) (5.79) (4.16)		
var 1 = 0.277 C + 0.011 var 4 + 0.708 var 5	.27	2.2
(1.06) (1.28) (1.77)		
Growth rate labour productivity		
var 2 = 0.320 C + 0.255 var 7 + 0.198 var 3	.57	8.1*
(2.08) (3.03) (3.32)		
var 2 = 0.627 C + 0.153 var 3	.25	4.3
(4.24) (2.07)		
var 2 = 0.585 C + 0.462 var 6	.22	3.8
(3.41) (1.94)		
var 2 = 0.685 C + 0.185 var 7	.18	2.9
(4.80) (1.71)		

* - significant at the 1 percent level
C - constant
var 1 - growth rate total productivity
var 2 - growth rate labour productivity
var 3 - growth rate labour intensity product mix
var 4 - total increase in fertilizer consumption per hectare, 1880-1910
var 5 - growth rate non-agricultural employment (as a share of the total labour force)
var 6 - growth rate livestock density per head of the agricultural population
var 7 - proxy for level of protection offered to agricultural sector

Britain the average rent per hectare dropped from about 91 shillings in 1870 to about 66 shillings in 1910, a drop of 27.5 percent. (67) So the price of fertilizers and concentrated feeds relative to the land price fell much less than on the Continent. In France, the other core country that did not participate in the 'green revolution' of these years, land prices also fell by more than 20 percent (Appendix, Table A.2). So British and French farmers had rational motives for not increasing the purchase of the new land-saving inputs as rapidly as farmers in the rest of Western Europe.

To some extent it is problematic to determine what was cause and what was effect. The rise in land prices in the other countries was also the result of the fact that farmers adapted very well to the changing economic circumstances, and that they increased agricultural productivity and therefore were able to pay higher rents and higher land prices. In Britain and France landowners were forced to lower rents as incomes in agriculture declined and productivity stagnated. So this purely economic explanation is not completely satisfactory.

The different farm structure in Britain compared with most Continental countries may also help to explain the stagnation of agriculture there. Large holdings which were dependent on wage labour clearly dominated British agriculture, whereas Continental agriculture was increasingly practised on small family farms. In a detailed analysis of available statistics F. Dovring has shown this striking contrast in farm structure: whereas the median British farm employed about eight men in 1900, comparable continental farms employed only 3 to 5 men, Italy and Austria being the main exceptions to this rule.(68) For the small family farms of continental agriculture the rapid rise of wage costs after 1870 was not a major obstacle to further productivity growth, as these farmers did not hire much labour. Instead they profited very much from the new land-saving technology which made it possible to reduce underemployment and intensify production. (69) So the seemingly paradoxical development of a much more labour-intensive product mix combined with a sharp rise of the real wage level, may also to some extent be explained by the increased self-exploitation of these farmers, who were prepared to work on their own land for incomes that remained below the going wage rate. (70) Such a course of action was not open to British farmers, who used much wage labour and really had to pay the much higher wages.

The almost stagnating development of the institutional superstructure of British agriculture is a third element in the explanation of its relative decline. After about 1890 cooperatives began to play an important role in the transformation of agriculture on the Continent. Credit cooperatives supplied the working capital for the purchase of the new inputs and the enlargement of the livestock, marketing cooperatives created efficient trade channels for the new inputs, and the increased market surplus and cooperative dairy factories brought the great advantages of the centrifugal cream separator within the reach of the small farmer. (71) In Scandinavia, the Low Countries (apart from Wallonia), Germany, Switzerland, Ireland and large parts of Eastern Europe cooperatives fundamentally reorganised rural markets. By 1910 in these countries most farmers were a member of some kind of cooperative. (72) Almost nothing of this kind occurred in Britain, France and Southern Europe. There the membership of cooperatives remained restricted to a small minority of farmers. (73)

Again cause and effect are hard to distinguish: the rapid development of the cooperative movement on the Continent was to same extent a by-product of the transformation of agriculture, which gave rise to increasing strains on existing rural markets and thereby to the need to reorganize the marketing system.

Equally absent from Britain were state-sponsored agricultural extension services. Although the first agricultural experimental station had already been set up in Rotherhamsted in 1843, it was the Germans who set the example in the organization of a more or less nation-wide system of agricultural research and extension services, largely sponsored by the state. (74) Between 1870 and 1914 a number of core countries adopted the German model, as did the United States and Japan, but in the United Kingdom and France these institutions were only set up after the First World War. (75)

With its relatively high land-man ratio, its large consolidated farms and the important role wage labour still played in its agricultural labour force, Britain would have profited most from new labour-saving technologies. The relatively slow development of this kind of technological progress also contributed to the stagnation of British agriculture up to about 1930. (76)

So the diverging development of the agriculture in the countries of Western Europe on the one hand and of Britain - and France and Italy - on the other hand was clearly connected with different farm structures and institutional development. The continental family farms profited highly from innovations and were able to increase output and productivity in spite of unfavourable economic circumstances. The large 'capitalist' farmers in Britain, and perhaps also their continental counterparts in the Bassin Paris and in southern Italy, were unable to adapt to these circumstances in a successful way, so they sacked their labourers, extensified production and awaited better times.

5.Conclusion.

The main conclusions may be summarized as follows. European agriculture in 1870 was characterized by large differences in agricultural productivity, which can be discerned in two dimensions:

1. Different factor endowments in particular different land-labour ratios, resulted in corresponding relative factor prices and in large differences in the labour intensity of the product mix. Countries with an unfavourable land-labour ratio like Belgium and Italy specialized in relatively labour-intensive crops, whereas in countries with a high land-labour ratio like Denmark and Britain much less labour-intensive crops were grown. This resulted in different combinations of land productivity and labour productivity.
2. Different levels of total agricultural productivity were closely related to the level of development of the entire economy. A more advanced level of economic development resulted in a growing urban demand for agricultural products and the gradual disappearance of chronic shortages of working capital on the countryside. Low-productivity agriculture did occur in countries with a small non-agricultural sector an a low livestock density (the latter is used as an indicator of the lack of

working capital).

Technological progress in agriculture in the period 1870-1914 was characterized by a strong land saving bias. The most important innovations were the chemical fertilizers, concentrated feeds, the mechanical cream separator and in the field of marketing, the cooperative movement. All these innovations tended to strengthen the economic position of small family farms. In spite of rapidly rising real wages, the growth of agricultural productivity was clearly connected with a rise in the labour intensity of the product mix, which was made possible by the adoption of land-saving innovations and the rise of the small family farm. The protection offered by various European governments against the worst consequences of the fall of cereal prices after 1875 also seems to have stimulated the growth of productivity in these countries. Most surprisingly in the period 1870-1914 is the stagnation of British agriculture, which in 1870 was still at the forefront of agrarian development. Some underlying causes of this stagnation, mainly connected with the institutional structure of British agriculture, have been suggested.

Appendix. The data base.

1. Countries.
All data relate to the territory of the countries mentioned within the borders of 1913. This means that Poland is the part of Russian Europe known as Congress Poland, Austria and Hungary are the two parts of the Habsburg Empire, Elzas-Lotharingen is part of Germany and that Ireland is the combination of present day Northern Ireland and the Republic of Ireland. In this paper, Britain refers to England, Scotland and Wales, while the United Kingdom refers to these plus Ireland. The Russian data are restricted to the fifty gubernyas of European Russia.

2. Agricultural population.
This variable is estimated by multiplying the share of the male labour force working in agriculture with the total population (see paragraph 2). For some countries of which official statistics of the agricultural population are available, like Austria and Belgium, the variable estimated in this way hardly differs from the official figures. In Poland and Russia only one official census was held in 1897. Its data were extrapolated into estimates for 1870 and 1910 on the basis of data for the growth of the rural population.

3. Area under cultivation.
Official estimates of the total area under cultivation in Norway, Hungary, Russia and Italy in 1870 were missing and have been made by the author, mainly based on the 1910 data and an assumed increase of the area, which was mostly based on the increase of arable land. As the increase in the area under cultivation was in most countries very low, this could be done without harming the final results very much.

4. Livestock.
Only for Poland and Russia do the statistics on the livestock population seem rather unreliable; in all other countries these statistics were based on periodic counts which showed consistent results. The data were converted into livestock units using the following weights: horses and cattle 1.0, pigs 0.2 and sheep 0.1.

5. Agricultural output.
Gross output was estimated by adding the estimated output of 26 products, using relative world market prices, and by taking the price of one tonne of wheat as a numerator (text, paragraph 2). These 26 products were: wheat, rye, spelt, barley, oats, maize, buckwheat, rice, mixed corn, pulses potatoes, sugar beet, flax and hemp (both linen and seed), wine, olive oil, citrus fruits, beef, veal, pork, mutton, milk and wool. No data on horticultural products, especially important in the Netherlands and Italy, nor on the products of forestry and fishery were collected. Also same rather minor products like eggs, poultry, goat milk, cole-seed and rape-seed were not taken into account. The output of livestock products sometimes had to be estimated indirectly on the basis of estimates of meat consumption, as official figure were missing (e.g.Russia). The estimates for 1870 are therefore particularly subject to rather large margins of error. In most exercises the estimates of gross output in 1870 prices were used. As is shown in Table A.1, differences between estimates in 1870 and in 1910 prices were about the

Table A.1. Main data on output and inputs.

	Agricultural Population[a]		Cultivated Area[b]		Livestock[c]		Gross Output[d] prices 1870		prices 1910
	1870	1910	1870	1910	1870	1910	1870	1910	1910
Denmark	927	1,090	2,700	2,880	1,829	3,155	2,306	4,678	5,496
Britain	5,327	4,702	12,300	12,990	9,944	11,762	12,455	13,203	15,387
Netherlands	1,432	1,798	2,050	2,154	1,809	2,598	2,713	4,532	5,539
Belgium	1,950	1,958	1,920	1,943	1,779	2,514	2,999	4,420	5,340
France	17,916	15,971	36,000	37,000	19,000	20,821	32,604	37,841	43.328
Ireland	2,944	2,371	8,227	8,236	5,026	5,933	4,728	5,016	6,187
Norway	861	748	800[f]	987[f]	1,322	1,463	908	1,118	1,365
Sweden	2,038	2,109	3,292	3,646	2,615	3,595	2,858	4,763	5,663
Germany	22,216	23,137	35,400	34,800	23,054	31,236	29,309	57,043	68,776
Switzerland	1,374	1,197	2,150	2,300	1,215	1,723	1,509	2,074	2,527
Italy	16,349	19,205	19,000	20,773	5,087	8,856	14,914	21,025	23,197
Poland	4,100	7,250	8,100	9,200	4,738	8,000	3,688	7,926	9,707
Russia	45,150	68,700	120,000	130,000	43,350	59,670	48,897	74,495	84,427
Hungary	10,829	13,368	18,000	21,400	9,511	12,014	8,799	16,697	18,646
Austria	13,701	15,170	18,399	18,367	9,871	12,565	9,923	17,473	21,013
Spain	-	13,000	-	40,683	-	4,899	-	13,386	14,676
Europe[e]	147,114	178,774	288,338	306,676	140,149	185,906	178,608	272,303	316,598

a in thousands
b in thousand hectares
c in thousand livestock units
d in thousand wheat units (= one tonne of wheat)
e fifteen countries (excluding Spain)
f probably too low

Table A.2 Wages, rental values and wheat prices.

	currency	Daily wage agricultural labourer		Rent per hectare		Wheat price per tonne	
		1870	1910	1870	1910	1870	1910
Denmark	Kroner	1.3	2.8	14	21	209	137
Britain	Shilling	2.4	3.1	91	66	249	148
Netherlands	Gulden	1.0[a]	1.5	45[a]	55	133[a]	107
Belgium	Franc	1.9	2.5	110	110	309	194
France	Franc	2.3	3.0	53	41	306	255
Ireland	shilling	1.3	1.8	24	24	240	145
Norway	Kroner	1.4	2.7	-	-	181	150
Sweden	Kroner	1.2	2.5	-	-	183	147
Germany	Mark	1.2	2.0	36	55	224	203
Switzerland	Frank	2.5	3.8	-	-	310	225
Italy	Lire	1.5	2.4	-	-	310	290
Poland	Rouble	-	0.7	-	-	-	73
Russia	Rouble	0.5[b]	0.8	6.9[c]	6.8[d]	61[b]	68

a - 1880
b - 1882
c - 1887/88
d - 1901

same for the countries studied, varying from 10 percent in Italy and Spain to 23 percent in Ireland. As a result this choice of a set of relative prices had no influence on the outcome of the analysis.

6. Prices of products.
To estimate the 'world market' prices of table 1, data on agricultural prices in Sweden, Russia, Belgium, Switzerland, the Netherlands, Germany, France, Italy and Ireland were collected. The sources are mentioned in the following summary of statistical and historical publications.

7. Wages of agricultural labourers and prices of land.
These data were rather difficult to collect. Only for eight countries were estimates of land prices or rental values available, and for Austria, Hungary and Spain no statistics on wages in agriculture were found either. For Germany and Denmark land prices were converted into rental values by assuming an annual rent of 3 percent of the land price, which was about the average percentage in Belgium and France.

8. Other inputs.
The statistical sources of the other inputs are mentioned in Tables 4, 8, 9 and 10.

9. A note on biases in the estimation of productivity.
There are two serious biases in the estimates of productivity presented here. As mentioned in the text of paragraph 2, the share of the agricultural population that is really active in agriculture was probably smaller in the more prosperous countries, where children began to attend schools regularly and women began to restrict themselves to household activities. As a result, agricultural productivity in the more developed countries may be relatively underestimated.
The other bias works in the opposite direction. As complete data on intermediate inputs like concentrated feeds, fertilizers, the share of the arable crop fed to the livestock and the value of depreciation of agricultural machinery, were missing, the net output could not be estimated. The importance of most inputs increases rapidly with rising productivity. The only intermediate input which becomes less important is the quantity of seed used, as yield ratio's rise with rising productivity. This does cancel out some part of the growing use of purchased inputs, as Table A.3 shows. Still, net output in the core countries was probably about 70 per cent of gross output, or even less in some cases, whereas in Eastern Europe this percentage was probably about 80 percent. So by using estimates of gross output, agricultural productivity in the (semi-)peripheral countries is relatively somewhat underestimated. Both biases mentioned will probably, as a rule, largely cancel each other out.

10. Tests of the accuracy of the estimates of agricultural production
As a rule, the statistics for the area under cultivation and for the output of vegetable products were fairly accurate, but the figures for animal production were scarce and subject to large margins of error. To test the latter figures and estimates, simplified fodder balances were reconstructed for the year 1910, in which the food value of the output of hay and the consumption of concentrated feeds was compared with the output of the livestock sector. The yield of hay per hectare was taken as proxy of the total land productivity of the livestock sector, as reliable and comparable

Table A.3 Estimates of the share of seed, fertilizer and concentrated feeds in gross output (in percentages and prices of 1910).

	seed		fertilizer	conc.feeds
	1870	1910	1910	1910
Denmark	7.0	3.9	1.1	13.7
Britain	4.4	3.2	2.3	21.9
Netherlands	4.8	3.2	7.6	14.2
Belgium	7.6	3.9	5.2	12.9
France	9.1	7.8	2.2	-
Ireland	7.0	3.7	(2.3)	(21.9)
Sweden	9.5	6.6	1.7	-
Norway	4.9	4.0	1.2	-
Germany	10.9	6.2	3.6	4.9
Switzerland	4.3	1.9	0.8	7.1
Italy	6.6	5.3	1.4	-
Russia	16.2	14.6	0.1	-
Hungary	13.2	9.5	(0.6)	-
Austria	14.2	9.4	(0.6)	-
Spain	-	7.6	1.0	-

Sources: Tables 8 and 9.

Table A.4 The output of livestock products and the production and consumption of fodder per hectare of non-arable land (including fallow land) in 1910.

	(1) output of livestock products (wheat units: prices 1870)	(2) (1) as a percentage of total output per hectare	(3) average yield of haylands (tonnes per hectare)	(4) average consumption of concentrated feeds per hectare of non-arable land (tonnes)	(5) (3) + (4) in food values [a]	(6) (1)/(5) estimated productivity livestock sector
Denmark	1.72	106	3.7	0.5	4.7	0.37
United Kingdom [b]	0.66	77	3.6	0.3	4.2	0.16
Belgium	2.23	98	4.1	0.8	5.7	0.39
Netherlands	2.12	101	4.2	0.6	5.4	0.39
France	0.63	62	2.7	-	2.9[c]	0.22
Norway	1.00	88	3.1	-	3.3[c]	0.30
Sweden	1.35	103	3.4	-	3.7[c]	0.36
Germany	1.48	90	4.3	0.2	4.8	0.31
Switzerland	0.76	84	-	0.1	-	-
Italy	0.34	34	1.6	-	1.7[c]	0.20
Poland	0.51	59	2.2	-	2.3[c]	0.22
Russia	0.40	69	1.3	-	1.4[c]	0.29
Hungary	0.34	43	-	-	-	-
Austria	0.66	69	2.8	-	2.9[c]	0.23

a. the food value of concentrated feeds (especially of the oil seed cakes) was at least two times as high as the food value of hay.
b. Britain and Ireland.
c. estimated (consumption of concentrated feeds almost negligible).

Table A.5 Estimates of the growth of agricultural production (or value added), 1870-1910 (in percent).

	Van Zanden	Others	
Denmark	103	71	Hansen
United Kingdom	6	8	Ojala
France	16	25	Toutain
Germany	95	87	Hoffmann
Sweden	67	77	Krantz and Nilsson
Italy	41	35	Istat (Indagina)
Poland	115	119	Kostrowicka
Russia	52	ca. 80	Goldsmith
Austria	76	78	Sandgruber
Hungary	90	127	Katus

statistics on the output of other fodder crops were not available for most countries.

Table A4 presents the most important data. From columns (1) and (2) it appears that international differences in the productivity of the livestock sector were even larger than in agriculture as a whole. Only in the countries with a very well developed livestock sector like Denmark, the Low Countries and Sweden, was the production per hectare of non-arable land as high as total land productivity agriculture. In the other countries, where livestock farming was mostly practised rather extensively and where a lot of less fertile land was used, production per hectare remained below that in the arable sector. This was also reflected in international differences in hay yields, which varied from more than 4 tonne per hectare in the Low Countries and Germany to 1.3 tonne in Russia (column (3)). When the even larger international differences in the consumption of concentrated feeds were added, it was clear that many of the differences in the productivity of the livestock sector could be explained by differences in the supply of fodder (column (6)). The correlation between column (1) and (5) is very high ($r = .92$, significant at the 1 percent level), differences in the supply of fodder explaining 84 percent of the international differences in the productivity of the livestock sector. Only the very low productivity of British livestock farming cannot be explained in this way.

A final test of the estimates produced here is to compare the growth of agricultural production with independent estimates for various countries, made by independent authors. Table A.5 presents this comparison. Although there are some striking differences, which may be the result of the use of different concepts, or, as in the case of Russia, of somewhat different geographical areas, these differences are much less pronounced than the very large similarities. The comparison shows that my estimates are reasonably accurate.

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23. Chorley, 'Agricultural revolution',; large parts of (Western)Germany probably also belong to this first region.
24. For Spain see Figure 6. The available statistics on cereal production in Romania and Bulgaria point in the same direction, see Mitchell, Statistics, 208, 212, 245, 250.
25. R. Sandgruber, Osterreichische Agrarstatistik 1750-1918 (Wien, 1978) 177-181, 213-215; S. Kieniewicz, The emancipation of the Polish peasantry (Chicago, 1961) 190-195, 203-210, 221-226.
26. F.M.L. Thompson, 'The land market in the nineteenth century', in: Minchington (ed.), Essays, 50-51. For differences in the quality of the land between France and the United Kingdom: O'Brien and Keyder, Economic growth, 109-111.
27. Van Zanden, Ontwikkeling, 92, 137.
28. Dovring, Land, appendix 4.
29. See Dovring, Land, 125.
30. R.D.Crotty, Irish agricultural production (Cork, 1966) 66-84; L.M. Cullen, An economic history of Ireland since 1660 (London, 1972) 137.
31. Hayami and Ruttan, Agricultural development.
32. B.F. Johnston and P. Kilby, Agriculture and structural transformation, (London, 1975) 34-48.
33. F.M.L. Thompson, 'The second agricultural revolution, 1815-1880', Economic history review, XXI (1968/69) 69-71.
34. Thompson, 'Agricultural revolution', 68.
35. E.J.T. Collins, 'Labour supply and demand in European agriculture 1800-1880', in: E.L. Jones and S.J. Woolf (eds.), Agrarian change and economic development (London, 1969) 74-76; F. Dovring, 'The transformation of European agriculture', Cambridge economic history of Europe VI (Cambridge, 1965) 643.
36. Dovring, 'Transformation', 647-649.
37. Van Zanden, Ontwikkeling, 133-134.
38. See note 20.
39. See the studies mentioned in note 21.
40. This characteristic of the Russian rural economy was the basis of Chayanov's famous theory of peasant economy; see A.V. Chayanov, 'The theory of peasant economy ', in: D. Thorner, B. Kerblay and R.E.F. Smith (eds.), A.V. Chayanov on the theory of peasant economy (Homewood, 1966)
41. The population of the fifteen countries studied here rose from 265 million in 1870 to 388 million in 1910, by on average 0.96 percent per annum.

42. This may have been the result of a decline of agricultural productivity in the period 1860-1910; see J. Vives Vicens, An economic history of Spain (Princeton, 1969) 646.
43. Hayami and Ruttan, Agricultural development, 111-120.
44. Van Zanden, Ontwikkeling, 260-261.
45. H. Brugger, Die Schweizerische Landwirtschaft 1850-1914 (Biel/Zurich) 262-265; Wade, Determinants, 294-330; D. Andrews, M. Mitchell, A. Weber, Comparative time series 1870-1975, in: R. Cecil (ed.) The development of agriculture in Germany and the U.K. (Kent, 1979) III, 84; Bublot, Production, 63-65.
46. These figures are different from those published by Dovring, 'Transformation', 656, mainly because I calculated average comsumption per hectare of total cultivated land (including pastures) and Dovring calculated consumption per hectare of arable land.
47. For instance, Van Zanden, Ontwikkeling, 242.
48. Van Zanden, Ontwikkeling, 288.
49. See also Dovring 'Transformation' 656.
50. Andrews a.o., 'Comparative time series', 84.
51. E.M. Ojala, Agriculture and economic progress (London, 1955) 213.
52. Wade, Determinants, 213-215.
53. Hayami and Ruttan, Agricultural development, 137-138; Van Zanden, Ontwikkeling, 289-290; Bublot, Production, 278-285.
54. E.H. Whetham, The agrarian history of England and Wales, VIII 1914-1939 (Cambridge, 1978) 7.
55. Dovring, 'Transformation', 641-642.
56. Dovring, 'Transformation', 647-649; Collins, 'Labour supply', 74-76.
57. For instance J.A.Perkins,'Farm mechanization and labour in Germany 1850-1914' in: H.Winkel and K.Herrmann (eds), The development of agricultural technology in the 19th and 20th centuries (Ostfildern, 1984) 59-77; even Britain was no exception to this rule, see Whetham, History, 41-42.
58. E. Jensen, Danish agriculture (Copenhagen, 1937) 174-178; Dovring, Land, 208-209; Wade, Determinants, 52-53; Whetham, History, 11, 22-23.
59. Van Zanden, Ontwikkeling, 272; Jensen, Agriculture, 317-318.
60. Dovring, 'Transformation', 644; J.M.G. van der Poel, Honderd jaar landbouwmechanisatie in Nederland, (Wageningen, 1967) 212.
61. Dovring, 'Transformation', 643-647; Whetham, History, 41-42; Bublot, Production, 238-239; Perkins, Mechanization, 76.
62. The growth rate of fertilizer consumption in this period cannot be used as a variable as consumption was still (close to) zero in many countries in 1870.
63. Based on Tracy, Agriculture, 3-123, and the country-studies in A. Milward and S.B. Saul, The economic development of continental Europe (London, 1973) and A. Milward and S.B. Saul, The development of the economies of continental Europe (London, 1977).
64. Tracy, Agriculture, 3-123.
65. The average annual growth rates of agricultural productivity of countries without and with significant protection for the agriculture were 0.66 and 1.03 per cent respectively.
66. Wade, Determinants, 39; Ojala, Agriculture, 210.
67. One additional factor might have been the loss of political power and prestige attached to the ownership of land, see Thompson 'Land market', 50-51.
68. Dovring, Land, 109-112.
69. Small farmers also profited from one major labour-saving technology, i.e.

the centrifugal cream separator, especially when the factory was organised on a cooperative basis; Van Zanden, Ontwikkeling, 263-269; Jensen, Agriculture, 317-318.

70. Chayanov, Theory, Chapter VI, for the theoretical analysis of this phenomenon; see also Wade, Determinants, 194-198; Van Zanden, Ontwikkeling, 335.
71. Dovring, Land, 199-212; Jensen, Agriculture, 318-323; Van Zanden, Ontwikkeling, 273-281.
72. Dovring, Land, 199-212.
73. Dovring, Land, 196; E.J.Hobsbawm, Industry and empire (London, 1968) 168-169.
74. Hayami and Ruttan, Agricultural development, 137-138.
75. Hayami and Ruttan, Agricultural development, 138-142; Wade, Determinants, 61-62, 236-237; Bublot, Production, 278-285; in Denmark the state also played a minor role in the setting up of experimental stations and extension services, Jensen, Agriculture, 178-181.
76. The agriculture in the United States, which was also very land extensive and dependent on labour-saving technological progress, also stagnated between 1900 and 1930; Hayami and Ruttan, Agricultural development, 145-146.

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