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International Comparative Analysis of Agricultural Productivity : 1961-1995

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I. Introduction

To determine the regional and periodic transformation characteristics of agricultural growth, this study will take a look at the differences between the agricultural productivity levels in many regions and countries in the world. Changes in the level of production technology are shown by measurements of land and labour productivity. Through this examination, one will be able to understand the technological structure of the agricultural sector and its changes. In addition to this one can identify the major factors affecting technological changes in production structures. The major factors influencing technological transformation of agricultural production will be divided into some five groups:

1. *Factor endowment.* The factor endowment of a country determines the initial stage of production technology under given factor conditions. The ration of land per worker reflects the differences in factor endowment among countries. This ratio changes as the economy develops.

2. *Factor input substitution.* This generally means less input of land and labour, and more input of biochemical and mechanical technology (fertilisers and tractors respectively). The factor substitution directly affects the productivity levels of land and labour[1].

3. *The production composition.* This means that technology transformation goes hand in hand with the choice of certain outputs[2]. In this case, not only changes in prices of input factors affect the technological transformation. The relative output prices also play a decisive role in choosing outputs and changing the production structure. Protection policies of governments can for instance influence the selection of outputs.

4. *Changes in domestic demand.* This means that as consumer preferences change in the process of economic growth, agricultural sectors also change their production and technology to meet those demands.

5. *Trade.* Following on the previous factor, trade possibilities are important to maintain a proper

1. Hayami and Ruttan argue that the technological transformation due to changes in the relative price is due to the substitution of land and fertilizer and labor and power, explaining the induced technical change model. (Hayami and Ruttan, 1985, pp. 84-93)
2. Kuroda (1988) determined the influence of the output choices on the whole transformation of agricultural technology in Japan, by measuring trans-log production function on the crops sector and the livestock sector. Yu (1992b) examined output biased technical change in Korea by measuring the multi-production function. All of these explain the technological transformation of production due to different technical innovation rates and output choices in economic growth.

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balance of agricultural demand and supply within a country. Just like changes in demand, trade possibilities influence the domestic agricultural production.

If data sources are not specified, the data used have been taken from or calculated on basis of the database of the FAO, the so-called FAOSTAT database. This database is published on the Internet. Concerning agricultural output, the total production value is based on international dollar rates of 1979-81 measured by the FAO (1986a)[3]. The aggregation of agricultural output was carried out for a total of 99 agricultural outputs, excluding forest products and floricultural products[4]. Although the concept of value added production that excludes outputs used as fodder and seed is preferable to the usage of the total production value, the last concept is chosen because of the difficulty of distinguishing data of imported goods from data of domestic fodder and seeds[5]. And due to the lack of data available on input factors, stock data are used instead of flow data. When it comes to data of land use, the total farming area including permanent pasture is used. Regarding labour, data of agricultural employment are used. And as an indicator of biochemical technology we use the total input of chemical fertilizers. The input of agricultural machines in the countries concerned is measured by the variable of horsepower, used by tractors[6]. Food balance sheets and trade data of the FAO are used to obtain information on the situation of food supply and agricultural trade.

The main objective of paper is to grasp the characteristics of the world agricultural growth process since the 1960s. On behalf of this, we will firstly analyse the growth patterns of agricultural output by region and country (section II). Secondly, we will compare changes in input factors (section III) and agricultural productivity growth levels (section IV) for a number of regions and countries. In section V, the main five factors of agricultural growth are summed up. Finally, we will present a case study of the productivity growth levels of the leading countries in Europe and Asia (section VI).

II. Growth patterns of world agricultural output

2.1 Total agricultural production

Asia has the highest share in world agricultural production (table 2.1). This share has increased from 28 % in the early 1960s to nearly 41 % in the mid-1990s. The second and third largest production shares are on the account of Europe and North America respectively. In contrast to Asia, the European and North American production shares have been decreasing in the course of time. The decrease has been particularly large in Western Europe.

3. Before Rao's aggregation using prices in international dollars, Hayami and Ruttan (1971, 1985), and Yamada and Ruttan (1980) used wheat units as the weights. Since then, Van der Meer and Yamada (1990), Yu (1992a), Yamada (1992), Craig, Pardey and Roseboom (1997) used the aggregation by international dollars for the ouput aggregation to measure productivity. Teruin (1990) used PPPs (purchasing power parity) as the weight for the aggregation of agricultural products in EC countries and measured real productivity.
4. As a result, a country like the Netherlands, which is weighted in floricultural production, has the problem of underestimation in the aggregation of agricultural outputs.
5. Therefore, the countries using a lot of domestic fodder and seeds will have a great deal of double accounts.
6. In order to get rid of the difference in types of tractors in each country, I calculated using the prevailing tractor horsepower of each country and by time with the same standard. Refer to Van der Meer and Yamada(1990) .

Table 2.1 Regional shares in world agricultural production and annual growth rates of agricultural production. 1961/65-1991/95(compound rates).

	Share of total agricultural production(%)				Annual growth rate : %			
	1961/65	1971/75	1981/85	1991/95	1961/65 ~ 1971/75	1971/75 ~ 1981/85	1981/85 ~ 1991/95	1961/65 ~ 1991/95
World	100.0	100.0	100.0	100.0	2.7	2.4	1.8	2.3
Asia	28.2	30.1	34.1	40.6	3.4	3.7	3.6	3.5
Africa	6.2	6.2	5.6	6.2	2.6	1.4	2.9	2.3
Europe	23.7	22.4	20.8	17.1	2.2	1.6	-0.2	1.2
Western Europe	18.0	16.7	15.7	13.5	2.0	1.7	0.3	1.3
Eastern Europe	5.7	5.8	5.2	3.6	2.7	1.3	-1.7	0.8
North America	17.4	16.3	15.6	14.7	2.0	2.0	1.2	1.7
Latin America	9.9	9.8	10.8	11.0	2.7	3.3	2.0	2.7
Oceania	2.4	2.3	2.1	2.0	2.2	1.4	1.4	1.7
Former USSR	12.3	12.9	11.0	8.4	3.3	0.8	-0.9	1.0

Data source: FAO. AGROSTAT/PC.

Table 2.2 Agricultural output growth rates and composition by country, 1961/65 ~ 1991/95.

	Annual growth rates for 1961/65 ~ 1991/95(%)					Production shares in total output(%)			
	Output	Crops		Livestock		Cereals		Livestock	
	total	total	Cereals	total	Meat	1961/65	1991/95	1961/65	1991/95
Bangladesh	1.8	1.7	2.0	2.1	1.8	64	68	13	14
China	4.5	3.5	3.6	7.5	7.8	43	33	16	38
India	2.8	2.6	2.9	3.5	2.8	34	35	19	23
Indonesia	3.7	3.5	4.4	5.1	4.9	39	48	10	15
Japan	1.4	-0.6	-1.1	4.0	5.2	37	17	29	62
Korea Rep.	3.9	2.3	0.6	8.6	8.2	62	24	12	45
Malaysia	3.9	2.6	2.1	7.2	6.9	20	12	16	42
Pakistan	3.9	3.9	3.9	4.0	4.8	21	21	46	47
Philippines	3.0	2.6	3.4	4.3	4.3	29	32	20	29
Thailand	3.5	3.6	2.2	3.1	4.5	52	36	23	21
Belgium-Lux.	1.7	1.4	0.6	1.8	3.2	9	7	73	75
Denmark	1.4	2.1	1.9	1.1	2.2	17	20	75	69
France	1.4	1.4	2.8	1.4	1.7	16	24	53	53
Germany	0.6	0.5	2.3	0.7	1.0	11	18	64	65
Greece	2.2	2.1	2.3	2.5	3.1	13	13	26	28
Ireland	2.5	-0.2	1.3	3.1	3.8	10	7	74	89
Italy	1.2	0.7	1.0	1.9	2.8	13	13	37	45
Netherlands	2.6	1.8	-0.6	2.8	4.0	5	2	74	79
Portugal	1.1	-0.6	-0.4	3.4	3.8	12	8	28	56
Spain	2.3	1.4	1.8	3.8	5.1	14	12	30	46
UK	1.1	1.8	2.3	0.8	1.1	14	19	72	65
Canada	2.1	2.9	2.0	1.1	1.9	37	37	52	38
U.S.A.	1.7	2.1	2.1	1.4	1.9	24	27	53	48
Argentina	1.6	2.7	1.5	0.7	0.6	18	17	60	45
Brazil	3.5	3.0	3.1	4.4	4.6	14	12	31	40
Mexico	3.0	2.2	3.2	4.0	3.7	18	19	36	49
Australia	1.9	3.2	2.5	1.2	2.1	16	20	75	62

Data source: FAO. AGROSTAT/PC.

Table 2.3 Regional shares in world crop and livestock production and annual growth rates of crop and livestock production, 1961/65 and 1991/95.

	Crops production			Livestocks production		
	Production share		Annual growth rate(%)	Production share		Annual growth rate(%)
	1961/65	1991/95	1961/65~1991/65	1961/65	1991/95	1961/65~1991/65
World	100.0	100.0	2.2	100.0	100.0	2.4
Asia	37.4	46.9	3.0	14.7	31.5	5.1
Africa	7.8	7.8	2.2	3.9	4.0	2.5
Europe	19.0	13.0	0.9	30.0	22.5	1.4
Western Europe	13.4	9.7	1.1	24.3	18.4	1.5
Eastern Europe	5.6	3.3	0.4	5.8	4.1	1.2
North America	13.9	13.5	2.1	22.1	16.1	1.3
Latin America	10.0	10.8	2.5	9.6	11.2	2.9
Oceania	0.9	1.1	2.9	4.6	3.2	1.2
Former USSR	10.9	6.7	0.6	14.1	10.5	1.4

Data source: FAO. AGROSTAT/PC.

In the period 1961/65-1991/95 the world agricultural production increased on average by 2.3% annually (table 2.1). Annual growth rates of 2.7% were realized until the mid-1970s. These high growth rates were largely due to the so-called 'Green revolution' in Asia and the high growth rates of the 1960s decreased gradually over time and amounted to 2.4% in 1971/75~1981/85 and 1.8% in 1981/85~1991/95. The growth rates of Asia and Latin America were above average in every considered period (table 2.1). Especially the growth rates of China, Korea, Malaysia, Pakistan, Indonesia and Thailand were very high (table 2.2). On the other hand, agricultural growth rates in Europe, North America and Oceania have been relatively low. Within the group of European countries, Ireland and the Netherlands experienced the highest growth rates. Of the American countries, the growth rates of Mexico and Brazil are most strikingly. The agricultural output of Eastern Europe and the former USSR decreased sharply in the 1990s.

The remarkable high growth of agricultural production in Asia is mainly the result of technological innovations and general economic growth. The many agricultural development projects and investments improved the Asian means of production and the Asian infrastructure. Asian agricultural productivity levels increased rapidly as chemical fertilizers and agricultural machinery were introduced[7]. Nevertheless, there are large differences between the agricultural growth among the Asia.

2.2 Crop and livestock production

Performances in agricultural production could become clearer when a distinction is drawn between crop production and livestock production.

The average world crop production increased by 2.2% annually (table 2.3). The annual growth rates of Europe and the Former USSR remained well under the world average growth rate, while the Asian crop production performed well above average. The Asian performance regarding livestock production

7. Research on the Green Revolution and technological innovation in Asian agriculture was done abundantly in the 1970s and the 1980s. But, always it can't be evaluated to be the same about the result of the technological innovation and agricultural growth by each Asian country in this period. (see Yamada, 1992).

was even more outstanding. The remarkable growth rates of agricultural output in most of the Asian countries are highly attributable to the growth of the livestock production, although crop production has also considerably increased (table 2.2). However, Japan reduced its crop production in the period concerned. Livestock production has grown tremendously in all Asian countries, with the exception of Bangladesh and India. In China and Korea annual livestock production growth amply exceeded 7%. Likewise, the European livestock production has generally grown faster than crop production. On the contrary, crop production in North America has increased obviously by more than livestock production.

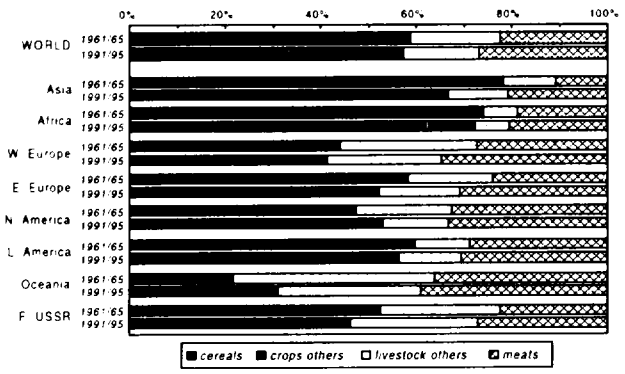

Figure 2.1 Comparison of the production composition by region in agricultural sub-sector, 1961/65 and 1991/95.

The composition of world agricultural production in 1991/95-period has not changed substantially from that in the period of 1961/65 (figure 2.1). The production share of cereals is relatively large in Asia and North America. In Europe, this share is relatively low. In the Netherlands the cereal production makes up only 2% of agricultural output. The share of meat production in agricultural output has increased strikingly. Especially in Asia and Europe the production composition shifted remarkably in favour of meat. In Asia, the share of livestock production is generally less than 50%, except for Japan in the 1991/95 period. In contrast to this, livestock products make up more than 50% of total production in most European countries, with the exception of Greece, Italy, and Spain. The shares of livestock production are world's highest in Ireland, the Netherlands, and Belgium-Luxembourg. Only few regions, among which are Oceania and North America, have in the period concerning increased the share of crop production at the expense of livestock production.

2.3 Some closing remarks

The differences between the countries' agricultural production growth and production composition are the result of differences in economic growth, food consumption and agricultural policy in each country. The rapid economic growth of the Asian countries in the last few decades has increased food consumption and production remarkably. Most Asian countries have increasingly oriented their food policies towards raising food production to get over the chronic food deficiencies in the past few decades. Nevertheless, up to now the domestic food supply is still insufficient. On the other hand, most European countries have taken a production adjustment and set up an export policy within the Common Agricultural Policy (CAP) to get rid of their surplus production.

III. Changes in input factors

3.1 Agricultural land

The quantities of land and labour input differ significantly among the various regions and countries concerned. With 26%, Asia is holding world's largest

Table 3.1 Regional composition and growth rates of agricultural workers in the world, 1963, 1973, 1983 and 1993.

	Regional composition (%)				Annual compound growth rate (%)			
	1963	1973	1983	1993	1963-73	1973-83	1983-93	1963-93
World	100.0	100.0	100.0	100.0	1.26	1.30	1.35	1.30
Asia	71.4	75.0	77.0	78.2	1.76	1.56	1.51	1.61
Africa	11.7	12.6	13.3	14.0	2.02	1.79	1.91	1.91
Europe	6.1	4.0	2.6	1.8	-2.98	-2.97	-2.53	-2.82
Western Europe	3.2	1.9	1.2	0.8	-3.60	-3.07	-3.15	-3.27
Eastern Europe	2.9	2.1	1.3	1.0	-2.12	-2.90	-1.98	-2.33
North America	0.6	0.5	0.4	0.3	-1.81	-0.44	-1.08	-1.11
Latin America	4.6	4.4	4.0	3.5	0.82	0.55	-0.18	0.39
Oceania	0.2	0.2	0.2	0.2	0.51	0.96	1.49	0.99
Former USSR	5.2	3.3	2.5	2.0	-3.35	-1.24	-0.89	-1.83

Data source: FAO. AGROSTAT/PC.

share in agricultural land. Africa's share in agricultural land is 22%. Europe only holds about 4% of the world agricultural area. The total cultivated land area in the world is relatively small because 70% of total agricultural land is used for permanent pasture.

The composition of agricultural land used differs greatly among the regions. The share of arable land is quite large in Europe and North America. In Oceania, Latin America and Africa permanent pasture sum up to a share of more than 80% in agricultural land use. In Europe this share is only 37%.

With an annual growth rate of 0.2%, the total area of agricultural land in the world has hardly changed during the period of 1963~1993. The largest increase of agricultural land has taken place in Asia and Latin America. Contrary to this, the area of agricultural land in Europe has decreased between 1963 and 1993. This is reflected by the demand for land in non-agricultural sectors induced by economic growth and industrialization.

3.2 Agricultural labour

The differences in the regional composition of agricultural employment among the countries are very obvious. By far the largest part of the world agricultural labour force is employed in Asia, i.e. almost 80% (table 3.1). The second largest share of the world agricultural work force is employed in Africa. And until recently, the number of agricultural workers has been increasing in these two regions, while the agricultural work force in almost all the European countries as well as Japan and Korea has been continually decreasing (table 3.2)[8]. The European agricultural labour input levels are the highest in Greece, Portugal and Ireland, although these shares are considerably lower than the Asian ones. The North American and Australian agricultural labour force is very small as well.

3.3 Agricultural machinery, fertilizer and feeds

In general, the inputs of agricultural machinery, chemical fertilizers and grain feeds have been increasing. The increase in the use of tractors has been significantly high in Japan, Korea, Pakistan, India and Thailand. The other countries have also increased their tractor input, but more slowly than the Asian countries. The growth of tractor input clearly reflects the factor substitution of agricultural

8. Of course, the trend of agricultural labour input differs highly among the countries within a region. See for example Yamada (1992).

Table 3.2 Agricultural factor input by country, 1963~1993.

	Input of agricultural land				Agricultural labour input			Other inputs		
	Annual growth(%)	Land use(%)			Annual growth(%)	% of total labour force		annual growth rate 1963-93		
	1963-93	arable area	perm.crops	perm.pasture	1963-93	1963	1993	tractor	fertilizer	feed grain
Bangladesh	0.3	92	2	6	1.2	82	63	6.3	10.4	-2.2
China	1.2	19	1	81	2.0	78	72	7.3	10.6	7.2
India	0.1	92	2	6	1.3	73	63	12.0	11.0	2.4
Indonesia	0.3	43	29	28	1.6	73	54	7.6	10.5	8.8
Japan	-0.5	79	9	13	-3.9	28	6	18.4	0.0	4.6
Korea Rep.	0.1	88	8	4	-2.0	61	15	30.2	3.5	12.0
Malaysia	2.0	24	72	4	0.2	59	24	9.9	8.7	9.9
Pakistan	0.5	79	2	19	2.0	66	49	14.7	12.2	8.5
Philippines	1.2	53	35	12	1.2	64	44	2.8	6.2	4.8
Thailand	1.9	82	15	4	1.7	83	61	10.4	12.7	6.5
Belgium-Lux.	-0.4	52	1	46	-3.0	8	3	4.2	-1.3	-0.5
Denmark	-0.4	93	0	7	-2.7	15	5	2.1	0.3	0.6
France	-0.4	60	4	36	-3.9	19	5	3.1	1.6	1.3
Germany	-0.4	68	1	31	-3.9	13	3	2.1	-1.1	0.3
Greece	-0.1	28	12	60	-2.3	51	21	8.1	3.0	4.3
Ireland	-0.8	29	0	71	-2.4	33	13	5.2	3.7	0.9
Italy	-0.8	55	18	27	-3.9	28	8	5.8	2.6	1.2
Netherlands	-0.5	46	1	53	-1.1	10	4	3.8	-0.2	-1.7
Portugal	0.1	57	19	24	-2.3	41	16	9.4	1.6	4.9
Spain	-0.3	50	16	34	-3.8	40	10	7.5	3.2	3.6
UK	-0.5	35	0	64	-1.3	4	2	1.1	1.1	-0.7
Canada	0.5	62	0	38	-3.0	14	3	2.4	5.3	2.3
USA	-0.1	44	1	56	-0.8	6	3	1.7	2.6	1.2
Argentina	0.0	15	1	84	-0.4	19	11	4.4	9.2	2.0
Brazil	1.3	18	3	79	-0.4	59	20	8.3	9.2	4.3
Mexico	0.0	23	2	75	1.2	51	26	4.4	6.0	7.8
Australia	0.0	10	0	90	0.0	10	5	1.9	2.4	3.5

Data source: FAO. AGROSTAT/PC.

labour by machinery.

The increase in the consumption of chemical fertilizers is also very high in Asia. This does however not hold for Japan and Korea. Since the 1970s, the increase in the use of fertilizers has been slowing down in Japan. This development is rational in view of the diminishing returns of chemical fertilizers. In Europe, the growth rate of fertilizer use has been very high in the 1960s, but it has declined afterwards. Since the mid-1980s, the fertilizer use has been decreasing in some European countries.

The consumption of feed is a good indicator for the structure of livestock production. In particular, the consumption of feed grains does usually point to an increase of the intensive livestock production. The very rapid growth of Korea's feed grain consumption is for example closely linked to the large increase of Korea's livestock production. The feed grain consumption in Europe countries has decreased since the mid-1980s.

To put it briefly, the Asian factor input in agriculture has developed different from the European. And even within a single region, there are large differences with respect to the tendency of input changes. This variety is caused by the gaps in economic level and factor endowment conditions. Above all, the tendencies of Japan and Korea are rather conspicuous in comparison with other Asian countries.

IV. Changes in agricultural productivity growth

4.1 Agricultural land productivity

As opposed to labour productivity, the Asian and African growth rates of land productivity are above average (table 4.1). Whereas the growth rates of land productivity keep growing in Asia, they have been gradually decreasing in most of the European countries since the 1970s. In Western Europe and North America the growth rates of land productivity have in fact been less than average. But, with regard to the absolute level of the agricultural land productivity, Europe stands out above the other regions. The land productivity levels of Oceania and Africa are far under the average.

For each country has a different initial factor endowment, factor productivity levels differ as well. Each country's productivity level has changed variously with economic growth and input substitution. As far as land productivity levels are concerned, the Netherlands, Belgium, Japan and Korea perform very well (table 4.2). On the contrary, Australia's land productivity level is the lowest among the countries concerned, in both 1961/65 and 1991/95. The gap in land productivity between these two countries spreads out to be a factor of 97 up to 134 during the last three decades. In the last two decades, very noticeable growth rates of land productivity have been experienced in Korea, Ireland, Pakistan, Indonesia, China, and Mexico.

4.2 Agricultural labour productivity

The absolute levels of agricultural labour productivity differ very strongly among the regarded regions and countries (table 4.3 and 4.4). In North America the productivity level is by far the highest, at well over $42.000 per worker (table 4.3). In Western Europe and Oceania productivity levels amount to $15.000 and $9.000 respectively. Nevertheless, productivity levels in Belgium and Denmark are equally high as the North American levels. Until the mid-1970s, the productivity levels of the Netherlands were still above those of Belgium and Denmark, but they caught up with the Netherlands very rapidly. Generally, the growth rates of European labour productivity were relatively high during the period of 1961/65-1991/95, but declined gradually. In Asia and Africa, productivity levels are less than $500 per worker, with the exception of Japan and Korea. The lowest level of labour productivity is found in Bangladesh.

For a long time, every region's agricultural labour productivity level has been increasing (table 4.3). The European labour productivity levels experienced the highest growth rates of the regions concerned. Africa's labour productivity growth has always been far below the world's average. And off all countries, Spain and Korea have realized the highest growth of labour productivity, i.e. more than 6% per annum during the period of 1961/65 to 1991/95. In the course of time most of the average growth rates of labour productivity have decreased.

Land and labour productivity levels are good indicators for agricultural growth and technological development. The indicator of agricultural labour productivity reflects the processes of economic development and factor substitution. Moreover, the indicator of agricultural land productivity reflects the physical agricultural production technology and production structure. Accordingly, there could be an interconnection between the growth patterns of land productivity and labour productivity. In the case of Western Europe, land productivity is very high and growth of labour productivity has been higher than in any other region in the period concerned(figure 4.1). In the right upper corner of figure 4.1, the

Table 4.1 Agricultural land productivity levels and growth rates, 1961/65-1991/95.

	Land productivity : Int. $ / ha				Annual growth rate : %			
	1961/65	1971/75	1981/85	1991/95	1961/65 ~ 1971/75	1971/75 ~ 1981/85	1981/85 ~ 1991/95	1961/65 ~ 1991/95
World	128	162	201	235	2.41	2.18	1.56	2.05
Asia	153	202	277	365	2.84	3.20	2.81	2.95
Africa	34	44	50	66	2.54	1.34	2.86	2.24
Europe	568	732	880	907	2.56	1.86	0.30	1.57
Western Europe	611	780	953	1033	2.47	2.03	0.81	1.77
Eastern Europe	466	620	714	624	2.91	1.41	-1.33	0.98
North America	198	245	294	334	2.16	1.82	1.30	1.76
Latin America	92	110	144	171	1.85	2.68	1.76	2.10
Oceania	29	34	41	48	1.81	1.74	1.59	1.71
Former USSR	130	176	188	164	3.08	0.69	-1.38	0.78

Data source: FAO. AGROSTAT/PC.

Table 4.2 Agricultural land productivity levels and growth rates, by country.

	Land productivity : Int. $ / ha				Annual growth rate : %			
	1961/65	1971/75	1981/85	1991/95	1961/65 ~ 1971/75	1971/75 ~ 1981/85	1981/85 ~ 1991/95	1961/65 ~ 1991/95
Bangladesh	520	578	721	812	1.1	2.2	1.2	1.5
China	155	222	289	413	3.6	2.7	3.7	3.3
India	261	310	415	575	1.7	3.0	3.3	2.7
Indonesia	196	269	419	538	3.3	4.5	2.5	3.4
Japan	1714	2374	2887	3093	3.3	2.0	0.7	2.0
Korea Rep.	941	1301	2049	2893	3.3	4.7	3.5	3.8
Malaysia	280	417	482	477	4.1	1.5	-0.1	1.8
Pakistan	244	319	434	656	2.7	3.1	4.2	3.4
Philippines	466	577	675	793	2.1	1.6	1.6	1.8
Thailand	378	428	541	608	1.2	2.4	1.2	1.6
Belgium-Luxembourg	1681	2196	2541	3140	2.7	1.5	2.1	2.1
Denmark	1169	1283	1680	1989	0.9	2.7	1.7	1.8
France	605	763	940	1050	2.4	2.1	1.1	1.9
Germany	1120	1357	1586	1515	1.9	1.6	-0.5	1.0
Greece	310	438	556	620	3.5	2.4	1.1	2.3
Ireland	283	376	504	768	2.9	3.0	4.3	3.4
Italy	736	1048	1211	1321	3.6	1.5	0.9	2.0
Netherlands	1942	2960	4249	4814	4.3	3.7	1.3	3.1
Portugal	489	521	537	659	0.6	0.3	2.1	1.0
Spain	259	382	510	571	3.9	2.9	1.1	2.7
UK	549	676	819	877	2.1	1.9	0.7	1.6
Canada	152	177	217	243	1.5	2.1	1.1	1.6
U.S.A.	205	256	311	356	2.3	2.0	1.3	1.9
Argentina	71	80	106	115	1.2	2.8	0.8	1.6
Brazil	121	133	205	229	1.0	4.4	1.1	2.2
Mexico	76	110	164	182	3.8	4.1	1.1	3.0
Australia	20	25	32	36	2.0	2.4	1.3	1.9

Data source: FAO. AGROSTAT/PC.

Table 4.3 Agricultural labour productivity levels and growth rates, 1961/65-1991/95.

	Labour productivity ($/worker)				Annual compound growth rate (%)			
	1961/65	1971/75	1981/85	1991/95	1961/65 ~ 1971/75	1971/75 ~ 1981/85	1981/85 ~ 1991/95	1961/65 ~ 1991/95
World	666	768	855	894	1.43	1.08	0.44	0.98
Asia	263	308	379	463	1.57	2.10	2.04	1.90
Africa	353	375	361	396	0.59	-0.38	0.95	0.38
Europe	2584	4328	6877	8724	5.77	4.97	3.53	4.75
Western Europe	3793	6646	10793	15274	5.77	4.97	3.53	4.75
Eastern Europe	1321	2147	3270	3372	4.98	4.30	0.31	3.17
North America	18026	26485	33672	42199	3.92	2.43	2.28	2.88
Latin America	1443	1732	2272	2824	1.84	2.75	2.20	2.26
Oceania	7646	9067	9508	9388	1.72	0.48	-0.13	0.69
Former USSR	1564	3027	3707	3689	6.83	2.05	-0.05	2.90

Data source: FAO. AGROSTAT/PC.

Table 4.4 Agricultural labour productivity levels and growth rates, by country.

	Labour productivity ($/worker)				Annual growth rate (%)			
	1961/65	1971/75	1981/85	1991/95	1961/65 ~ 1971/75	1971/75 ~ 1981/85	1981/85 ~ 1991/95	1961/65 ~ 1991/95
Bangladesh	193	203	216	232	0.5	0.6	0.7	0.6
China	195	244	306	402	2.3	2.3	2.8	2.4
India	282	294	346	430	0.4	1.7	2.2	1.4
Indonesia	256	312	428	484	0.4	1.7	2.2	1.4
Japan	776	1468	2770	3911	6.6	6.6	3.5	5.5
Korea Rep.	341	491	863	1985	3.7	5.8	8.7	6.0
Malaysia	685	1000	1219	2006	3.9	2.0	5.1	3.6
Pakistan	431	497	561	744	1.4	1.2	2.9	1.8
Philippines	422	547	658	719	2.6	1.9	0.9	1.8
Thailand	377	446	589	643	1.7	2.8	0.9	1.8
Belgium-Lux.	10272	20701	33182	42697	7.3	4.8	2.6	4.9
Denmark	10941	16212	28465	38098	4.0	5.8	3.0	4.2
France	5411	9539	16860	26862	5.8	5.9	4.8	5.5
Germany	4752	8747	13667	18962	6.3	4.6	3.3	4.7
Greece	1497	2902	4517	5918	6.8	4.5	2.7	4.7
Ireland	4309	7676	12606	18992	5.9	5.1	4.2	5.1
Italy	2475	4772	8195	11363	6.8	5.6	3.3	5.2
Netherlands	10478	18954	27183	30922	6.1	3.7	1.3	3.7
Portugal	1254	1768	1843	3476	3.5	0.4	6.6	3.5
Spain	1694	3736	6496	10640	8.2	5.7	5.1	6.3
UK	11901	17605	22379	24446	4.0	2.4	0.9	2.4
Canada	9076	13738	22184	42137	4.2	4.9	6.6	5.3
USA	20054	29333	36446	42898	3.9	2.2	1.6	2.6
Argentina	7221	9088	12747	13072	2.3	3.4	0.3	2.0
Brazil	1195	1459	2666	3757	2.0	6.2	3.5	3.9
Mexico	1218	1578	1955	2036	2.6	2.2	0.4	1.7
Australia	22335	29465	35082	38245	2.8	1.8	0.9	1.8

Data source: FAO. AGROSTAT/PC.

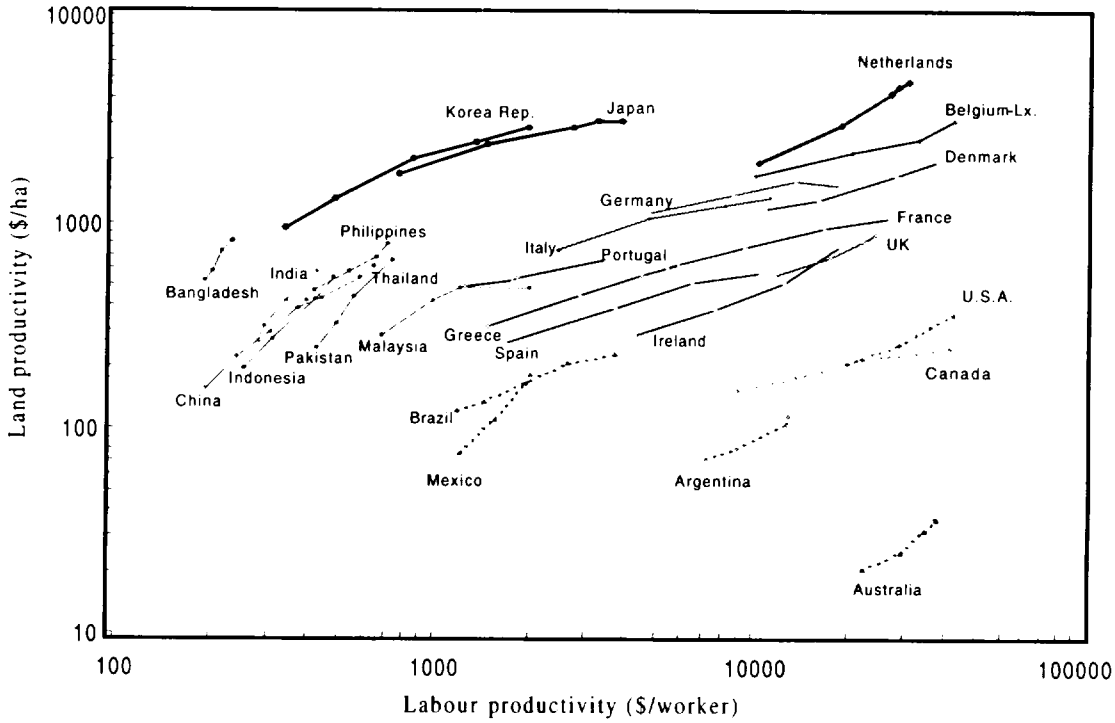

Figure 4.1 Growth paths of agricultural land and labour productivity, 1961/65, 1971/75, 1981/85 and 1991/95

Table 4.5 Agricultural land per worker and growth rates, 1961/65-1991/95

	Agricultural land per worker (ha/worker)				Annual compound growth rate (%)			
	1963	1973	1983	1993	1963-73	1973-83	1983-93	1963/93
World	5.2	4.7	4.2	3.8	-0.96	-1.08	-1.10	-1.05
Asia	1.7	1.5	1.4	1.3	-1.23	-1.07	-0.74	-1.01
Africa	10.4	8.6	7.2	6.0	-1.90	-1.70	-1.86	-1.82
Europe	4.5	5.9	7.8	9.6	2.66	2.82	2.10	2.53
Western Europe	6.2	8.5	11.3	14.8	3.22	2.88	2.70	2.93
Eastern Europe	2.8	3.5	4.6	5.4	2.01	2.84	1.67	2.17
North America	91.0	107.9	114.6	126.3	1.72	0.60	0.97	1.10
Latin America	15.7	15.7	15.8	16.5	-0.01	0.06	0.43	0.16
Oceania	266.5	264.1	233.1	196.6	-0.09	-1.24	-1.69	-1.01
Former USSR	12.0	17.2	19.7	22.5	3.64	1.35	1.35	2.11

Data source: FAO, AGROSTAT/PC.

paths of the Netherlands and Belgium are found. Their combined productivity levels are the highest of all countries. In the case of North America, the labour productivity level is world's highest, whereas the land productivity level is even under average. Most Asian countries follow the European growth path, although the lengths of the Asian growth paths are much shorter. The growth path of Japan and Korea are a different from the other Asian ones. Japan and Korea approach the European growth paths because of their high level of land productivity. After the mid-1980s, most productivity growth paths became shorter. This means that the growth performances of agricultural productivity in

Table 4.6 Agricultural land per worker and growth rates, by country.

	Land/Labour ratio (ha/pers.)				Annual growth rate (%)			
	1961/65	1971/75	1981/85	1991/95	1961/65~1971/75	1971/75~1981/85	1981/85~1991/95	1961/65~1991/95
Bangladesh	0.37	0.35	0.30	0.29	-0.57	-1.55	-0.48	-0.87
China	1.26	1.10	1.06	0.97	-1.32	-0.34	-0.87	-0.84
India	1.08	0.95	0.83	0.75	-1.27	-1.29	-1.06	-1.21
Indonesia	1.31	1.16	1.02	0.90	-1.21	-1.27	-1.26	-1.25
Japan	0.45	0.62	0.96	1.26	3.17	4.49	2.80	3.48
Korea Rep.	0.36	0.38	0.42	0.69	0.41	1.11	5.00	2.15
Malaysia	2.44	2.40	2.53	4.21	-0.19	0.53	5.23	1.83
Pakistan	1.77	1.56	1.29	1.13	-1.26	-1.84	-1.30	-1.47
Philippines	0.90	0.95	0.97	0.91	0.47	0.27	-0.71	0.01
Thailand	1.00	1.04	1.09	1.06	0.44	0.46	-0.31	0.20
Belgium-Lux.	6.1	9.4	13.1	13.6	4.43	3.31	0.40	2.70
Denmark	9.4	12.6	16.9	19.2	3.05	2.98	1.24	2.42
France	8.9	12.5	17.9	25.6	3.40	3.69	3.61	3.56
Germany	4.2	6.4	8.6	12.5	4.28	2.94	3.80	3.67
Greece	4.8	6.6	8.1	9.5	3.21	2.06	1.63	2.30
Ireland	15.2	20.4	25.0	24.7	2.97	2.05	-0.11	1.63
Italy	3.4	4.6	6.8	8.6	3.08	4.04	2.43	3.18
Netherlands	5.4	6.4	6.4	6.4	1.73	-0.01	0.04	0.58
Portugal	2.6	3.4	3.4	5.3	2.85	0.10	4.39	2.43
Spain	6.5	9.8	12.7	18.6	4.12	2.67	3.88	3.56
UK	21.7	26.1	27.3	27.9	1.86	0.47	0.21	0.84
Canada	59.6	77.7	102.0	173.1	2.67	2.77	5.43	3.62
USA	98.0	114.6	117.2	120.6	1.57	0.22	0.29	0.70
Argentina	101.1	113.5	120.7	113.9	1.16	0.62	-0.58	0.40
Brazil	9.9	11.0	13.0	16.4	1.03	1.72	2.36	1.70
Mexico	16.0	14.4	11.9	11.2	-1.10	-1.82	-0.65	-1.19
Australia	1091.0	186.1	111.1	1063.0	0.84	-0.65	-0.44	-0.09

Data source: FAO. AGROSTAT/PC.

most of the countries have stagnated.

4.3 The agricultural land per worker ratio

The land per worker ratio is a very important factor as it determines the initial conditions of agricultural development and the choice of agricultural technology[9]. The regional differences in the hectare per worker ratio are determined by the factor endowment conditions of a region. Land abundant regions (North America and Oceania) have higher levels of labour productivity, whereas land scarce regions with land-saving technology (Asia and Europe) have low levels of labour productivity and high levels of land productivity. Large quantities of land per worker are found in Oceania and North America, whereas in Asia this ratio is very small. Since the early 1960s, the amount of agricultural land per worker has been decreasing. This is due to the fact that the increase of agricultural workers, especially in Asia and Africa, is larger than the increase of agricultural land in the world. The regions in which the land per worker ratio has reduced are Asia, Africa and

9. See Hayami and Ruttan 1985.

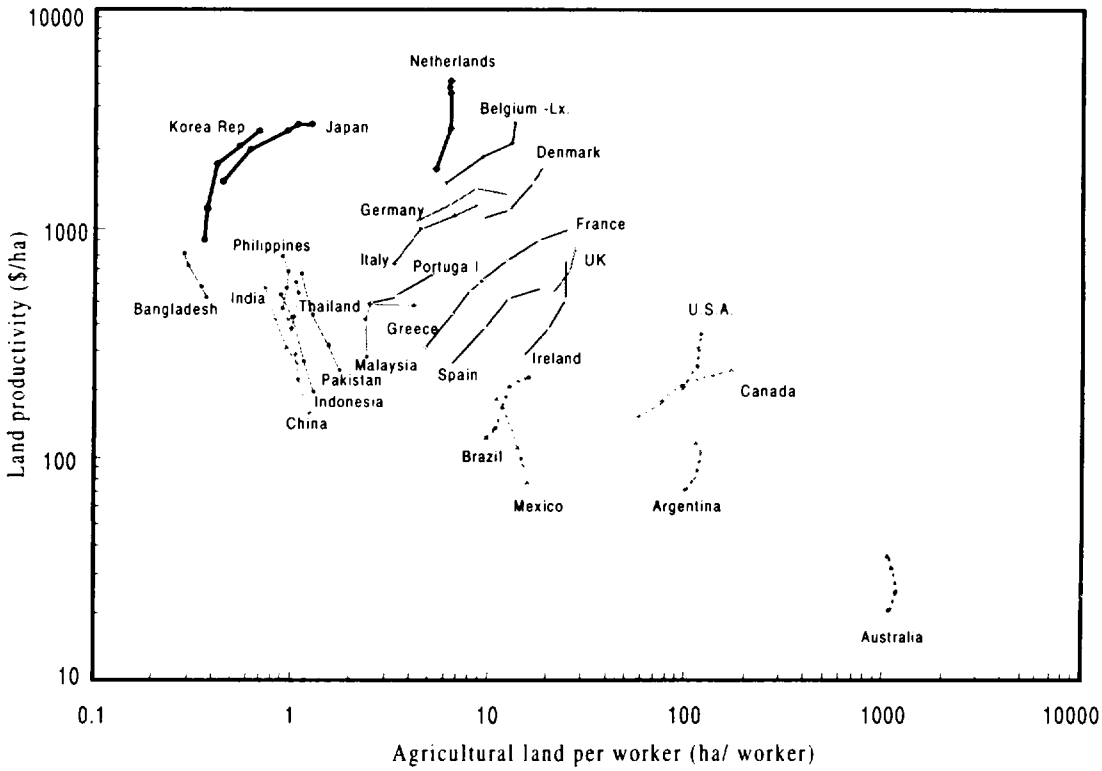

Figure 4.2 Agricultural land per worker and land productivity. 1961/65, 1971/75, 1981/85, and 1991/95

Data source: FAO, AGROSTAT/PC

Oceania. In the other regions, the agricultural land per worker ratio has increased in the same period.

In figure 4.2 the conditions of factor endowment and the resulting selection of technology are reflected. There appears to be an inverse correlation between the land per worker ratio and the land productivity.

Until recently, most Asian countries, with the exception of Japan and Korea, have been decreasing their land-labour ratio because of their high population pressure. Improvement of land per labour ratios in Japan and Korea are the result of the labour absorption on account of the rapid industrialization in these countries. In Europe, the scale of agricultural land per worker is the highest in France, UK, Ireland and Denmark. In the Netherlands and Portugal this ratio is relatively small. Most of the European countries have improved their land per labour ratio continuously during the last three decades. However, in the Netherlands and Belgium the improvement of the land per labour ratio has stagnated since the mid-1980s.

V. The characteristics of agricultural growth recapitulated

In this section we will in conclusion recall the most important factors that contribute to differences in the growth of productivity. These factors are distinguished into some five groups, namely: factor endowment, input substitution, the production composition, domestic demand, and trade. The analysis in the next chapter will be elaborated on these five factors.

5.1 Factor endowment

The classical factors of agricultural production and economic growth, land and labour are still very important. The factor endowment of a certain country determines its initial stage of production technology under given factor conditions. The ratio of land per worker reflects the differences in factor endowment conditions of each country. Furthermore it can explain the characteristics of the production technologies of each country (land-saving our labour saving technology). The most important indicator for understanding the factor endowment, i.e. the ratio of land per worker, is changed through a country's economic development process. Generally, there is an inverse correlation between land productivity and the land per worker ratio(figure 4.2). For example land scarcity in Japan, Korea, the Netherlands, Belgium and Denmark has been conducive to a high productivity of agricultural land in these countries.

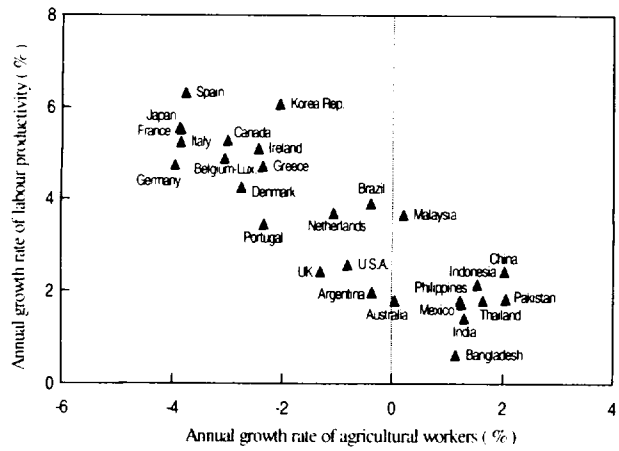

Figure 5.1 Labour productivity growth rates and labour input changes 1961/65 ~ 1991/95.

Labour productivity has generally been low in countries with a large share of agricultural workers in the total labour force. And logically, there is a clear negative correlation (of 0.88) between the change of agricultural labour input and the growth of labour productivity(figure 5.1). That means that a decrease of agricultural labour highly contributes to the growth of a country's labour productivity. This brings us to the next factor of agricultural growth: factor input substitution.

5.2 Factor input substitution

To induce an increase in the productivity levels of labour or land, one can substitute labour or land by the input of capital. A substitution of agricultural labour by machinery improves the land per worker ratio. Likewise, the increase of fertilizers improves the land productivity. The extent to which factors are substituted is among other things strongly linked to policy and price conditions.

Chemical fertilizers

The progress of innovations in the field of biochemistry and machinery explains the process of factor substitution very well[10]. Bio-chemical technology means the introduction of high yield verity and the increase of chemical fertilizers and pesticides used. Technical innovations in the field of machinery mean an increase in the input of machinery at the expense of labour. Figure 5.2 shows the correlation between the input of chemical fertilizers per hectare of cultivated land and the land productivity level in the periods of 1961-65 and 1991-95[11]. The correlation coefficient turns out to be as high as 0.91 in 1961/65 and 0.77 in 1991/95. It is entirely clear that the higher the input of fertilizers is, the higher the level of land

10. Hayami and Ruttan (1985) explain this factor substitution in economic development process as induced technical changes.
11. The cultivated land area is the total agricultural land area minus the permanent pasture area.

productivity will be. The input of chemical fertilizers is relatively high in Asia and Europe. Countries with a high level of fertilizer input are Japan and Korea. Recently, the fertilizer usage in China has been increasing very rapidly. In Asia, the amount of chemical fertilizers used per hectare increases continuously, with the exception of Japan. The level of chemical fertilizer input per cultivated land of the Netherlands is the highest among all the countries. Moreover, fertilizer input levels are relatively high in Ireland, UK and Belgium-Luxembourg. However, since the 1980s, the input levels of the chemical fertilizers per hectare have declined in most European countries.

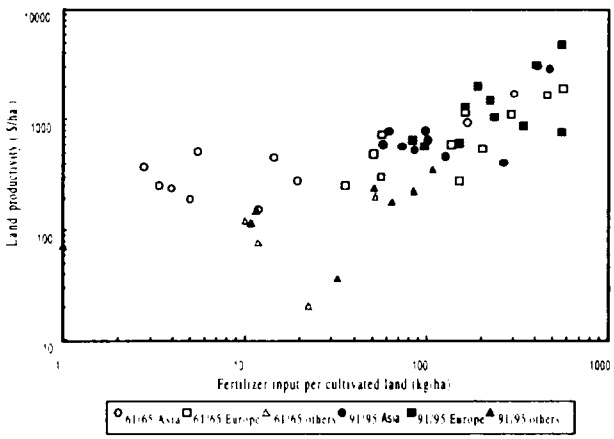

Figure 5.2 Land productivity and chemical fertilizer input per cultivated land area, 1961/65 and 1991/95.

Data source: FAO, AGROSTAT/PC

Agricultural machinery

There is a close connection between the degree of substitution of labour by agricultural machinery and the level of labour productivity(figure 5.3). The correlation coefficient between the levels of tractor horsepower per worker and the labour productivity levels has been found to be 0.92 in both 1961/65 and 1991/95. The levels of the tractor per worker ratios are relatively high in Europe, America and Australia. From 1991-65 onward, the levels have shifted upwards. In most of the Asian countries, the levels of horsepower per worker are very low, with the exception of Japan. The growth rates of the Asian tractor per worker ratio have been very high during the last three decades. Actually, it applies for almost every region/country that the substitution of labour by machinery has continuously increasing until recently. Nevertheless, there is still an extremely large gap between the country with the highest level of tractor per worker ratio and the one with the lowest ratio.

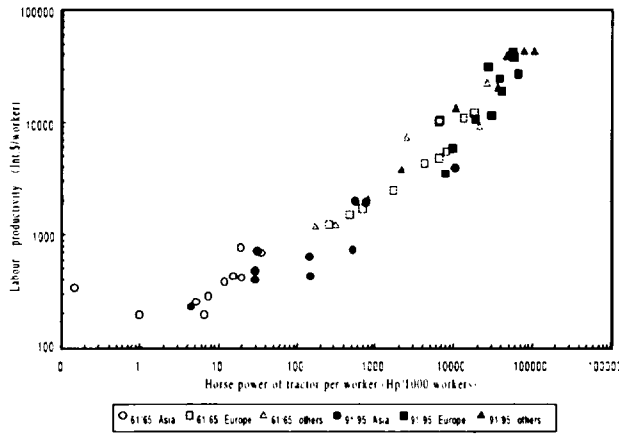

Figure 5.3 Tractor horsepower per agricultural worker and labour productivity, 1961/65 and 1991/95.

Data source: FAO, AGROSTAT/PC

5.3 Production composition

If the factor-input distribution is changed when there is a gap of factor productivity and technical innovation among the production technology of agricultural products, the factor productivity of the aggregated production function has to change naturally. This is the effect of product composition to productivity changes. It is very difficult to measure this effect precisely because of the non-separation of factor inputs by product. Mundlak

(1963, 1971) tried to measure the technology gap among products under the assumption of an implicit production function. Kuroda (1988) tried to measure output biases of technical changes by differences in technological changes between crops and livestock in the post-war Japanese agriculture by means of a trans-log cost function. Likewise, Yu (1992b) verified output bias technical changes in Korea by estimating multi-product production functions between vegetables/fruits and other crop production. However, these measurements have many restrictions. Nevertheless, it is clear that changes in the production composition under different production technologies for each product do influence the factor productivity of the aggregated agricultural production. We have already confirmed that growth rates of each country's sub-sector differ strongly. Especially the increase of livestock production in Asian countries is remarkable.

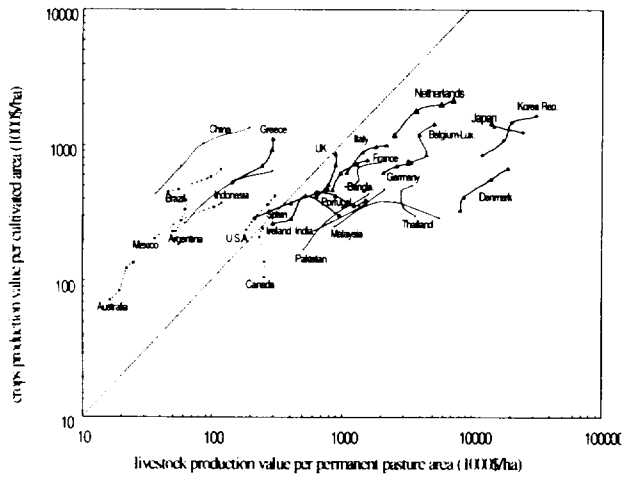

Figure 5.4 Changes of production value per land area by cultivated area and permanent pasture area, 1961/65, 1971/75, 1981/85 and 1991/95.

Data source: FAO, AGROSTAT/PC

In figure 5.4 changes of factor productivity levels of livestock and crop production are compared. Of course there is a problem in the definition of land productivity that has to do with the quality problem of agricultural land. Nonetheless, the figure can be meaningful to understand to relationship between changes in levels of aggregated land productivity and the production composition. In figure 5.4, each country can be divided into three groups: a high land productivity group (for example Korea, Japan, Belgium, Denmark and the Netherlands), a low land productivity group (Australia and the Americas) and a middle group. The extended line from the origin is defined as the same land productivity for both products. Many countries are located at the right side of this line. Korea, Japan and Denmark are located most rightwards. This means that they have high land productivity levels in livestock production by intensive livestock farming. Consequently, the increase of livestock production, with its high land productivity in comparison to crops, induced total land productivity growth. Among other crops, such a development of the product composition occurs as well. The growth of the production of vegetables and fruit was for example remarkably high in Asia.

5.4 Domestic demand

Changes in the economic development of a country influence the disposable income levels and consequently the demand for agricultural products. The characteristics of demand changes are recognised by the food consumption structure. Generally, the consumption of cereals and starchy roots increases in the initial stage of economic growth. However, continuous growth of the income level is usually accompanied by a decrease of the consumption of these products. On the contrary, the consumption of vegetables, fruit and livestock products increases as the economy grows. This tendency can be observed clearly in the Asian and

European countries during 1961/65 to 1991/95. In the last three decades, the food consumption per person per year has changed in Asia and Europe. Nevertheless, there are large differences between the Asian and the European food consumption structure. In Europe, the consumption of fruits, vegetables and livestock products is fairly high, whereas Asia has a large consumption of cereals. The consumption of cereals and starchy roots decreases in most of the European countries.

On the other hand, it increases in some of the Asian countries such as China, India and Pakistan. The consumption of vegetables, fruits, and livestock products increases in most Asian and European countries. Especially the meat consumption has increased significantly in comparison with the other food groups. The growth rates of milk consumption differ strongly between Asian and European countries. In Korea, Thailand, Japan and China the milk consumption increased significantly, whereas the milk consumption in most of the European countries declined since the 1980s. These country-specific demand alterations affect the production structure. This is an adjustment process to the demand-supply balance. However, the adjustment of the production structure is a difficult task. The situation of excess supply in agricultural production is even often more problematic than the situation of excess demand. Because of the positive correlation between consumption growth and production changes for livestock products and cereals, i.e. respectively 0.82 and 0.64, one could think that there is a good production adjustment to demand changes (figure 5.5). Most countries increased their cereal production while the consumption of cereals has been continuously declining during the past three decades. These countries have to adjust for their excess supply by export or stock control. In livestock products, the balance is a little better.

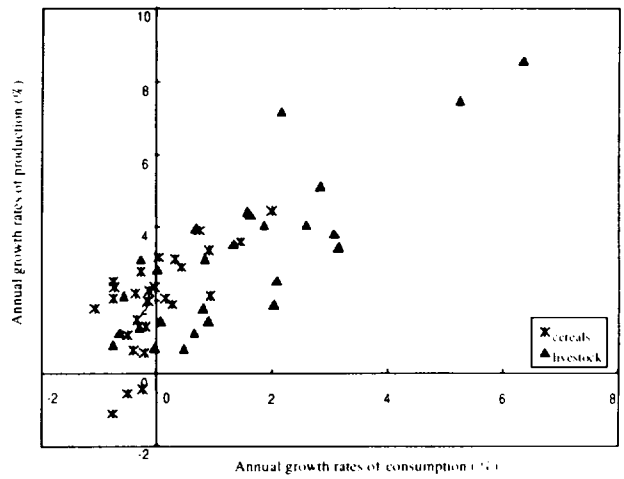

Figure 5.5 Annual growth rates relation between production and consumption by cereals and livestock products, 1961/65 ~ 1991/95.

Data source: FAO, AGROSTAT/PC

Qualitative and quantitative changes of demand require an adjustment at the supply-side. A stagnating demand with a simultaneous increase of the production causes inefficiencies at the supply-side. Accordingly, production adjustments that comply with a demand change improve the efficiency of factor distribution in the production sector. Many political interventions are being used on behalf of these production adjustments.

5.5 Trade

Each country's agricultural trade flow typifies the balance of food demand and supply of that country. Of course various factors are involved in trade results, such as price conditions, trade systems, policies, production structures and consumption patterns for food and so on. Therefore, it is difficult to detect causal relations between trade and changes of the production structure.

Figure 5.6 shows the total export value of food

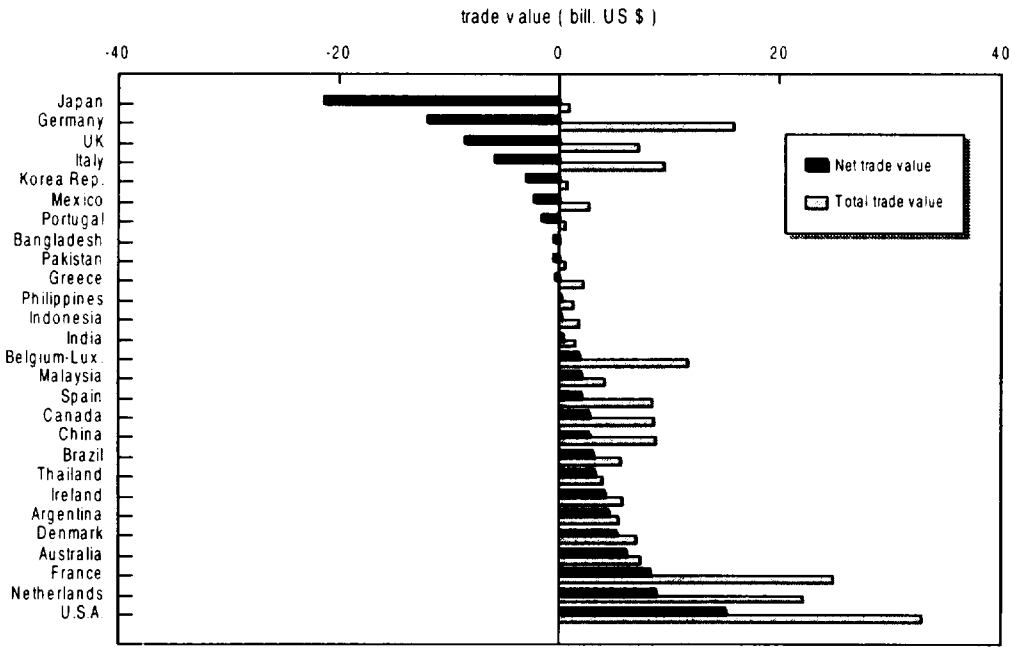

Figure 5.6 Net trade balance value and total export value for food (exclude fish) in 1992/94. (billion US dollar)

Data source: FAO. AGROSTAT/PC
Note: Net trade values are total export value minus total import value.

(excluding fishery) and the net value of the trade balance in 1992/94. From this, it follows that the USA. France, and the Netherlands are the upper three countries with regard to total en net agricultural trade. Japan and Korea are the biggest net food importing countries in Asia. Germany, the United Kingdom and Italy are the biggest importing countries within Europe. The character of the Japanese and Korean position is different from that of Germany, UK and Italy. As opposed to Germany, the UK and Italy, Japan and Korea are pure food importing countries because of their small export amounts.

During the last three decades, both the total food trade value and the number of net exporting countries have been increasing considerably. Especially, the increase of the net export value of cereals from France and meat from the Netherlands are remarkable. In contrast with this, Japan and Germany have strongly increased their net import value of food. In the case of Japan, the net import value increased for almost all food groups. Germany mainly increased the net import value of fruit, vegetables and meat.

Europe's trade balance of cereals has changed drastically during this period. Germany changed from a net cereal importing country into a net exporting country, just like Greece and Denmark. The value of the cereal export of France increased very strongly. Yet, France is the second export country of cereals at the world trade market. These changes are closely linked to the changes in the European Union's agricultural policy.

The increasing imbalance of food supply and demand of each country has led to an increasing dependence on food trade. Net food importing countries such as Japan, Germany and UK could not satisfy the domestic demand for food without

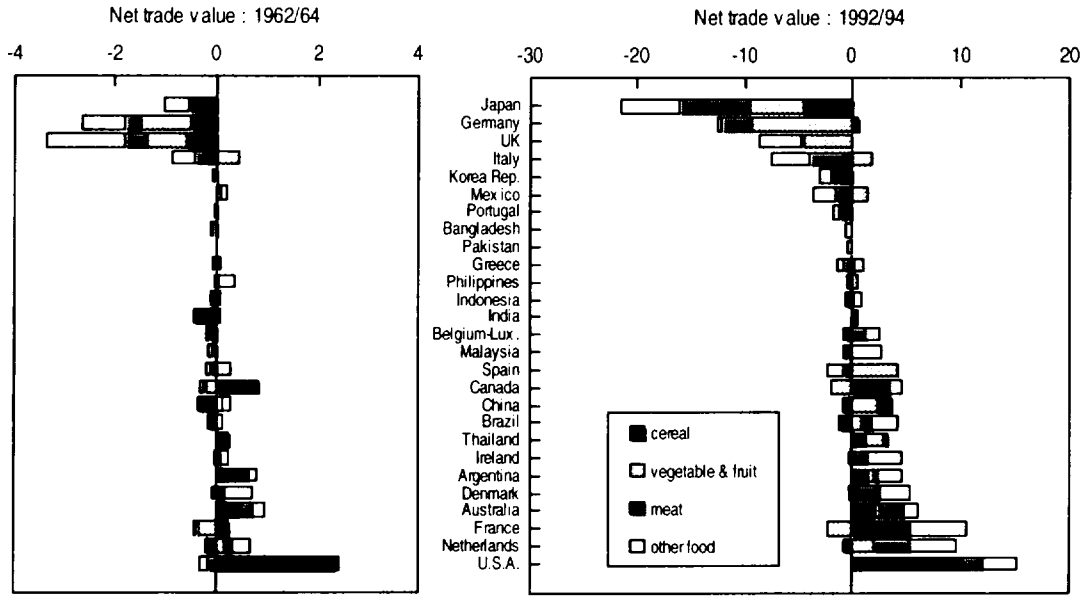

Figure 5.7 Net trade balance value by sub-food group, 1962/64 and 1992/94, (billion US dollar)

Data source: FAO, AGROSTAT/PC
Note: Net trade values are total export value minus total import value.

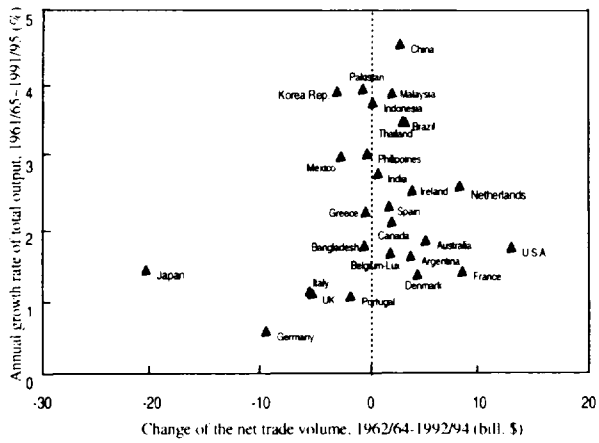

Figure 5.8 Correlation between agricultural output growth and change of net trade value for food total. 1961/65 ~ 1991/95.

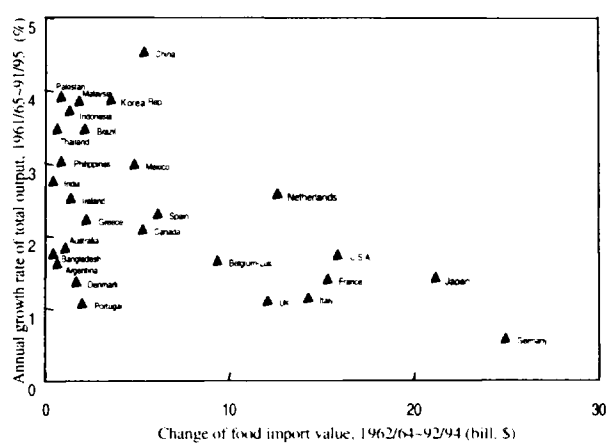

Figure 5.9 Correlation with agricultural output growth and change of import value for food total. 1961/65 ~ 1991/95.

foreign products, whereas net food exporting countries like the USA, the Netherlands and France could not dispose of domestic food products without a foreign market.

Although Japan increased its net import value very strongly and the USA increased their net export value of food trade quite strongly, both countries experienced relatively low growth rates of agricultural production in the same period(figure 5.8). It seems that a high dependence on either import or export of food has a negative effect on the growth of domestic production. This relationship becomes clearer when the relation between the increase of the import value and the growth of

domestic production are considered(figure 5.9). This relation shows that the growth of the domestic agricultural production is relatively low in the countries with a strong increase of the food import value during the last three decades. Growth rates of domestic production in the countries that are highly dependent on food import turn out to be under 2% annually, except for the Netherlands. This same relationship applies for sub-food groups. In the case of cereals, of all countries considered, Japan has increased its import the most during the last three decades. At the same time, the Japanese growth rate of the domestic cereal production has been the lowest off all countries considered. Domestic production growth rates are only about 2% per year in the net cereal exporting countries such as the USA, France, Canada and Australia as well.

VI. Case study: technological leading countries in Asia and Europe

6.1 Estimating the production efficiency

By estimating a production function, we want to measure the efficiency of a country's production technology, compared to the world average technical level[12]. On behalf of this, a Cobb-Douglas production function is used with A as the total agricultural area (in hectares), L as agricultural labour (number of workers), F as chemical fertilizer input (in kilograms), and M as the tractor input (measured in horsepower). The dependent variable is the final output value Y (in international dollars).

The estimated function is the following:

$$(1)\quad \ln(Y_{ij}) = \ln a + \ln(A_{ij})^{\alpha 1} + \ln(L_{ij})^{\alpha 2} + \ln(F_{ij})^{\alpha 3} + \ln(M_{ij})^{\alpha 4} + \mu$$

with:

a = constant

μ = error term

i = country[13]

j = time: 1963, 68, 73, 78, 83, 88, and 1993[14].

Structural dummy variables are adopted because of differences in production technologies between Asia and the other regions. Particularly, land and tractor inputs differ quite strongly among the region. Therefor, formula (1) is transformed as follows:

$$(2)\quad \ln(Y_{ij}) = \ln a + \ln(A_{ij})^{\alpha 1} + \ln(L_{ij})^{\alpha 2+\beta 1(dl)} + \ln(F_{ij})^{\alpha 3} + \ln(M_{ij})^{\alpha 4+\beta 2(dm)} + \mu$$

with:

(dl) and (dm) : Asian country = 1,
other country = 0.

Since a structural change of production technologies in the world is expected after the 1980s, the formulas (1) and (2) have been estimated for two periods, one before 1980 and one after 1980. The results of these estimates are shown in table 6.1.

The results of the estimates have proven to be statistically very significant. The results show that the Asian countries have of relatively high elasticity of labour and a relatively low elasticity of tractor input in production technology. This result reflects

12. It is very strong assumption to assume production technology in each country on homogeneity. But, this is take to efficiency measurement of each country against the international average production technology. Hayami and Ruttan (1985) called such a kind of function by meter-production function.

13. Because of insufficient data, Bangladesh has been excluded from the 29 comparative countries.

14. The final output is a five-year moving average.

Table 6.1 The results of the estimation of the production function.

Parameter and Variable	Period 1:1963. 68. 73. 78		Period 2:1983. 88. 93	
	Reg. 1	Reg. 2	Reg. 3	Reg. 4
Constant(a)	1.863 (8.993)	1.542 (7.967)	2.000 (7.601)	1.630 (6.390)
α 1. Land (A)	0.220 (8.163)	0.168 (6.439)	0.216 (7.239)	0.176 (5.562)
α 2. Labour (L)	0.278 (11.052)	0.259 (8.443)	0.191 (6.157)	0.170 (4.193)
β 1. Asia labour shift(dl)		0.200 (5.816)		0.215 (4.034)
α 3. Fertilizer (F)	0.196 (5.826)	0.097 (2.854)	0.256 (4.524)	0.136 (2.270)
α 4. Tractor (M)	0.171 (6.813)	0.351 (9.262)	0.204 (5.440)	0.385 (6.728)
β 2. Asia tractor shift(dm)		- 0.232 (-5.606)		- 0.215 (-4.167)
Adj. R^2	0.923	0.942	0.92	0.934
Number of observation	104	104	78	78

Note : The figures in parentheses are t-values.

Table 6.2 Technically high-efficiency countries and efficiency coefficients in each region.

	Period 1	Period 2
Asia		
Japan	1.0434	1.0275
Korea	1.0295	1.0255
Europe		
The Netherlands	1.0534	1.064
Belgium-Luxembourg	1.0265	1.0289

the intensive use of labour-using technologies in Asia and the widespread tractor-using production technologies in other regions. The production elasticity of chemical fertilizers and tractors has increased recently. These changes of the parameters point at the factor substitution progress.

The technical efficiency of agricultural production in each country is measured by the regression result of Reg.2 and Reg.4 in table 6.1. From each region. the two most technically efficient countries are shown in table 6.2 in Asia and Europe. The result completely comes up to the expectations. which have been pronounced at the beginning of this section.

VII. Closing remark

World agricultural production has been experienced a very strikingly change since 1960's. Especially the change in Asian region is very remarkable. While the agriculture in Asian region went through the growth of its production with agricultural productivity growth and technical change. advanced regions in agriculture such as western Europe and north America had an opposite situation. the adjustment of production surplus. That is to say. the change of world agricultural production has commonly been in the process of overcoming the imbalance of the food demand-supply for the last 35 years. It has been experienced the production increase to get over a food shortage and the production adjustment to settle the problem of production surplus.

The difference of characteristics of growth process by each country and period has a close influence on regional conditions and the process of economic growth. Its difference functions as an important factor to decide characteristics of agricultural growth path and technical change. The characteristics of agricultural growth path by stages related with the process of economic growth can be arranged as below:

Stage of the under-development economy: It is the initial stage of economic development. In this stage. most workers are engaged in primary industry sector. There is labour surplus in the agricultural

part. and food shortage is generally shown in this stage. Its agricultural technology level is very poor. and the agricultural production is carried out by traditional production technology in this stage. Many developing countries come under this category. There are long-tern efforts for technology development such as improvement of the infrastructure to increase the food production. educational training. etc. and short-term efforts to solve the food shortage together. In general. the increase of agricultural productivity slows down remarkably. and the diffusion of new technology is very difficult.

Stage of the developing economy: When the growth of income and economy begins to continue through the turning point of the economy. agricultural labour flows out into non-agricultural sector. and the rate of agricultural labour starts to decrease. At the same time. the production technology in agricultural sector improves. and then. technological change due to bio-chemical input substitution and machinery input substitution is made progress. In this stage. the policy of input factor price and output price raises its head as an important issue to encourage input substitution of agricultural sector to go on smoothly. The agricultural productivity increases remarkably in this stage. and the growth of food production is realized.

Stage of the developed economy: When the advanced stage of the economy begins through the high-growth stage. the industrial structure is maintained with stability. and the rate of agricultural labour and production is strikingly on the decrease. The level of agricultural production technology is very high. and the production capacity comes up to surplus condition. While the total demand for food is limited. the quality of demand is changed variously. In this stage. the adjustment of production sector according to the demand change is needed: therefore. the policy of production structure adjustment is an important problem in agricultural sector. Many advanced countries are included in this category. The total agricultural productivity is not greatly augmented. However. production technology by products remarkably changes to cope with a variety of demands. The higher this flexibility of structural change in production sector is. the more the efficiency of agricultural production sector is on the increase.

When characteristics of technical change of agricultural production make progress in three stages above related with the economic development. five factors studied in section 5: factor endowment. factor substitution. production composition. domestic demand and trade condition have an effect on the change of production structure by stages. That is to say. agricultural production technology in under-development stage is greatly under the control of factor endowment condition. and that in developing stage is influenced by factor substitution. In factor substitution. bio-chemical technology is diffused first. and then mechanical technology is introduced as agricultural labour is decreased. As the economy develops and enters the advanced stage. the change of production technology and products composition coping with the change of the consumers' preference has an effect upon the change of the agricultural production technology. In this stage. agricultural production technology have to choose technical change to adjust flexibly the demand change. as well as technical change due to factor substitution so as that the sustainable and stable growth of agriculture is possible.

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