AGRICULTURAL ADAPTATION TO ADVANCING ECONOMY*

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For a long time it has been customary to estimate a country's advancement by the level of per head gross national product converted to United States dollars. Every economist has long been aware that this method is greatly defective, exaggerating the differences between countries—because the purchasing power of money in the poorer countries is very substantially higher than is indicated by its exchange rate. Not to mention the obviously anomalous movements introduced into the figures by sudden changes in exchange rates, of which there have been many in recent years. This method, showing for some of the poorest countries supposed per head incomes for $100 per head per year or less have been received with dismay by sympathetic observers, who ask how any community can possibly maintain life on such an income. In truth, this method of converting by exchange rates was deliberately adopted by United Nations, at the time of its formation, because United Nations' contributions had to be assessed in proportion to countries' estimated gross national products, and the underestimation of real products introduced by exchange rate valuations greatly eased the burden of contributions on the poorer nations.

A number of preliminary attempts to make real international comparisons of the purchasing power of money, some of them dating back to the early years of this century, have now been superseded by a really thorough study.[1] For sixteen countries, ranging from the lowest to highest income levels, of which the Republic of Korea was one, while per head incomes appeared to show a range of 50 to 1 between the highest and lowest countries when converted on the exchange rate, this difference, while still substantial, has been reduced to 16 to 1. Sometimes the exchange rate is found to understate the true purchasing power of the currency more than threefold.

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[1] *International Comparisons of Real Product and Purchasing Power* by I. B. Kravis, A. Heston, & R. Summers, Johns Hopkins University Press, 1978. The principal results were summarised, together with approximate estimates for nearly a hundred other countries, were given in *Economic Journal*, June 1978.

TABLE 1

	Real gross domestic product per head (USA = 100, 1970)	Factor by which exchange rate understates the true pruchasing power of the country's currency (1970)
Kenya	6.33	2.12
India	6.92	3.34
Philippines	12.0	3.11
Republic of Korea	12.1	2.24
Columbia	18.1	2.50
Malaysia	19.1	2.36
Iran	20.3	2.42
Hungary	42.7	1.98
Italy	49.2	1.37
Japan	59.2	1.49
United Kingdom	63.5	1.39
Netherlands	68.7	1.35
Belgium	72.0	1.31
France	73.2	1.26
West Germany	78.2	1.22
USA	100.0	1.00

Even in the economically advanced countries of Western Europe the exchange rate still understates the true purchasing power of the currency, in comparison with USA, by a substantial proportion, mainly because of the relatively low price of services, which do not enter into international trade.

These international data will be used for making estimates of the long-term income elasticity of demand for agricultural products. Estimation of income elasticities from cross-section studies comes up against the serious objection[2] that consumption depends on what is sometimes called "permanent income." Not that anything is permanent in this world; but families do plan their consumption in the light of what they expect to be their sustainable income, which can be approximately measured by a weighted average of current incomes and those of the recent past, with weights diminishing as we go further back into the past. Cross-section studies, so often used for estimating income elasticities, must necessarily, in almost all cases, be based on current income only, which fluctuates more than "permanent income." It follows that such studies will *understate* income elasticities.

There is less objection to estimating income elasticities from long time series; but this method also has difficulties.

Estimation of income elasticities from such international comparison carries the implicit assumption that pritce elasticities of demand for agricultural products are low.

[2] See Milton Friedman, *A Theory of the Consumption Function*, 1957.

The Republic of Korea has what is almost the lowest ratio of cultivable land to agricultural labour force. In 1975 2.38 million farm households with an average of approximately 5 million people working in agriculture had only 2.24 million hectares of cultivated land.

In an advanced economy, agricultural output may be measured in terms of money. But in view of the widely different prices prevailing in different countries, this is not suitable for international comparisons. Still less is it suitable for measuring the agricultural output of less advanced countries, where a large fraction of the output may be consumed by producers, without being sold at all, and that which is sold commands relative prices very different from those prevailing in the advanced countries.

This problem was first faced by J.L. Buck in his monumental study *Land Utilisation in China*, published in the 1930's. For each region of China he took as his basis one kilogram of the type of grain most widely produced in that region, and converted all of the agricultural output into grain-equivalents in accordance with their relative valuation against grain in the local markets. While such a method would be questionable in an advanced country with a diversified output, it is defensible in a less advanced economy, where grain itself constitutes a large proportion of the whole output. Note that the various products are included at the economic value (in the local market), and not at the calorific equivalent. A kilogram of meat obviously has more relative value than is indicated certainly by its calories; and some products, such as cotton and tea, have no calorific value at all.

Buck's method was extended to a number of Asian countries by the Dutch economist De Vries, agricultural adviser to the International Bank, who had worked for many years in Indonesia. He took as his unit a kilogram of milled rice. Agricultural output, converted to these units, was expressed per head of the entire population. For certain purposes we need to know agricultural output per head of the agricultural population; although in the least advanced economies there is no great difference, as agricultural population constitutes a very large fraction of the whole. It is usually necessary to measure per head of whole population, because the less advanced economies do not have the precisely defined labour force found in the advanced economies. In the busiest seasons the whole family may be working on the farm; while for a large part of the year they may be engaged in other activities, or resting. However for some purposes production may be measured per male worker recorded in the agricultural labour force.

Taking account of physiological needs for calories and protein, for some diversification of diet, the need for some reserve against emergencies, and for a minimum of the most urgent non-food requirements such as clothing, De Vries estimated 250 kilograms of milled rice equivalent per head per year as a subsistence minimum, below which a population

would be facing actual hunger. As productivity rises above this level, an agricultural population gradually finds itself with more to sell in order to purchase urgently needed non-food requirements. But it is not until a figure of about 500 has been reached that the farmer can face the additional food requirements of draught animals. Once these are employed he can cultivate a larger area (if land is available) and per head production should continue to increase. It is not until it has reached the figure of 750 that a farmer can afford to keep meat animals, principally pigs and poultry, who are our direct competitors for the supplies of grain.

This system was extended to a large number of countries throughout the world by Hayami[3]. In this case he took a ton of wheat as his unit. For the conversion of other agricultural products to wheat equivalents he used three different sets of relative prices, namely those prevailing in the USA, Japan and India.

Unfortunately for international comparisons, the price of *unmilled* rice stood (in the 1957–62 period of comparison) at 1.58 times the price of wheat in USA, and 1.16 times its price in Japan, as against a factor of 0.94 for India, which is more in accordance with prices prevailing in the world market. (In both USA and Japan the price of rice is supported far above the international level by governmental action.) Indian price weight are therefore used in the following comparison. The Republic of Korea was not covered in Hayami's survey, and a separate estimate has been made.

TABLE 2

ASIAN PRODUCTIVITY COMPARISONS*

Tons wheat-equivalent per year (Indian price weights)

	Per male engaged in agriculture	Per hectare agricultural land
Japan	10.18	7.10
Taiwan	6.71	9.65
Sri Lanka	4.06	2.97
Republic of Korea	3.98	5.19
Philippines	3.72	1.85
Pakistan	2.19	—
India	1.77	0.87

*Hayami's figures for 1960 except Republic of Korea 1964–66.

Hayami has pointed out elsewhere that there is an understandable tendency for countries with abundant supplies of agricultural land to devote their main efforts to improving product per man, principally by the use of machinery; whereas those with scanty land supplies seek to improve

[3] *An International Comparison of Agricultural Production and Productivities* by Yujiro Hayami and others, University of Minnesota Agricultural Experiment Station Technical Bulletin 277. 1971.

primarily product per hectare, mainly by the use of fertilisers. This has been shown to be true, both by current and historical international comparisons. On the other hand, if we compare, say, Japan and India we can see great differences in productivity both per man and per hectare.

Further improvements in Korean productivity are possible, both per man and per hectare, though we must of course remember that Japan, still more Taiwan, have more favourable climates.

Possible ways of increasing productivity will be discussed below.

Such improvements in productivity however will probably be slow, and with Korea's very limited supply of agricultural land, and unfavourable climate, it is clear that the main advances must come in the non-agricultural sector.

Everything turns on the rate at which non-agricultural employment can be increased. In a report which I prepared for Pakistan in 1952, basing myself on all the information then available about the past rates of growth of non-farm employment in other countries, particularly Japan and Russia, I concluded that the maximum possible rate was 4% per year. However in the modern world the pace of industrialisation can now be much more rapid. For many years now Korea has been increasing non-agricultural employment at the rate of 8% per year. Though this has not been done without certain strains, it has been successful, and it is assumed that this pace can be continued.

This leads me to make estimates for the rate of growth of real national product higher than those of the official Fourth Economic Development Plan (covering the years up to 1981 though my estimates are continued to 1985). Apart from being of interest in themselves, such estimates are necessary for forecasting the demand for the principal agricultural products. The official plan estimates the rate of growth of real gross national product, which in recent years has averaged 11.2% per year, at 9.2% per year.

While the numbers engaged in non-agricultural employment have been rising so rapidly, the movements in their real product per head have been curiously uneven. From 1953 to 1965 the figure was stationary, or slightly declining. Then followed an extraordinary period of growth up to 1973, of 7.8% per year increase in real product per person employed. Since 1973 this has averaged only 3.6% per year, comparable with the rate of improvement in productivity in other industrial countries. It is expected that this latter rate will continue.

The official plan estimates population growth at 1.6% per year, and the growth of the economically active population at twice this rate, or 3.2% per year. My estimates are higher in both cases. It is clearly necessary to make population and labour force estimates as a basis for projections of real national product and of demand for foods. Though the census appears to be accurate, birth and death registrations are seriously de-

fective, and estimates have to be made by indirect methods. The *Korean Economic Statistics Yearbook* estimates 1975 population at 34.68 millions, an increase of 2% per year on the 1970 figure. However the United Nations Demographic Yearbook raises the estimate to 35.28 millions, implying a higher rate of overall growth, and a larger number of births.

While it is clear that fertility has fallen rapidly from its peak about 1960, there is much uncertainty about its present level. Lee-Jay Cho[4] made annual estimates of total fertility up to 1966, distinguishing metropolitan, urban and rural. ("Total Fertility" is the theoretically calculated final total offspring per average woman living up to the end of her reproductive period, if the specific rates of reproductivity prevailing in the current year continue). His figure fell from its maximum of 5.95 in 1960 to 4.48 in 1966.[5] However in a later publication he raised his estimate to 4.7 for 1967 falling to 4.1 in 1973. Another estimate[6] confirms 4.7 about 1967, falling to 3.9 by 1973.

The method used is to take Lee-Jay Cho's 1966 specific fertilities as a standard, and apply them to the age tables of the adult female population to estimate "standard births", which can be compared with actual births up to 1975, thus giving us some idea of the rate of fall of fertility. Further moderate declines in fertility are extrapolated. Though this method is uncertain, it must be pointed out that it only applies to a small proportion of the population. Most of the expected population of 1985 has already been recorded at the census, and the only figures required are mortality adjustments.

The acceleration of population increase, in spite of declining fertility, is due to the great increase in numbers of women entering reproductive age. The number of women aged 20 to 29 is estimated at 2.71 million for 1975, 3.57 million in 1980, and 4.20 million in 1985.

As is indicated in the official plan, employment is estimated to rise

TABLE 3
POPULATION PROJECTION

	1966	1965–70	1970–75	1975–80	1980–85
"Standard births" at 1966 specific fertilities (millions)		4.68	5.20	6.06	7.25
Actual births (millions)		4.38	4.27	5.27[a]	6.05[a]
Deduced total fertility (millions)	4.48[b]	4.19	4.06	3.9[c]	3.75[c]
Estimated population at end of period (millions)		31.43	35.28	38.60	42.83
Per year increase during period (%)		2.0[d]	2.5	1.9	2.2

[a] Estimated from line below [b] Assumed [c] Extrapolated [d] 1966–70

[4] *Population Index*, January-March 1971.

[5] Population Council, *Studies in Family Planning*, Vol. 5 No. 5, May 1974.

[6] Shin Kyn Chang, *Asian Economies*, September 1974.

much more rapidly than population.

A "demographic" estimate of the employable population can be made by applying the labour force participation rate for each male and female age group shown by the 1970 census to the estimated age structure of the population (extrapolated forward and backward from the 1970 census by use of current mortality rates). These figures are compared with the numbers known to be in employment up to 1975. The difference between "demographic" and actual employment in 1970 represents the unemployed, together with a small difference in the definition made since the 1970 labour force participation rate tables were prepared.

In considering the comparative demands for labour of agricultural and non-agricultural employment, it will not suffice to work on annual averages. The quarterly figures show that agriculture (taken together with forestry and fishing) has an extreme peak of labour demand each June. This is met in part by additions to the labour force, and in part by temporary release of labour from non-agricultural employments, particularly manufacture and construction. In the following table an attempt is made to forecast the employment position at the June agricultural labour peak in 1980 and 1985. The continued expansion of non-agricultural employment is expected to lead to a marked shortage of agricultural labour for the June peak in 1985, necessitating drastic reorganisation of agricultural operations.

TABLE 4

EMPLOYMENT (*Numbers in Millions*)

	1960	1965	1970	1975	1980	1985
1. "Demographic" labour force	7.68	8.93	10.38	12.28	14.24	16.04
2. Actual employment[a]	6.78	8.21	9.75	11.83	14.07[c]	16.25[c]
3. Line 2/Line 1	.883	.918	.938	.963	.988[b]	1.013[b]
4. Estimated June peak employment			10.86	13.31	15.8	18.3
5. Non-agricultural employment	2.34	3.40	4.83	6.40	9.40[d]	13.82[d]
6. Line 5 reduced for June agricultural peak			4.20	6.05	8.83	13.0
7. Labour available to agriculture for June peak			6.7	7.3	7.0	5.3

[a] Revised basis 1960 figure adjusted proportionately to the revision

[b] Extrapolated

[c] Calculated from Line 3

[d] Last two entries extrapolated at 8% per year growth

The June peak employments in agriculture, forestry and fishing were 7.54 million in 1976, 7.16 in 1977, and 6.90 in 1978. A continued reduction in this peak demand for labour in agriculture will be necessary.

We are now in a position to bring the information together and make the forecast of real national product and consumption.

The agricultral gross output figures from national accounts are not con

TABLE 5
REAL NATIONAL PRODUCT FORECAST

	1970	1975	1980	1985
Non-agricultural Employment (millions)	4.83	6.40	9.40[a]	8.312[b]
Product per man-year ('000 won at 1970 prices)	384	514	595	782
Non-agricultural product (billion won at 1970 prices)	1,853	3,290	5,593	10,807
Non-agricultural product (billion won at 1970 prices)	1,853	3,290	5,593	10,807
Agricultural gross output[c] (billion won at 1970 prices)	925	1,170	1,490	1,870
Do less intermediate goods[d] (billion won at 1970 prices)	725	893	1,113	1,348
Gross domestic product (billion won at 1970 prices)	2,578	4,183	6,706	12,155
Government Consumption Expenditure[d] (billion won at 1970 prices)	282	410	625	935
Private Consumption[e] (billion won at 1970 prices)	1,884	2,684	4,404	8,181
Population (millions)	31.43	35.28	38.60	92.83
Per head consumption ('000 won at 1970 prices)	59.9	76.1	114.1	191.0

[a] Extrapolated at 8% per year
[b] Extrapolated at 3.6% per year
[c] Extrapolated at 4.5% per year
[d] Separately extrapolated
[e] Actual for 1970 and 1975. For 1980 and 1985 calculated on the assumption that gross capital formation, including stocks, and export surplus, will be 25% of gross domestic product.

firmed by the FAO index for Korean output (presumably with a different weighting system) but are confirmed, up to 1971, in a separate study by Sung Hwan Ban.[7] Any revision would only make a slight difference to the total. In Table 5 consumption is estimated on the assumption of 25% of the gross domestic product being required for gross capital formation, including stocks, and export surplus. The official plan uses a figure of 26%, as against the 27% which has prevailed in recent years. However in the official plan it is expected that some 7 or 8% of gross investment would be financed from abroad.

We now turn to the international figures of consumption to estimate income elasticities for those agricultural products for which demand is expected to show a substantial increase. In each case examined the income-consumption relationships (both plotted logarithmically) show a fairly regular international pattern, which is used to project Korean demand. It will be seen however from the table that, while recent Korean demand

[7] Conference on Agricultural Growth, East-West Centre, University of Hawaii, 1973.

has been in line with the international pattern for fruit and vegetables, and for eggs, and above in the case of tobacco, it stands at less than half the expected level for meat, and at very much lower levels still for oils and fats, and for milk. As Korean real incomes continue to rise it is not, of course, expected that consumption of these three latter commodities will immediately jump to the expected international level. But it is expected that the difference between Korean and international levels of consumption will be progressively reduced i.e. that consumption of these commodities will rise even more rapidly than indicated by the international estimate of income elasticity.

It is reasonable to relate demand for particular agricultural products to per head value of real consumption, not real gross product, which may include varying elements of investment and government services. In the definitions used in the international comparison of incomes, the government provision of education and health services is included in private consumption.

Before using these data however a small adjustment is made. There have always been great difficulties in making international comparisons of the price and quantity of services. In Kravis's comparisons price measurements are made for some services (repairs, entertainment, hairdressing, restaurants, hotels). However for domestic medical and educational services quantity comparisons are made simply on the basis of the number employed in each country. It appears that this method understates the higher productivity of service workers in the more advanced economies. That productivity in the service industries, contrary to what is sometimes supposed, does advance is indicated by international comparisons, and also time series of service prices. This adjustment leads to a 12% raising of the international value of consumption in the United States; for other countries the effects are smaller.

The Kravis study makes an important innovation. Most international comparisons in the past have restated other countries' national products, consumption etc. revalued in $US. This leads to certain distortions, placing a relatively high price on some services, and relatively low prices on automobiles, household equipment etc. In this book is designed an "international currency" in which measurements are made. A unit of this currency, in the aggregate, has the same purchasing power as $1 within the United States in 1970. But the *relative* prices peculiar to the United States have been eliminated in favour of international average relative prices.

The food consumption figures are from FAO food balance sheets referring to the years 1964–66. While the income and consumption data relate to 1970, the difference is not expected to have any serious effect. The consumption of milk includes the estimated fresh milk equivalent of butter, cheese, dried milk and other dairy products. Butter is excluded from the oils and fats total.

TABLE 6

INTERNATIONAL CONSUMPTION COMPARISONS

	Total per head consumption in International money		*kg*	*kg*	*kg*	*kg*	*kg*	*kg*	International money	
	As given	Revised	Cereals[a] & roots	Meat	Milk[b]	Fish	Oils & Fats	Eggs	Fruits & Vegetables	Tobacco
Kenya	209	206	186	18.1	49.9	3.1	3.6	0.5	27.6	2.4
India	234	219	164	1.2	42.8	1.9	3.5	0.1	19.2	4.7
Philippines	444	455	169	15.0	7.7	20.9	5.0	2.5	3.8	9.3
Republic of Korea	416	412	274	5.6	0.7	15.6	0.9	1.9	31.8	10.3
Columbia	617	595	145	29.5	108.5	2.1	7.3	3.8	38.7	26.9
Malaysia	602	617	173	12.9	26.8	23.5	10.2	3.0	30.1	16.4
Iran	697	663	165	13.9	60.3	0.4	6.4	1.0	40.3	10.7
Hungary	1,347	1,380	226	50.8	141.3	2.8	24.4	9.8	68.8	41.3
Italy	1,560	1,572	202	36.9	173.0	10.0	16.3	9.6	126.4	37.5
Japan	1,609	1,608	176	11.3	38.9	62.5	7.5	10.0	62.4	27.1
United Kingdom	2,038	2,143	175	69.5	245	10.8	27.4	16.0	67.2	54.6
Netherlands	2,051	2,211	159	54.0	369	9.1	42.3	12.1	81.6	65.4
Belgium	2,276	2,359	181	63.7	397	18.8	25.1	13.4	84.4	61.7
France	2,149	2,280	160	77.3	419	17.2	20.7	11.1	88.5	40.6
W. Germany	2,111	2,189	168	66.5	349	17.9	25.3	13.7	58.2	28.9
USA	3,261	3,656	150	87.3	293	8.5	32.2	18.1	117.7	61.0
Estimated income elasticity			Not estimated	.88	.93	Not estimated	1.10	1.03	.60	.88

[a] Expressed in wheat equivalent

[b] Including milk equivalent of dairy products

The consumption figures include net import, less any recorded net increases in stocks. Deductions for supposed waste have not been made. (See Table 6)

Income elasticity was not estimated for fish, where consumption depends so much upon local circumstances. This provides a substitute (though not kilogram for kilogram) for meat demand. Nor was an estimate made for the consumption of cereals and roots, where elasticity is expected to be negative. The exceptionally high figure for Korea may have included mistakenly some barley used for livestock feeding. It is of course complementary to the unusually low consumption of meat and dairy products; and may be expected to show a large decline as real incomes improve.

An analysis has not been made of the demand for coffee, tea etc., or for sugar and its products, which commodities, it is assumed, will be imported. Some of the increased demand for other foodstuffs may also be met from imports; this will depend on the productive capacity of an improved Korean agriculture, to be considered below.

The following shows the results of applying the international income elasticities and average consumption levels to estimated Korean total per head real consumption figures up to 1985.

TABLE 7

ESTIMATED PER HEAD CONSUMPTION ON INTERNATIONAL DATA

	Actual		Calculated		
	1964–6	1970	1975	1980	1985
Korean per head total consumption					
1000 won of 1970 purchasing power		59.9	76.1	119.1	191.0
International money		912	523	784	1,313
Per head consumption					
Meat (*kg*)	5.6	13.7	16.9	24.2	57.0
Milk & milk equivalent of milk products (*kg*)	0.7	38.6	48.2	70.1	114.3
Oils & fats (*kg*)	0.9	4.5	5.8	9.1	16.0
Eggs (*kg*)	1.9	1.9	2.4	3.7	6.3
Fruit & vegetables (international money)	31.8	31.8	36.6	46.7	63.7
Tobacco (international money)	10.3	8.2	10.1	14.4	22.7

We finally have to consider what an improved Korean agriculture can do to meet these expected rapid increases in demand for certain products, bearing in mind that it will still have an exceptionally high labour supply per hectare of land, though threatened in the near future with a diminution of labour supplies in the present June peak period. We should also bear in mind that, as a considerably advanced industrial economy, Korea will be able to import substantially increased quantities of agricultural produce, including (as are now imported into Japan) large amounts of coarse grain as feeding stuffs for animals.

The first consideration must be to reduce, if possible, the sharpness

of the peak demand for labour. Here something may be learned from Japan. Japan also has a high ratio of labour to land, though admittedly with a more favourable climate. An interesting and simple example quoted by Isobe[8] compares a farm of 1.9 *ha*, with 2.8 man equivalent labour units, growing single-cropped rice, vetch and mulberry, with a slightly smaller farm of 1.5 *ha*, and 2.4 labour units, growing double-cropped rice, wheat, barley, vetch, fruit and vegetabels, and keeping poultry. Both require a certain amount of animal draught power, between April and June, though the second is better spread, not exceeding 20 hours per week, while the former may require nearly 40. The second farm is able to spread its labour requirements far better; have temporary maxima just under 150 in June and September. The former farm on the other hand has a violent labour peak of over 300 hours required in the first week in June, and another peak in October, while for much of the winter less than ten hours a week are required.

For a much colder climate however a Japanese exercise[9] in linear programming has also been undertaken. Currency has been converted to wheat equivalents on the wheat price of 45.000 yen/ton, which appear to be approximately in line with the prices of most agricultural products. (If we converted on the price of milled rice of 95,000 yen/ton we would get much lower results. But the Government-supported price for rice in Japan appears to be out of line with that of other products.) The plan is for a family settling in Hokkaido, the cold northern Japanese island where land is fairly abundant. The family is assumed to contain $2\frac{1}{2}$ or 5 labour units, each regarded as capable of working 27 days/month, 10 hours/day from May to July, 9 in September, and 8 for the rest of the year. The family is to employ draught animals, but otherwise to maintain Japanese standard of intensive cultivation. Under these circumstances, and in this climate, the programme rejected wheat, sugar beet and potatoes, and called for

TABLE 8

MARGINAL PRODUCTIVITIES OF LAND FOR FAMILY OF $2\frac{1}{2}$ LABOUR UNITS IN HOKKAIDO

Hectares	Present methods marginal product *t/ha. wheat equiv.*	*Hectares*	With expected future yield increase marginal product *t/ha. wheat equiv.*
0– 2.5	2.55	0– 2.5	3.00
2.5– 8.2	1.60	2.5– 8.6	2.07
8.2– 8.5	1.52	8.6–11.5	2.03
8.5–10.6	1.32		
10.6–12.1	1.16		

[8] *Farm Planning with Special Reference to the Management and Improving of Small-scale Family farming*, Japanese Ministry of Agriculture, October 1956.

[9] Yajima, *World Population Conference*, 1965.

concentration on dairying and soyabeans.

Under these circumstances, the marginal productivity of land change by discrete steps, indicating, for this family, an optimum holding of 12.1 hectares, yielding an income of 20.5 tons wheat equivalent. Improved yields are expected to indicate a slightly lower optimum farm of 11.5 hectares, raising the income to 26.7 tons wheat equivalent.

Mathematical programmes[10] have been prepared for a still smaller farm in Taiwan with three able-bodied workers and only half a hectare of land (90 per cent irrigated). The ratio of cropped to cultivated land in Taiwan has risen, not surprisingly, from 1.16 in 1911–15 to 1.32 in 1932–5, and 1.80 in 1956–60. A shortage of feeding stuffs rules out the possibility of intensifying through keeping more livestock, beyond one pig per family, living on his ration of 400*kg*/year of sweet potato, grown on 1/30th of a hectare of unirrigated land. The present family income of such a farm averages 2,180 *kg* milled rice (converting at 5.6 Taiwan dollars to the *kg*), which is not much above subsistence level, for a family probably consisting of 6 or 7 people. Total labour input is only 224 man-days/year, of which 60 are devoted to looking after the pig and growing his fodder. Assuming an eight-hour day, this represents some 3,600 man-hours/hectare/year of labour input. It means, of course, very great under-ocupation of the three potential workers; in the busiest months, a total of only 28 man-days is required in February and 27 in November, while in January and June only one man-day is required in each (work on the pig being excluded throughout).

At this intensity of labour input, one would have thought that any further intensification would have yielded little or no marginal return. The authors, using a linear programming method, still accepting the constraint that no livestock must be kept except the one pig, have devised a programme which increases total labour input by 75 per cent, and more than doubles the family income, to 4,630 *kg* milled rice equivalent, i.e. a marginal return actually greater than the previous average return. The programme indicates two crops of rice and winter cabbage on the irrigated land, groundnut, sweet potato and cabbage on the unirrigated. The pig still receives his 60 man-days in July, 59 in November and 55 in February (i.e. rather more than two men can provide); with mitigated slack periods, in which 12 man-days are demanded each in January and April, nine in September and six in October.

This remarkable study brings hope even to the most exceptionally densely populated areas—provided they have adequate water.

It must be added however that in this Taiwan programme the "shadow price" of labour (i.e. what it would be economically worth while for the farmer to pay) is zero. Such very high labour inputs per hectare of land are not expected to last long, once alternative employment is available.

[10] Hsieh and Lee, *World Population Conference*, 1965.

A further interesting application of linear programming in a cold climate has been made in a mountainous region in Greece[11] with small farms averaging 3.5 hectares and 3–4 labour force. Programming can improve labour utilisation by 10–20%, with peak demand June-August, but still only providing occupation for 30% of the available labour in December and January.

A theoretical exercise in preparing a programme in which capital was supposed to be available in unlimited quantities still could only occupy 50% of the available labour in the coldest months.

These results draw attention to the importance of developing part-time seasonal non-farm employment for the farm population, which is now extensive in Japan.

[11] Kitsopanides, "Farm Planning for Increasing Family Income in Western Macedonia Greece", *Journal of Agricultural Economics*, December 1973.