

The first green revolution: the growth of production and productivity in European agriculture, 1870-1914

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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 per hectare.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 west European countries. This trend was only interrupted by the agricultural depression of 1818-35. 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 labourers expressed in kilograms of wheat doubled in almost all European countries between 1870 and 1910 (table 3).

¹ Slicher van Bath, *Agrarische geschiedenis*, pp. 243-62.

² Chorley, 'Agricultural revolution'.

³ Slicher van Bath, *Agrarische geschiedenis*, pp. 123-8.

⁴ See for instance Thompson, 'An inquiry'; van Zanden, *Economische ontwikkeling*, pp. 119-22; *Recensement de l'agriculture*, 1880 and 1895 (for Belgium).

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.

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 sharply increased the attractions 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 size structure of farm holdings, comparable to the trend in many branches of industry in this period; small-scale producers would have been forced to become 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 marked 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.⁵ 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, notably chemical fertilizers and purchased feed stuffs (maize and oilseed cakes), were typically land saving,⁶ and 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 shall attempt to explain this first 'green revolution'; why did some countries participate fully in these changes and why did others, especially Britain, whose prospects seemed so good in the 1870s, remain behind?

The analysis is based on a detailed database covering about 60 agricultural and economic variables for 16 countries. This database and the method for estimating international differences in agricultural productivity are described first.⁷ Then follows a cross-sectional analysis of international differences in agricultural productivity in 1870. Finally an attempt has been made to explain productivity growth during the period 1870-1910.

⁵ For the rapid decline of the number of agricultural labourers (and the rise of the family farm) in western Europe in these years: Fitzpatrick, 'The disappearance'; Ó Gráda, 'Agricultural decline', pp. 189-92; van Zanden, *Economische ontwikkeling*, pp. 331-7; Jörberg, *History*, II, p. 337; Wade, *Institutional determinants*, pp. 174-6.

⁶ Hayami and Ruttan, *Agricultural development*, pp. 111-5.

⁷ Full details are given in van Zanden, *The first green revolution*, which is available from the author on request.

I

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. By about 1870, detailed statistics on the area under cultivation, on the production of cereals and other arable crops, and on livestock were generally available.⁸ The exceptions were Britain, where statistics on cereal production were not collected until the 1880s, 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. In general, they probably underestimated the true values as they were often collected for tax purposes. Under-reporting was probably larger in countries like Britain which had just started to collect these statistics than in countries in which the series dated back to the first half of the century (for instance, France, Belgium, the Netherlands, and Ireland). As government bureaucracy grew more competent and the level of intervention in local affairs increased, the statistics became more accurate.⁹ Therefore, studies based on these statistics may tend to overestimate the growth of agricultural production, especially in the British case.

In spite of this rather broad database, little research has been done on international differences in agricultural productivity. The major problem has been the difficulties caused by the existence of national currencies, for which the rates of exchange might vary enormously over time and which were often out of line with real differences in purchasing power. The much debated study by O'Brien and Keyder, for example, 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.¹⁰ In a study of levels of agricultural productivity in five European countries in the period 1850-1980, van der Meer and van Ark adopted a different indirect approach. They converted real output and input series, taken from a number of country studies, into US dollars using 1975 purchasing power ratios.¹¹

The major drawback to these indirect approaches is 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 different countries. Moreover, in the van der Meer/van Ark approach, the biases of the time-series of the individual countries, all of which are calculated in different ways, tend to cumulate over time; as a result margins of error increase sharply with distance in time from the bench-mark year (1975).

An alternative approach is to make a direct comparison, in which all agricultural outputs (and inputs) are converted into one 'constant' numerator,

⁸ The most important statistics are collected by Mitchell, *European historical statistics*, pp. 197-334.

⁹ For instance Holgersson, 'Cultivated land'; Coppock, *Land use*, pp. 16-7; van Zanden, *Economische ontwikkeling*, pp. 202-3.

¹⁰ O'Brien and Keyder, *Economic growth*.

¹¹ I am grateful to Drs C. van der Meer and H. H. van Ark for allowing me to see their unpublished work on this subject.

for example wheat units or calories.¹² 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 analysed and relative prices of outputs and inputs change. So a somewhat modified direct method is used in this analysis, in which all inputs and outputs are converted to 'wheat units' using current world market price relatives.

In more detail the method adopted 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 output of arable products is calculated by multiplying the harvested area by the yield per hectare. The output of livestock products is estimated by multiplying the livestock by the yield per head (cow, pig, or sheep); for instance, the milk yield per cow varies from 2.5 tonne in the Netherlands to 0.7 tonne in Poland. The total area under cultivation, the agricultural population, and the livestock totals 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 calculations the price of a tonne of wheat is the numerator. The world market prices are taken from a large number of published prices for the individual countries, most relative prices in the countries of western Europe not diverging very much.¹³ The relative prices of a few products, especially olive oil, rice, wine, and, to a lesser extent, flax, potatoes, and milk, did vary significantly. In these cases the 'world market prices' were taken from price data for the most important centres of production, for example, in the case of subtropical products, Italy and France. In this way the index number problem is circumvented.

Statistics of the most important inputs were also collected. The estimates of the total area under cultivation were in some cases rather crude. This was especially true for rough grazing, particularly important in mountainous regions, which was included in some official statistics. Estimates of the agricultural labour force were even more problematic. First, in some countries, like Poland and Russia, no reliable occupational censuses were taken until the end of the nineteenth century. Second, 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.¹⁴

It proved impossible to reconcile 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 dependent on agriculture. This

¹² Bairoch, 'Niveaux'; Helling, 'Berechnung'.

¹³ This was especially true for relative prices in 1865/74. As a result of the much increased protectionism in Europe after 1875, international price differences increased after that date. I therefore used relative prices of 1865/74 in the greater part of the analysis; see for example Tracy, *Agriculture*, pp. 22-32.

¹⁴ Van Zanden, *Economische ontwikkeling*, pp. 67-76; Bairoch, *La Population*.

was estimated by multiplying the share of the male labour force working in agriculture by the total population. In this way the problem of estimating the female labour force was avoided.

Other parts of the database, such as statistics of other inputs (seed, fertilizer, feedstuffs) and of the prices of the main inputs, also posed problems. Only for eight countries could complete sets of estimates of all data be collected. Part of the analysis has therefore been restricted to a smaller set of countries.

II

In the nineteenth century the economic landscape of Europe was characterized by large international differences in the level of development. 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 Maddison, GDP per head in Russia was only about one-third of the British level; the rest of Europe varying between these extremes.¹⁵

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

Of course, there were very large international differences in agricultural productivity. Figure 1 shows these differences with respect to two variables: gross output per head of the agricultural population and gross output per hectare of land under cultivation. Three regions can be discerned in Europe. The first region, here called the core, was made up of countries with a highly productive agriculture (Denmark, Britain, the Netherlands, Belgium, and France). It is the region where the 'agricultural revolution' of the period 1750-1880 originated (i.e. in the Low Countries) and had spread.¹⁶ It formed a nucleus of labour-intensive and land-intensive agriculture. Four countries, Belgium, the Netherlands, Britain, and Denmark, were on what may be called the 'efficiency' frontier in 1870. With their specific resource combinations, these countries had realized the highest levels of agricultural production per hectare and per head.

The second group of countries, characterized by medium levels of productivity, lay in a circle around the core. In these semi-peripheral countries the level of productivity was about one-third lower than in the first region.¹⁷ In eastern Europe, the third region, this level again falls by one-third. In this third region labour productivity was, with the exception

¹⁵ Maddison, *Phases; idem, Economic growth*.

¹⁶ Chorley, 'Agricultural revolution'; Newell, 'Agricultural revolution'; see also the regions distinguished by Slicher van Bath, 'Yield ratios', p. 16.

¹⁷ The level of total productivity was measured on the basis of a Cobb-Douglas production function, in which land, labour, and livestock are weighted as 0.35, 0.50, and 0.15; these tentative weights are based on Bublot, *La Production*, p. 32-3, and van Zanden, *Economische ontwikkeling*, p. 125.

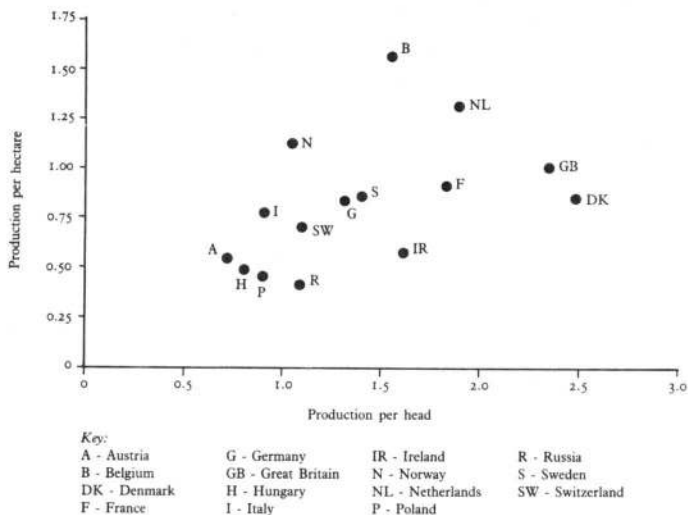


Figure 1. *Agricultural productivity in 1870: production per head of the agricultural population and production per hectare of cultivated land in wheat units*

Source: van Zanden, *First green revolution*, pp. 37-47.

of Russia, well below 1.0, or less than the equivalent of 1,000 kg of wheat produced per head of the agricultural population, and land productivity was about 0.5, or 500 kg of 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 (figure 5). The same probably holds true for the Balkan countries.

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.¹⁸ But the main pattern is clear: a core of very intensive and highly productive agriculture on the borders of the North Sea, a circle of countries with medium productivity consisting of most of the rest of present-day western Europe, including Italy,

¹⁸ Sandgruber, *Österreichische Agrarstatistik*, pp. 177-81 and pp. 213-5; Kieniewicz, *The emancipation*, pp. 190-5, 203-10, and 221-6.

and the 'periphery' of countries with low productivity in eastern and southern Europe.

There were large differences in relative factor endowments especially in the core region, as is clear from figure 1. In Belgium, only one hectare of cultivated land was available per head of the agricultural population; in Denmark, the other extreme case, the comparable figure was almost three hectares.

The different factor endowments resulted in large differences in relative factor prices (figure 2). In Belgium an agricultural labourer had to work almost 60 days to rent a hectare of land; in Britain the comparable figure was 38, and in Denmark only 10. Figure 2 shows that a clear relationship existed between the relative price of land and the land/man ratio for the eight countries for which these statistics are available. Only the dot for Britain is clearly above the regression line, which may point to the more capital-intensive nature of British agriculture.

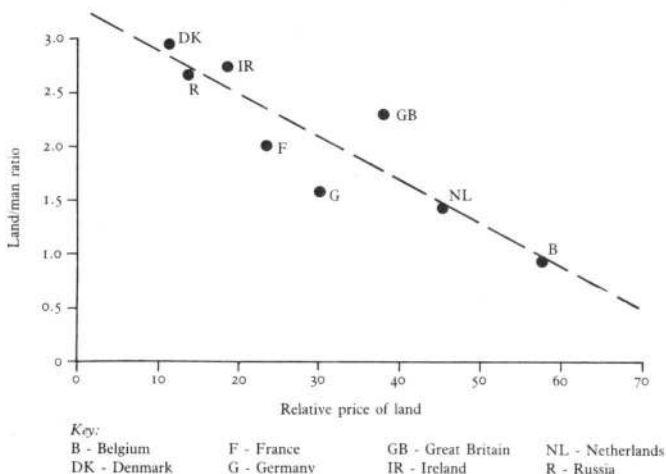


Figure 2. *Relative factor endowments and the relative price of land versus labour, 1870*

Source: see source note, fig. 1.

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. On the basis of data collected by Döring it seems clear 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.¹⁹ Comparable evidence of the labour intensity of livestock farming is less convincing. It is, however, clear that the production of pork and of milk was relatively labour intensive, unlike sheep-breeding which was often labour extensive. The share of the aforementioned labour-intensive products in total output was used to estimate the labour intensity of the product mix.

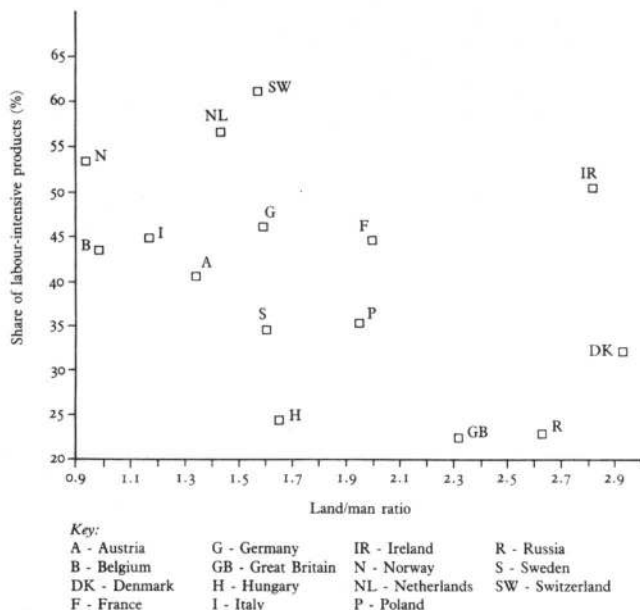


Figure 3. *The relationship between the land/man ratio and the share of labour-intensive products in output, 1870*

Source: see source note, fig. 1.

In figure 3 this share is set out against the land/man ratio. With the notable exception of Ireland, figure 3 shows a rough relationship between the labour intensity of the product mix and the available quantity of cultivated land per head of the agricultural population. The case of Ireland suggests that the adoption of labour-intensive crops may to some extent be a one-way process. The high score for Ireland 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

¹⁹ Dovring, *Land*, app. 4.

blight the land/man ratio improved again as a result of massive emigration, but these crops remained of great although somewhat declining importance. The extensification of Irish agriculture after 1850 took the form of a strong increase in livestock farming at the expense of arable farming.²⁰

It is also clear from figure 3 that productivity was almost independent of product mix. Britain, for instance, had about the same product mix as Russia and Hungary. Productive regions produced similar crops to unproductive 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 no more than 20 to 30 per cent of total gross output. In some core countries this figure was much higher, up to 64 per cent in the Netherlands and 48 per cent in Denmark, but in Belgium and France the percentage was also low, about 30 per cent, and in semi-peripheral countries like Switzerland, Ireland, and Norway it was again more than 50 per cent.

It is clearly 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, under the pressure of changing relative factor prices, and through the adoption of more labour-intensive crops, farmers were able to adapt to changing resource endowments; in most cases, growing population pressure.

III

An explanation for the large differences in the level of agricultural productivity is much more difficult 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 (e.g. fertilizers), or to substitute for land (e.g. concentrated feeds). When labour is the most important bottleneck, inputs like agricultural machinery are bought as a substitute. In this view rising productivity is the result of the development of increasingly efficient and profitable inputs and their adoption by farmers.²¹

A second hypothesis comes from the classical theory of economic growth. Low productivity is seen as the result of a low level of commercialization and specialization. In the absence of sufficient market outlets, 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 tends to involve large-scale indebtedness to outside creditors. Only a sharp increase of production for the market, induced for example by improvements in the rural infrastructure, will reduce the level of underemployment and stimulate a process of specialization and commercialization on the countryside.²²

²⁰ Crotty, *Irish agricultural production*, pp. 66-84; Cullen, *An economic history*, p. 137.

²¹ Hayami and Ruttan, *Agricultural development*.

²² Johnston and Kilby, *Agriculture*, pp. 34-48.

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 refuse 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.²³ 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.²⁴ In the same way the development and spread of new agricultural machinery in Europe was concentrated in Britain in the period before 1870, although the changes in British agriculture lagged behind those in the United States.²⁵

Table 1. *Consumption of chemical fertilizers and oilseed cake in 1870 and 1880 in some core countries*

	Fertilizers (kg per hectare)		Oilseed cake (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

Notes: ^a all concentrated feeds

^b probably insignificant

Sources: Wade, *Institutional determinants*, pp. 292-330; Andrews et al., 'Comparative time series', p. 72; Bublot, *La Production*, pp. 67-81; van Zanden, *De economische ontwikkeling*, pp. 226, 254.

There is some doubt whether these innovations were already of much importance by 1870 and therefore whether they played a large role in raising productivity. In about 1870 the new inputs were still not widely used. Only in the Low Countries and the United Kingdom were chemical fertilizers used on a significant scale, and the same was probably true of concentrated feeds (table 1). France and Denmark, both countries of high productivity, used almost no fertilizers and purchased feeds. Different levels of adoption of new inputs cannot in any case 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.²⁶

²³ Thompson, 'The second agricultural revolution', pp. 69-71.

²⁴ *Ibid.*, p. 68.

²⁵ Collins, 'Labour supply', pp. 74-6; Dovring, 'The transformation', p. 643.

²⁶ Dovring, 'The transformation', pp. 647-9.

The second hypothesis seems to offer a better explanation. To test the hypothesis, the following variables were correlated with the estimated level of total productivity (calculated on the basis of a Cobb-Douglas production function):

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 11 countries estimates of GDP per caput were also introduced as a variable.²⁷
2. 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 to indicate the level of capital intensity.
3. To check if the land/man ratio and the product mix influenced productivity, both variables were included in 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 2. *The explanation of international differences in the level of agricultural productivity in 1870 (equations that proved statistically significant at the 5 per cent level)*

	R^2	F
$\text{prod} = 0.142 c + 0.0213 \text{ share}$ (0.84) (6.02)	0.74	36.3
$\text{prod} = 0.595 c + 0.0010 \text{ GDP}$ (2.58) (2.97)	0.49	8.8
$\text{prod} = 0.327 c + 1.282 \text{ catt./hect.}$ (1.28) (3.23)	0.45	10.4

Notes:

- c: constant
 prod: estimated total productivity
 share: share of non-agricultural employment in total labour force
 catt./hect.: livestock units per hectare
 GDP: GDP per caput
 t-statistics are shown in parentheses

Source: van Zanden, *First green revolution*, pp. 37-47.

Table 2 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 total productivity and

²⁷ See n. 15.

explains more than 70 per cent of the variance of this variable. Agricultural productivity was also positively correlated with GDP per caput and livestock density per hectare.

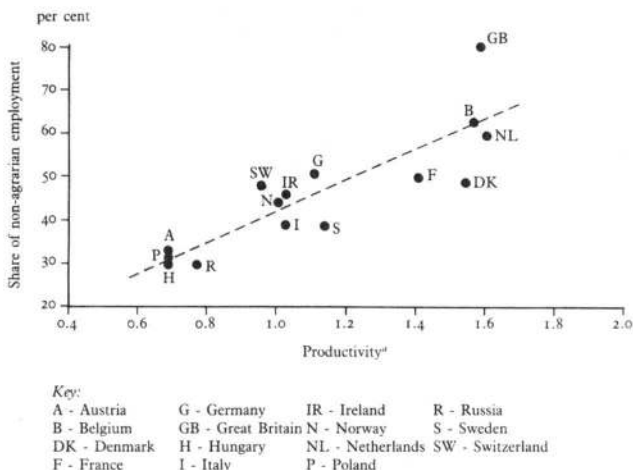


Figure 4. *Total agricultural productivity and the share of non-agrarian employment in the total labour force, 1870*

Note: ^a see n. 17 for a definition of productivity.

Source: see source note, fig. 1.

Figure 4 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 per cent of the population worked outside agriculture and in the semi-peripheral countries this figure was 40 to 50 per cent. In the core region there was a larger variance, 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 extent of the structural transformation of the economy and of the level of demand from the urban sector.²⁸ To put it more bluntly, a highly productive agriculture was always a part of a well-developed economy.

²⁸ For French evidence on the role of urban demand, see Grantham, 'Agricultural supply'.

IV

During the 1870s the economic tide turned for European agriculture. The price of cereals, which had reached a peak in the 1850s and again in the early 1870s, started to decline as a result of the sharply increasing exports of wheat and maize from America. Unfavourable weather in the late 1870s added to these difficulties by causing a succession of crop failures. In the 1880s cereal prices dropped very rapidly, and this continued until 1896, when the price of most cereals was less than half that of the early 1870s. 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 by only 10 per cent between 1865/74 and 1905/13, and in France the decline was 17 per cent, compared with about 40 per cent in countries without protection for cereal farmers like Britain and Denmark.

Table 3. *Real wages of agricultural labourers and meat consumption per caput in Europe, 1870-1910*

	Real product wages (in kg wheat)		Consumption 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 ^d	30 ^d

Notes:

^a production of meat per caput

^b 1881/3

^c 1880

Sources: van Zanden, *First green revolution*, pp. 20, 37-47.

On the input side of the production process there were also a number of rather unfavourable developments for European farmers. 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 product wages expressed in wheat rose by 80 per cent or more in almost all countries between 1870 and 1910, Russia and France being the main exceptions (table 3). As agriculture was very labour intensive, labour costs accounting for 30 to 50 per cent of total expenses, farmers faced great difficulties in keeping their costs down. At the same time the price of the other fundamental factor of production, land, was also rising. Farmers had to change their mode of production radically to meet the twin pressures of rising costs and rapidly falling output prices.

Rising real wages resulting in rising living standards were, of course, in another sense, more favourable to the agricultural sector, since they caused the consumption of agricultural products per caput to rise rather rapidly almost everywhere. The demand for items of consumption beyond the normal reach of those living close to bare subsistence, like most livestock products, rose especially rapidly, as did the demand for horticultural products in the core countries (table 3). Only in Russia did the level of meat consumption not increase. As a result of the sharply rising demand for livestock products and of the less intense international competition in this field, the price of livestock products rose relative to the price of cereals. Specialization in livestock farming was one of the ways in which farmers managed to meet the challenge of the agrarian depression.

In spite of these generally unfavourable circumstances, farmers in many countries succeeded in increasing production and productivity rather rapidly. As table 4 shows, European agricultural output increased by more than 1 per cent a year, marginally higher than the growth rate of the European population,²⁹ and total productivity increased by 0.65 per cent a year. As the area under cultivation hardly increased, the rate of growth of land productivity was almost as high as the increase of output; the rise of labour productivity was slower.

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 surprising are the diverging paths of development in the core countries: 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 growth of both 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 was still rising 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.

²⁹ The population of the 15 countries studied here rose by 0.96 per cent per annum from 265 m. in 1870 to 388 m. in 1910.

Table 4. *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 ^a
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

Note: ^a 15 countries

^a for definition, see n. 17

Sources: van Zanden, *First green revolution*, pp. 37-47.

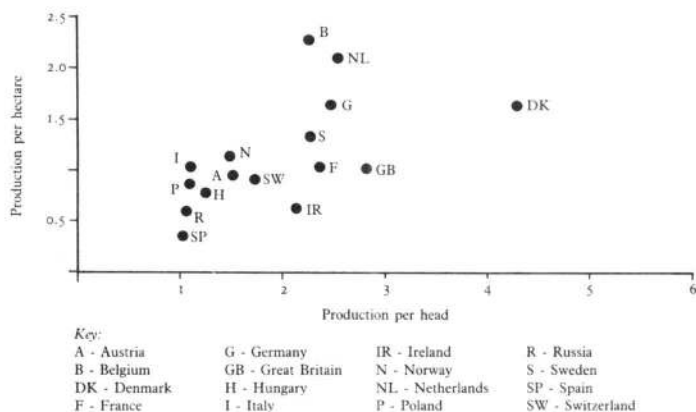


Figure 5. *Agricultural productivity per head and per hectare in 1910 (in wheat units and prices of 1870)*

Source: see source note, fig. 1.

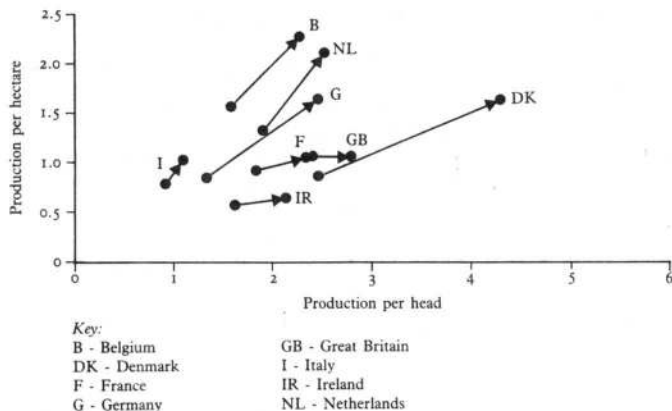


Figure 6. *The growth of agricultural productivity per head and per hectare in eight countries of western Europe, 1870-1910 (in wheat units and prices of 1870)*
 Source: see source note, fig. 1.

Figures 5 and 6 give a graphical presentation of these developments. The 'efficiency frontier' was pushed forward by the three small core countries in this period. Britain fell behind and Germany moved rapidly forward. Germany, Belgium, Denmark, and the Netherlands seem to have been the most successful in adapting to the changing circumstances. In figure 5 the position of Spain is also given. It reveals a very low level of agricultural productivity; labour productivity and land productivity here were even lower than in eastern Europe.³⁰

V

The explanation for these developments has to begin with a survey of the main changes in agricultural technology. According to the theory developed by Hayami and Ruttan, two kinds of technologies can be distinguished: land saving and labour saving. Both will be briefly considered.³¹

Land-saving technology developed very rapidly in the years after 1870. The key change was the spread of the use of chemical fertilizers, associated with a massive increase in their supply, 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

³⁰ This may have been the result of a decline in agricultural productivity in 1860-1910; see Vives Vicens, *An economic history*, p. 646.

³¹ Hayami and Ruttan, *Agricultural development*, pp. 111-20.

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 per cent and for phosphate by as much as two-thirds between 1880 and 1900, after which they remained almost stationary. This contrasted sharply with the period before 1880, when fertilizer prices rose.³² The fall in fertilizer prices seems to have been general. They fell by an average 55 per cent in Germany between 1880 and 1905/13, by 42 per cent in Switzerland between 1882 and 1910, and by 47 per cent in Britain between 1870 and 1910.³³ As importing countries profited greatly from the low level of fertilizer prices, high import duties were not imposed and the trade in fertilizers remained almost completely free. Fertilizer consumption rose rapidly, especially after 1896 when agricultural prices started to rise again. Compared to the relatively low level about 1880, consumption more than quadrupled in Germany, France, Belgium, and Denmark and doubled in the United Kingdom, which lost its leading position after 1880 (tables 5 and 1). In most other countries it rose from virtually nothing in 1880 to the level estimated in table 5 in 1910.

Table 5. *Fertilizer consumption in 1910*

	(1) Kg N + P ₂ O ₅ + K ₂ O per hectare	(2) N + P ₂ O ₅ + K ₂ O in grain units per hectare ^a	(3) Col. (2) as a percentage of gross production
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

Notes:

^a 1 tonne N is taken as equivalent to 7.5 wheat units, 1 tonne P₂O₅ as equivalent to 1.35 wheat units, and 1 tonne K₂O as equivalent to 1.5 wheat units (based on Dutch and German price data)

^b Britain and Ireland

^c including Spain

Sources: *International yearbook of agricultural statistics*, 1915, and van Zanden, *First green revolution*, pp. 37-47.

About 1910 the level of fertilizer consumption ranged from negligible quantities per hectare in eastern Europe to 30 kg per hectare or more in

³² Van Zanden, *Economische ontwikkeling*, pp. 260-1.

³³ Brugger, *Schweizerische Landwirtschaft*, pp. 262-5; Wade, *Determinants*, pp. 294-330; Andrews et al., 'Comparative time series', p. 84; Bublot, *Production*, pp. 63-5.

Germany, Belgium, and the Netherlands. 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 lagged behind. In these countries the average fertilizer consumption was about 10 kg per hectare, a quantity similar to that found in the semi-peripheral countries.

In the countries of high fertilizer consumption there was an important breakthrough in the technology of production. The costs of producing additional manure, or of buying it from the cities, in order to increase arable yields, had been rising rapidly before 1880. These costs reflected the use of land to grow cattle fodder, and the huge labour input to feed the cattle, to collect the manure, and to spread it on the arable land. 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. Chemical fertilizers reduced these costs dramatically. In the region of 'Flemish agriculture' this type of mixed farming, which dated back to the middle ages, disappeared during the 20 years after 1895.³⁴

The next most important development in land-saving technology was the rapid growth of the use 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. A second source of supply of concentrated feed, oilseed cake, 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 price of oilseed cake dropped almost as much as the price of wheat.³⁵ As the prices of livestock products dropped proportionately much less, it became more profitable to increase livestock production by purchasing concentrated feeds. Livestock farming could become much more land intensive, as purchased feeds were substituted for the land on which cattle fodder was grown.

Only in a few countries did the consumption of these feeds become really important. Again the core countries were to the fore; in Belgium, the Netherlands, Denmark, and Germany the consumption of oilseed cake, maize, and bran rose rapidly. But in the United Kingdom the level of consumption stagnated after 1880, following the rapid rise during the years of 'high farming' between 1850 and 1880.³⁶ In most semi-peripheral countries, imports of concentrated feeds remained unimportant: even in France this input was adopted on a very restricted scale.³⁷ Although data on the level of consumption of concentrated feeds are much less complete, it is clear that the spread of this innovation broadly 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

³⁴ Van Zanden, *Economische ontwikkeling*, p. 242 and p. 288.

³⁵ Andrews et al., 'Comparative time series', p. 84.

³⁶ Ojala, *Agriculture*, p. 213.

³⁷ Wade, *Determinants*, pp. 213-5.

Netherlands, this was greatly stimulated by extension services supported by or set up by the government.³⁸ Cattle breeds with superior milk or meat producing capacities were increasingly used to augment the quality of the livestock.³⁹

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 nineteenth century. The efficiency and durability of these implements was greatly enhanced by the change.⁴⁰ 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 too difficult to manoeuvre for practical use.⁴¹ 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.⁴²

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.⁴³ 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 their revenue from dairy farming by 25 to 50 per cent by participating in cooperative factories.⁴⁴ 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.

Threshing machines, on the other hand, were mainly used by large farmers to 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 per cent of all holdings in Germany. In other countries for which more or less reliable statistics are available, about 5 per cent of all holdings possessed one (table 6), but only a minority of these machines was steam-driven; in Germany about 30 per cent but in the Netherlands only about 4 per cent used steam power.⁴⁵

³⁸ Hayami and Ruttan, *Agricultural development*, pp. 137-8; Bublout, *Production*, pp. 278-85.

³⁹ Whetham, *Agrarian history*, p. 7.

⁴⁰ Dovring, 'The transformation', pp. 641-2.

⁴¹ *Ibid.*, pp. 647-9; Collins, 'Labour supply', pp. 74-6.

⁴² Perkins, 'Farm mechanization'; Whetham, *Agrarian history*, pp. 41-2.

⁴³ Jensen, *Danish agriculture*, pp. 174-8; Dovring, *Land*, pp. 208-9; Wade, *Determinants*, pp. 52-3; Whetham, *History*, pp. 11, 22-3.

⁴⁴ Van Zanden, *Economische ontwikkeling*, p. 272; Jensen, *Danish agriculture*, pp. 317-8.

⁴⁵ Dovring, 'The transformation', p. 644; van der Poel, *Honderd jaar*, p. 212.

Table 6. *Percentage of holdings on which the farmer used his own or hired mechanical threshers, reapers, or sowing machines, c.1905*

Country	Date	Threshers	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: Dovring, 'Transformation', p. 644; Brugger, *Landwirtschaft*, p. 56; Sandgruber, *Agrarstatistik*, p. 117; Poel, *Landbouwmechanisatie*, p. 213; Katus, 'Growth', p. 96; agricultural censuses published in national statistical yearbooks for the total number of holdings.

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 real wages, although their use was often limited by mechanical failure. Although the data in table 6 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 1914.⁴⁶

This survey shows that technological 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 expect the relative price of land to rise, in the absence of biases in the direction of technological change. 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 7). In France, Ireland, and Britain, countries which after 1880 lagged behind in the adoption of the new land-saving innovations, no clear bias in the direction of technological change is evident; these countries merely moved along the production function estimated for 1870.

Attempts to test statistically the hypothesis that the growth of agricultural productivity in the period 1870-1910 was connected with the adoption of land-saving technologies have not been very successful, partly because of the small size of the sample of countries. The regression analysis showed that there was a rather loose positive relationship between the growth of

⁴⁶ Dovring, 'The transformation', pp. 643-7; Whetham, *Agrarian history*, pp. 41-2; Bublöt, *Production*, pp. 238-9; Perkins, 'Farm mechanization', p. 76.

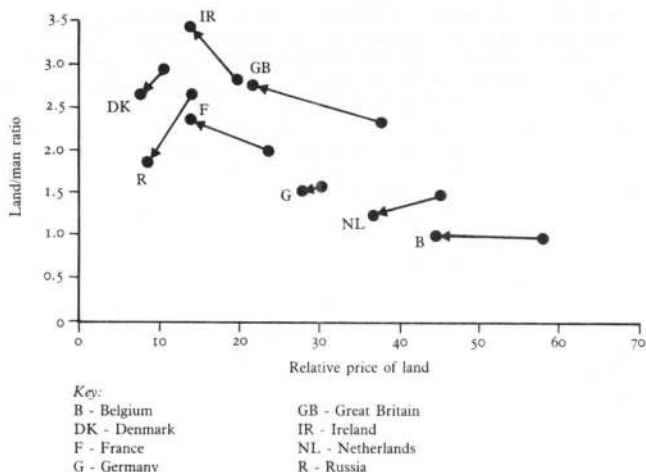


Figure 7. *Relative factor endowments and the relative price of land versus labour, 1870-1910*

Source: see source note, fig. 1.

productivity and the increase in the labour intensity of the product mix, a result which in any case did not disprove the hypothesis.⁴⁷

VI

Finally the question should be posed why some countries like 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 1870.⁴⁸ Whereas 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 1930.⁴⁹ Unfortunately, in the discussion of the decline of the British economy in the period after about 1870, not much attention has been paid to the role of agriculture. Therefore, only a few tentative suggestions can be made.

⁴⁷ Van Zanden, *First green revolution*, pp. 29-33.

⁴⁸ For France: Rutan, 'Structural retardation'.

⁴⁹ Wade, *Determinants*, p. 39; Ojala, *Agriculture*, p. 210.

A number of factors may help to explain the sudden change after 1870. It may be argued that 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 continued to rise on the continent after 1870, except for France, the prices of fertilizers and concentrated feeds fell by 40 per cent or more. In the United Kingdom, land prices and rents were relatively high in 1870, but fell almost continually thereafter until 1900, after which they increased slightly. In Britain the average rent per hectare dropped from about 91 shillings in 1870 to about 66 shillings in 1910, a drop of 27.5 per cent.⁵⁰ So the price of fertilizers and concentrated feeds relative to the price of land 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 per cent. 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.

What was cause and what was effect is hard to determine. The rise in land prices in most core countries was partly a result of the fact that farmers adapted very well to changing economic circumstances, increased agricultural productivity, and were therefore 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.

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 dominated British agriculture, whereas continental agriculture was increasingly practised on small family farms. In a detailed analysis of available statistics Dovring has shown this striking contrast in farm structure: whereas the median British farm employed about 8 men in 1900, comparable continental farms employed only 3 to 5 men, Italy and Austria being the main exceptions to this rule.⁵¹ 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. So the seemingly paradoxical development of a much more labour-intensive product mix combined with a sharp rise in 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.⁵² Such a course of action was not open to British farmers, who used much wage labour and had to pay the much higher wages.

The lack of institutional change in 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

⁵⁰ Ojala, *Agriculture*, p. 216.

⁵¹ Dovring, *Land*, pp. 109-12.

⁵² Chayanov, 'The theory', ch. 6, for the theoretical analysis of this phenomenon; see also Wade, *Determinants*, pp. 194-8.

continent. Credit cooperatives supplied the working capital for the purchase of the new inputs and the enlargement in livestock numbers; marketing cooperatives created efficient trade channels for the new inputs; and the cooperative dairy factories brought the great advantages of the centrifugal cream separator within the reach of the small farmer.⁵³ In Scandinavia, the Low Countries, Germany, Switzerland, Ireland, and large parts of eastern Europe cooperatives fundamentally reorganized rural markets. By 1910 in these countries most farmers were members of some kind of cooperative. Almost nothing of this kind occurred in Britain, France, and southern Europe. There membership of cooperatives remained restricted to a small minority of farmers.⁵⁴

Again cause and effect are hard to distinguish: the rapid development of the cooperative movement on the continent was to some 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. It may also be argued that the large commercialized farms in Britain did not need the cooperatives as much as the small family farms on the continent.

Equally absent from Britain were state-sponsored agricultural extension services. Although the first agricultural experimental station had been set up in Rothamsted 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.⁵⁵ 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.⁵⁶ Perhaps the slow development of labour-saving technology may also be attributed in part to the lack of institutions which experimented with and tested new machines. Such a lack is ironical in that Britain, with its relatively high land/man ratio, its large consolidated farms, and the important role that wage labour still played in its agricultural labour force, would have profited most from new labour-saving technologies.⁵⁷

So the diverging development of agriculture in the countries of western Europe on the one hand, and in Britain—and France and Italy—on the other hand, was probably connected with different farm structures and institutional development. Continental family farms profited greatly 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 Paris basin and in Italy, were unable to adapt to these circumstances in a successful

⁵³ Dovring, *Land*, pp. 199-212; Jensen, *Danish agriculture*, pp. 318-23; van Zanden, *Economische ontwikkeling*, pp. 273-81.

⁵⁴ Dovring, *Land*, pp. 196-212.

⁵⁵ Hayami and Ruttan, *Agricultural development*, pp. 137-8.

⁵⁶ *Ibid.*, pp. 138-42; Wade, *Determinants*, pp. 61-2, 236-7; Bublot, *Production*, pp. 278-85. In Denmark the state also played a minor role in the setting up of experimental stations and extension services; Jensen, *Danish agriculture*, pp. 178-81.

⁵⁷ Other explanations for the slow development of labour-saving technology are discussed by Ó Gráda, 'Agricultural decline', pp. 182-6.

way, so they sacked their labourers, extensified production, and awaited better times.

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