PART II

Population Growth and Food Production Increase —Prospects of Demand and Supply—

Chapter 4

Prospects of Population Growth and Food Demand and Supply in the APEC Region

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World Population Growth and Food Crisis

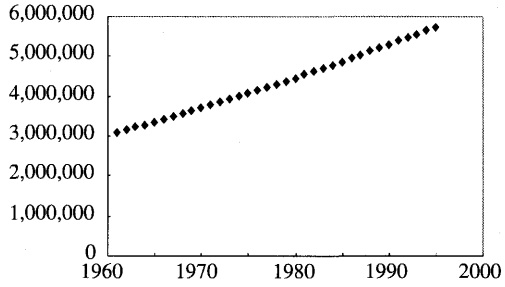
Introduction

The world population increased from 3.0 to 5.7 billion during the period between 1960 and 1995. Thus, 77 million people were added annually during this period. According to the UN projection, it will reach 7.1 billion in 2010. Thus, the increase will be 93 million people annually until 2010. This is equivalent to the whole Mexican population or three-fourths of the Japanese population in 1995. The population will grow more rapidly in developing countries: It will increase from 4.5 to 5.7 billion in 2010. On the other hand, that of developed countries will increase from 1.2 to 1.4 billion. Thus, the former proportion will increase from 78.9 to 80.3 percent.

The above situation will arise within only 15 years. However, the population growth will not stop in 2010. According to the UN projection, although the pace will be slower, it will reach 8.7 billion in 2030. Moreover, it will be 9.8 billion in 2050. Among them, 87.8 percent will live in the developing countries.

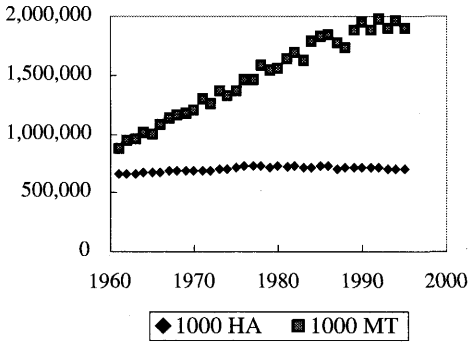
This rapid population growth reminds us of the well known warning given by Malthus in his famous *Essay on the Principle of Population as it Affects the Future Improvement of Society*. He argues that population grows geometrically, yet food supplies can grow only linearly. While the situation that Malthus worried about has never occurred, concerns about catastrophic food shortages have continued to arise.

For example, as shown in Fig. 1 and 2, the world population has been monotonously increasing while the recent world cereal production seems to be stagnant. Decrease in area harvested is not the sole reason.



Source: FAOSTAT

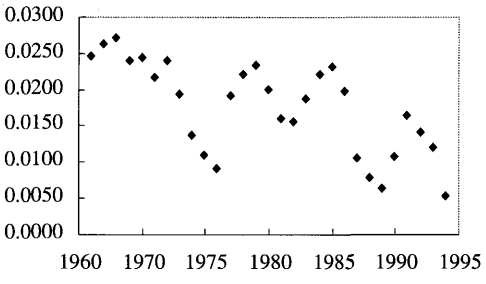
Fig. 1 World Population



Source: FAOSTAT

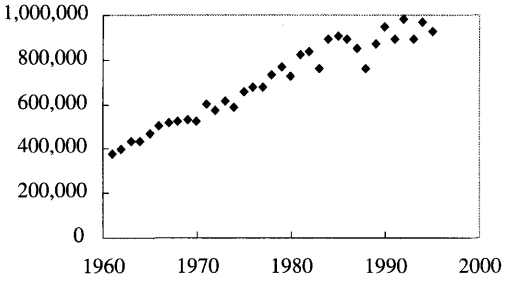
Fig. 2 World Cereal Production

(See Fig. 3 and 4.) The growth rate of yield also has been stagnant.[1] Therefore, if the recent trend is applicable to the future, we can derive pessimistic views.



Source: FAOSTAT

Fig. 3 World Yield Growth Rate



Source: FAOSTAT

Fig. 4 World Cereal Area Harvested

Recent Wake-up Calls

In the early 1970s, a wake-up call was presented by the Club of Rome [1970]. Various scenarios were simulated by using their WORLD III model. The major predictions are as follows: In the early twenty-first century, the world population will grow to the peak of 10 billion. As a result, per capita food production will drop to 15–25 percent of 1970 levels. Moreover, pollution will rise tenfold, and the most important resources will become depleted.

However, this pessimistic view was criticized by many optimistic economists. Their view can be summarized as follows: First, if an S-shaped logistic curve can be fitted to the future path of population growth, the population growth will automatically come to a halt at the end of the next 200-year period. Second, the limitations with respect to the resources will be overcome by the new technologies because necessity is the mother of invention. (See, for example, Herman Kahn, William Brown, and Leon Martel [1976].)

Recently, similar warnings were given by Meadows et al [1992] and Brown [1995, 1996, and 1997]. Among them, Lester Brown's projection is widely quoted by mass-media, consumer's associations, agricultural organizations, and so on because the projected results are so catastrophic.

Lester Brown also gave a wake-up call: According to *Full House*, world grain demand will be 2.7 billion tons while world production will be 2.1 billion tons. As a result, the demand shortage will be about 0.6 billion tons in 2030. A decreasing trend of yield and area harvested is assumed.

He pays more attention to China because her population is projected to reach 1.6 billion in 2030 while her annual income growth rate is projected to remain about 8 percent during this period. According to his recent book (*Who Will Feed China?*), the Chinese grain demand will increase to 480 million tons while her production will decrease to 270 million tons. As a result, her grain imports will be about 200 million tons in 2030. Roughly speaking, this is equal to this year's world grain trade.

Here, the production is assumed to decrease because some densely populated Asian countries show clearly that cropland is lost quickly due to industrialization, and that these countries become net importers of grain. For example, according to Brown, the grain production of Japan decreased by 32 percent during the period between 1960 and 1994. He, therefore, forecasts that if China follows this type of industrialization, her agricultural production will decrease by 20 percent by 2030.[2]

Moreover, if China increases its total grain use from 292 kilograms per person to the same as that of Taiwan (400 kilograms), the demand will be 641 million tons. As a result, her grain imports will increase by 369 million tons in 2030. As a whole, the world food consumption will be 2,675 million tons while world food production will be 2,121 million tons. Thus, the gap will be 526 million tons in 2030. Since this will increase food prices, the world's poor cannot afford to eat. The expansion of farm land is one of the options; however, it will trigger environmental problems.

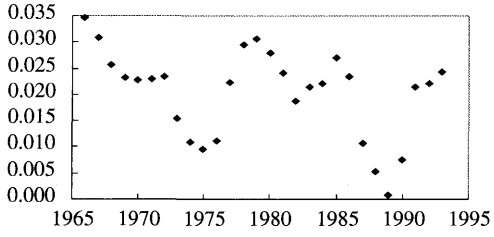


Fig. 5 Area Harvested in China

However, Brown's pessimistic view is criticized by many economists. (See, for example, Oga [1995] and Thompson [1996].) Their views can be summarized as follows:

(1) Brown's model is too crude because price effects are not counted. If the grain price increases as Brown expected, the grain demand will decrease by the law of demand. Similarly, the grain supply may increase. (See Appendix.)

(2) China's grain imports cannot expand so drastically because they do not have enough infrastructure (ports, warehouses, roads, and so on).

(3) China's farm land will not decrease drastically as Brown expected because her industrialization strategy will be different from that of East Asian countries

where their farm land has been dramatically decreasing during the process of industrialization. In other words, the Chinese population is too large to rely heavily on the imported food.

(4) The Chinese land productivity was overestimated because the area harvested was underestimated. Therefore, her actual land productivity is much lower. In other words, there is room to increase land productivity.

(5) Although the recent land productivity growth is not fast, new technologies such as biotechnology will overcome this situation.

Projections of International Organizations

Many international organizations have released their projection results, too. (See Table 1) In contrast with Brown, world supply and world demand are balanced in these predictions. For example, the forecast of the World Bank [1993] can be summarized as follows: In 2010, developed countries' production will be 1,045 million tons while developing countries' production will be 1,261 million tons. As a result, the world production will be 2,306 million tons.

Table 1 World Food Projection

	Developed Countries			Developed Countries			World		Growth Rate	
	Production	Consumption	Net Exports	Production	Consumption	Net Exports	Production	Consumption	Production	Consumption
USDA [2005]							2,121	2,121	1.11	1.11
MAFF No. 1 [2010]	1,057	924	134	1,331	1,465	−134	2,388	2,388	1.54	1.54
MAFF No. 2 [2010]	1,059	856	206	1,141	1,349	−206	2,200	2,200	0.98	0.98
FAO [2010]	1,028	886	162	1,318	1,480	−162	2,346	2,346	1.42	1.42
IFPRI [2010]	1,159	980	179	1,211	1,390	−179	2,370	2,370	1.48	1.48
World Bank [2010]	1,045	829	210	1,261	1,459	−210	2,306	2,306	1.30	1.30
IFPRI [2020]	1,134	946	188	1,545	1,733	−188	2,679	2,679	1.38	1.38
World Bank [2030]		947			2,350		3,297	3,297	1.59	1.59
Brown [2030]							2,149	2,675	0.35	0.98

Unit: million tons and percent

Note: MAFF No. 1 assumes that today's yield growth rate will be maintained.
MAFF No. 2 assumes that the yield growth rate will decrease and become half of today's level.

On the other hand, developed countries' consumption will be 829 million tons while developing countries' consumption will be 1,459 million tons. As a result, the world consumption will be 2,306 million tons. Finally, the real prices are predicted to decrease by 20 to 30 percent compared with those of 1990. In other words, the supply increase will be greater than demand increase. The required average growth rate of production is 1.3 percent per year. In this sense, their prediction is much more optimistic than Brown's.

The projections by the other international organizations are also optimistic: For example, the grain imports of developing countries predicted by FAO and IFPRI are 162 and 179 million tons, respectively. These are smaller than that of the World Bank. The required average growth rate of production is around 1.4 to 1.5 percent per year. In sum, according to them, the catastrophic world food crisis can be avoided.

The only exception is the projection of MAFF No. 2: they assume that the yield growth rate will be decreasing.[3] In this case, the world production (and consumption) will be 2,200 million tons. In contrast with the other organizations' predictions, the real prices are predicted to rise much higher than today's level. The estimated growth rate is also lower.

Some Limitations of Econometric Forecasting

The above results are derived by using sophisticated econometric models. Moreover, from the theoretical economics point of view, they are more careful. For example, price adjustment mechanisms are built in. In this sense, their results seem to be more reliable than that of Lester Brown. However, at the same time, we should keep in mind that some of their assumptions may be too optimistic:

First, most of them assume the linear type of technological progress; however, this sort of technological progress cannot be achieved automatically. Although necessity is the mother of invention, new technologies will not be introduced without appropriate public assistance.

Second, as Brown and Kane [1994] pointed out, the global fish catch peaked in 1989 and has remained static since then.[4] Thus, it is highly possible that fish consumption will be largely substituted by grain-fed meat consumption in the future. As a result, additional grain demand will be induced. However, this sort of substitution is not considered in the sophisticated econometric models.

Third, natural resource constraints such as water shortages, etc. are not fully taken into consideration in the models.

Fourth, environmental constraints such as soil erosion, salt damage, desertification, etc. are not fully considered.

Fifth, effects of nonagricultural sectors are not fully analyzed. For example, if manufacturing exports are more profitable, most farmers will not invest their money in agriculture. As a result, the supply curve of food may not shift towards the right.

Sixth, problems related to income distribution are not considered explicitly in the models. In other words, model builders implicitly assume that all the problems can be solved by the market mechanism. However, even today, there are 800 million people who are hungry.[5] They are hungry simply because they are poor. Thus, it is too short-sighted to believe that the market mechanism can solve everything.

Prospects of Population Growth and Food Demand and Supply in the APEC Region

In the previous section, a brief survey on the world-wide prospects of population growth and food demand and supply was shown. With this in mind, the prospects with respect to the APEC region will be discussed in this section. However, our approach is different from that of international organizations: We will not forecast how our future will be. Instead, we will estimate (at least) how much efforts we will

have to make.[6] For this purpose, we will estimate per-capita grain consumption in 2030 by taking income growth into consideration.

Demand Projection: Two Cases

Generally, per-capita grain consumption is a function of income and prices. However, if we look at the cross-section data, we do not need to take prices into consideration. With this in mind, by using 1990's cross-section data[7], the following relationship was estimated:

$$\log Y = \underset{(28.85)^{**}}{3.70} - \underset{(6.64)^{**}}{0.58\,D1} + \underset{(6.81)^{**}}{0.55\,D2} + \underset{(14.84)^{**}}{0.25 \log X} \qquad (1)$$

Adjusted $R^2 = 0.98$

where Y and X denote per-capita direct and indirect[8] consumption of grain and per-capita GDP, respectively. D1 is a dummy variable which is one for Japanese type fish eaters. D2 is a dummy variable which is one for US type meat eaters.

Case 1: Grain Consumption Induced by Population Growth Alone

Each sub-region's grain consumption induced by population growth alone is shown in Table 2. The second column shows each country's per-capita grain consumption in 1990. These figures are slightly different from those of Lester Brown because our figures were estimated by using formula (1).[9]

Table 2 APEC in 2030

	Per capita Consumption		Production	Population	Consumption		Necessary Growth Rate(Case 2)		
	Case 1	Case 2	1995	2030	Case 1 2030	Case 2 2030	APEC Only 1995-2030	APEC *1.2 1995-2030	APEC *1.3 1995-2030
	kg/year	kg/year	Million tons	Million	Million tons	Million tons	%	%	%
SEA1+PNG	205	240	70	404	83	97			
SEA2	262	326	26	109	29	36			
SEA3	427	530	1	4	1	2			
OCE	471	503	24	29	14	15			
China	314	428	405	1,526	479	653			
EA	373	455	10	89	33	40			
Japan	295	315	13	119	35	38			
NA	882	882	347	376	331	331			
LA	290	323	29	163	47	53			
APEC	377	455	925	2,818	1,053	1,265	0.90	1.43	1.66

SEA1: Indonesia & the Phillipines
SEA2: Malaysia & Thailand
SEA3: Singapore & Brunei
OCE: Australia & New Zealand
NA: USA & Canada
LA: Chile & Mexico
PNG: Papua New Guinea

Suppose that this consumption pattern does not change even after 1990.[10] Then, by using estimated population, the grain consumption of APEC in 2030 can be derived. The results are shown in the sixth column.

First, the Chinese grain consumption will increase from 356 to 479 million tons. Thus, even under such conservative assumptions, the Chinese grain demand will increase by 123 million tons. This is equivalent to 16 percent of the total grain consumption of the APEC region in 1990.

Second, the grain demand in APEC will increase from 771 to 1,053 million tons in 2030. In other words, as a whole, it will increase by 282 million tons. This is equivalent to 36 percent of the total grain consumption of APEC in 1990.

Case 2: Grain Consumption Induced by Population and Income Growth

In this case, the changes in income are taken into consideration.[11] The third column shows each country's per-capita grain consumption in 2005. These figures were obtained by using formula (1) and USDA data[12]

Suppose that the consumption pattern of 2030 is the same as that of 2005.[13] Then, the total grain consumption in 2030 can be estimated as shown in the seventh column.

First, the Chinese grain consumption will increase from 356 to 653 million tons. As a result, the Chinese grain demand will increase by 297 million tons. This is equivalent to 39 percent of the total consumption of APEC in 1990.

Second, the grain demand of APEC will increase from 771 to 1,265 million tons in 2030. In other words, it will increase by 494 million tons, and is equivalent to 64 percent of the total consumption of APEC in 1990.

Comparison with Production

To Satisfy the Regional Consumption

As previously mentioned, under the assumption of Case 1, the grain consumption of APEC is expected to reach 1,053 million tons in 2030. However, their recent cereal production is around 930 million tons.[14] Therefore, in order to balance them, the production is required to increase by about 122 million tons. This is equivalent to 13.5 percent of the production in 1995. The required growth rate is only 0.37 percent.

On the other hand, under the assumption of Case 2, the grain consumption of APEC is expected to reach 1,265 million tons in 2030. Therefore, in order to match this consumption, the production is required to increase by about 335 million tons. This is equivalent to 36.2 percent of the production in 1995. The required growth rate is 0.90 percent. This is higher than that of Case 1 but still below 1 percent.

To Satisfy the Other Regions' Consumption

In the previous section, the prospective grain demand of the APEC region was compared with their recent grain production. In other words, we implicitly examined the possibility of self-sufficiency within this region. However, this sort of examination

may be meaningless because this region has the responsibility to feed not only themselves but also the other regions.

If the APEC region has to take care of the other regions' grain demands, the annual growth rate of grain production must be higher than the one examined above. For this purpose, let us make a simple assumption that production-consumption ratio becomes 1.20 in 2030.[15] Then, in Case 2, this region's grain production must increase to 1,518 million tons. The required growth rate of production is 1.43 percent. Similarly, if the ratio becomes 1.30, the production must increase to 1.645 million tons. The required growth rate is 1.66 percent.

Since the average annual production growth rate of APEC for the period between 1975 and 1994 is 1.9 percent, the above mission doesn't seem to be impossible. However, this period includes the Green Revolution. If we adopt the period between 1980 and 1994, the growth rate was 1.2 percent. Then, the mission becomes impossible. Moreover, as shown in Fig. 6, the yield growth rate has a tendency to become smaller. Thus, without making special efforts to improve land productivity, these targets may not be easy to achieve.

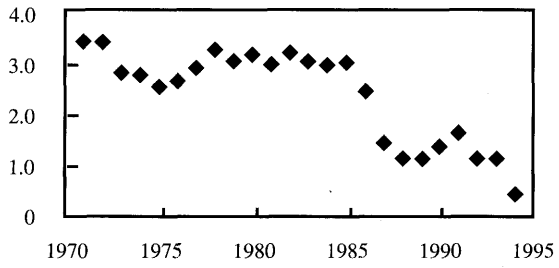


Fig. 6 Yield Growth Rate in APEC

Concluding Remarks

How Do We Approach the FEEEP Issues?

One of the main activities of APEC is to expand trade among the members. For this purpose, many attempts for liberalization and deregulation have been made. The related negotiations and studies have been and will be done in the routine activities of APEC. Then, why should we pick the FEEEP issues *independently*?

First, for the next generation, resource and environmental constraints must be taken into consideration now because their demand is not explicitly reflected in today's market. Therefore, although the market mechanism is useful for solving our generation's problems, it has limitations for the next generation's problems.

Second, even for our generation, there are still many problems to which the market mechanism can hardly give ideal answers. For example, if there are problems related to external economies (diseconomies), public goods, uncertainty, imperfect information, oligopolies, and so on, the equilibrium production in a perfectly competitive market becomes different from a socially optimal level. In other words, under these circumstances, perfect competition does not lead to maximum social welfare.

Third, there are income distribution problems. These are different from market

failure problems.[16] However, the market mechanism can hardly give ideal answers to these problems. According to the Food and Agricultural Organization [1996], there are 800 million hungry people even today. They are hungry simply because they do not have enough money. In this sense, the perfectly competitive prices may not be the "right" ones.

Needless to say, making efforts to utilize the market mechanism is important. However, as previously mentioned, the policy failure problems have been and will be discussed in the routine activities of APEC. Therefore, in order to obtain so-called benefit from division of labor, a different approach should be taken for the analysis of FEEEP issues.

What Can We Do?

Necessity of Evaluating Environmental Value of Agriculture

As is often pointed out, Asian farming based on paddy fields has the role of preserving the land and environment. On the other hand, agricultural activities contaminate ground water and induce soil erosion. If eternal economies or diseconomies are present, perfect competition does not lead to maximum social welfare. Therefore, it is necessary to evaluate these aspects of agricultural production.

In order to measure such aspects, several methods have been applied. Among them, Hedonic and CVM (contingent valuation method) approaches are widely used. However, as many economists have pointed out, the estimation results are still unstable. Therefore, further studies on these methods are required. Financial assistance will help these attempts.

Necessity of Further Agricultural Investment for Research and Irrigation

As optimistic economists point out, the Chinese yield may be much smaller because of the underestimation of area harvested. Therefore, it may be possible to increase their yield. Moreover, the development of biotechnology may be able to increase the land productivity in many countries.

However, as pessimistic economists point out, resource and environmental constraints on production such as degradation and "desertification" will be more serious. Moreover, according to some surveys, many irrigation facilities are getting older.

Therefore, in order to cope with the grain demand growth which will be induced by population increase, agricultural investment for research and irrigation is indispensable. However, compared with the non-agricultural investment, there are larger uncertainty and lack of information in the agricultural investment. Moreover, it takes more than ten years to receive the benefit from the agricultural investment. Thus, it may be too optimistic to expect the dramatic increase in private investment. Therefore, as an alternative, public investment may be still important.

Necessity of Education and Extension Services

As is often pointed out, shift-cultivation is one of the main causes of deforestation. This type of farming cannot be stopped unless these farmers can earn enough profit. In other words, improvement of agricultural productivity is one of the effective ways to stop deforestation.

However, unfortunately, the lack of education often prevents farmers from introducing more productive technologies. Sometimes they don't introduce high yield varieties simply because they don't know. This is the typical negative effect of imperfect information. Therefore, extension services and education should be provided by either governments or international organizations.

Necessity of Rural Poverty Reduction

Supply shortages may drive prices inevitably upward to balance demand and supply. Thus, the excess demand will be automatically cleared by the market mechanism. However, as is shown in the Appendix, this type of solution may not be preferable if today's food price is too high for poor people.

According to the statistics, more than 1 kg of grain per person per day is produced in the world. However, at the same time, 800 million people are still hungry. They are hungry simply because they cannot buy their food. Needless to say, compared with the rural residents of Sub-Sahara and South Asia, those of APEC members can earn higher income. However, as is often reported in the newspapers, the price hike of staple crops has been one of the main causes of political instability. In other words, the poverty problem cannot be neglected even in this region.

Since most of them are living in rural areas, they must have the means to generate income to buy food. For this purpose, rural development is indispensable. However, governments in many developing countries are eager for industrialization. As a result, there is a tendency for the priority of rural development to be relatively low in many developing countries. Therefore, rural poverty reduction programs should be more actively encouraged.

Appendix: Food Consumption and Income Distribution

Derivation of World Demand Curve

On average, about 900g of cereals are available per person per year. In terms of calorie intake, this is greater than the minimum energy requirement. However, according to FAO, there are about 800 million hungry people in the world. In order to understand this phenomenon, we have to understand the relationship between individual (household) demand curves and the world demand curve.

Figure A1 shows hypothetical food demand curves of the rich and the poor. The lower curve indicates the latter. Thus, when the price is higher than 2, the poor cannot buy any food. Moreover, if the minimum requirement of food is 1 unit, the poor cannot afford it when the price is higher than 1.

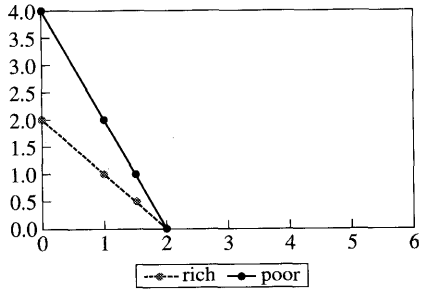


Fig. A1 Household's Demand Curve

The demand curve of a rich country can be obtained by horizontally aggregating the individual demand curve of the rich people. The demand curve of a poor country can be obtained in the same way. Thus, if we assume only one person is living in each country, the demand curves of these countries (Fig. A2) are the same as in Fig. A1.

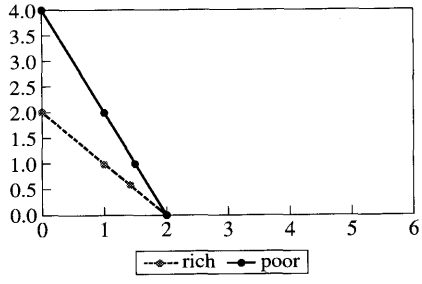


Fig. A2 Each Country's Demand Curve: Base Year

The world demand curve (Fig. A3) can be obtained by horizontally aggregating these two countries' demand curves if there are only two countries in the world. For example, when the price is 1, the demand in the rich country is 1.5 units. Similarly, the demand in the poor country is 1 unit. As a result, the world demand is 2.5 units when the price is 1.

Now, suppose that the world demand and supply curves are crossing at (2.5, 1) as

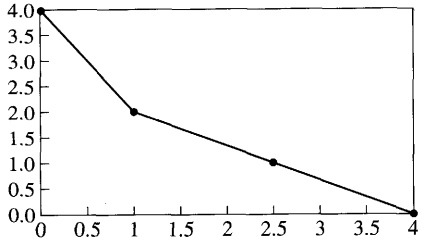


Fig. A3 World Demand Curve: Base Year

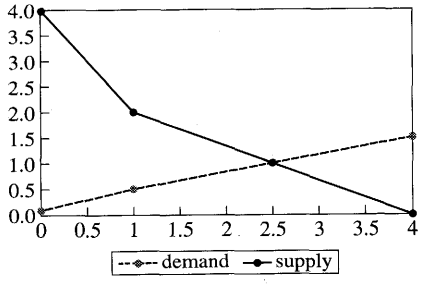


Fig. A4 World Demand and Supply

shown in Fig. A4. Then, the amount which the poor can buy is 1 unit. As previously mentioned, this is equivalent to the minimum requirement level. On the other hand, the rich can buy 1.5 units. This is the current mechanism of food distribution. There are still 800 million hungry people in the world even though the world per-capita grain production is above the minimum requirement level.

Case 1: Population Growth Only

Let us consider the effects of population growth in the poor country. For simplicity, we assume that the population of the poor country is two. Then, the demand curve of the poor country can be obtained by horizontally aggregating those of two poor people.

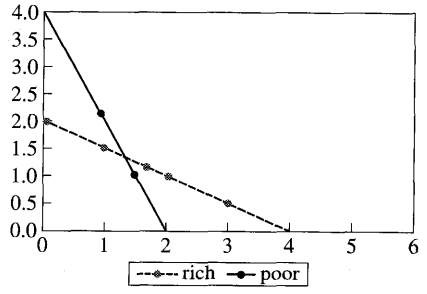


Fig. A5 Each Country's Demand Curve: Population Growth Only

For example, when the price is 1, the demand of the poor is 1. (Fig. A1) Thus, if the population is 2 people, the demand in the poor country is 2. As a result, the slope of this country's demand curve becomes less steep. (Fig. A5) On the other hand, the demand curve of the rich does not change.

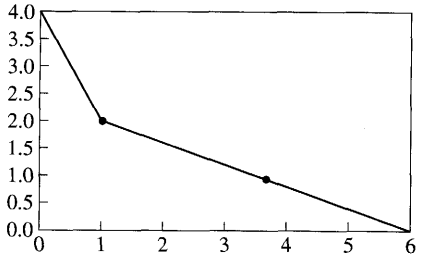


Fig. A6 Aggregated Demand Curve: Population Growth Only

The world demand curve (Fig. A6) can be obtained by horizontally aggregating these two countries' demand curves. For example, when the price is 1, the demand in the rich country is 1.5 units. Similarly, the demand in the poor country is 2 units. As a result, the world demand is 3.5 units when the price is 1.

As previously mentioned, the price should not be raised higher than 1 since the poor cannot afford the minimum requirement level of food. Thus, under this condition, the supply curve should be moved toward the right by at least 3.5 units.

Case 2: Income and Population Growth

Let us consider the effects of income and population growth in the poor country. As in Case 1, we assume that the population of the poor country is two. However, one of them is assumed to be rich. Then, this is equivalent to assuming that the population of the "rich country" is twice that of the base year while the population of the poor country does not change. Thus, their demand curves can be illustrated as Fig. A7.

The world demand curve (Fig. A8) can be obtained by horizontally aggregating

these two curves. For example, when the price is 1, the demand in the "rich country" is 3 units. On the other hand, the demand in the poor country is 1 unit. As a result, the world (aggregated) demand is 4 units when the price is 1.

As previously mentioned, the price should not be raised higher than 1 since the poor cannot afford the minimum requirement level of food. Thus, under this condition, the supply curve should be moved toward the right by at least 4.5 units.

In this paper, the prospects with respect to the APEC region was discussed. However, we did not forecast our future. Instead, we estimated (at least) how much effort we will have to make. This Appendix explains how we should interpret the results.

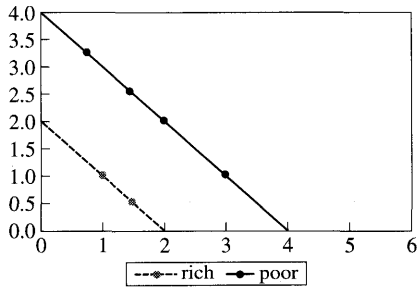


Fig. A7 Each Country's Demand Curve: Income and Population Growth

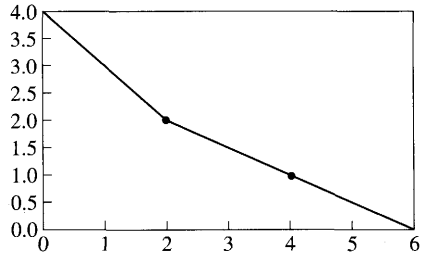


Fig. A8 Aggregated Demand Curve: Income and Population Growth

Notes

1. production = yield* area
2. Another reason is the recent stagnant trend of area harvested. (see Fig. 5)
3. MAFF No.1 assumes that today's yield growth rate will be maintained.
4. according to the FAO statistics, the world fish production has increased recently. The expansion of cultured fish production is the main reason.
5. according to FAO[1996b], most of these people are living in South Asia and Sub-Saharan Africa.
6. See Appendix.
7. Data sources are Brown [1994, 1995, and 1997], Council for Economic Planning and Development [1994], and World Bank [1992].
8. In order to produce meat, we need feed. Thus, meat consumption can be considered as "indirect" grain consumption.
9. Here, the estimated Chinese per-capita grain consumption (314 kg) is not so much different from Brown's estimation. Since this is obtained by setting D1=0 and D2=1, the Chinese consumption pattern is different from those of Taiwan, Hong Kong, and Singapore.
10. For the interpretation, see Appendix.
11. Usually, the relationship derived from the cross-section data is different from that of time-series data because some developing countries may not follow the path which developed countries took. Also, for the interpretation, see Appendix.

12. Per-capita GDP can be estimated by using growth rates of population and real GDP in USDA [1997].
13. The main reason why we chose 2005 is the data availability of USDA [1997]. Thus, the changes in income during 2005 to 2030 are not taken into consideration. Moreover, the per-capita grain consumption of USA and Canada are assumed not to increase after 1990. In this sense, the results may have a downward bias. In 2005, the per capita grain consumption of China will be almost the same level as that of 1990's Hong Kong.
14. The average of cereal production for the recent three years is 924 millions.
15. This is almost the same as today's level.
16. Theoretically, Pareto optimality can be derived without altering the income distribution.

References

Brown, R. L. and H. Kane (1994), *Full House*, W. W. Norton & Company.

Brown, R. L. (1995), *Who will Feed China: Wake-Up Call for a Small Planet*, W. Norton & Company.

Brown, R.L. (1997), *State of the World 1997*, World Watch Institute.

Council for Economic Planning and Development (1994), *Taiwan Statistical Data Book* 1994, Council for Economic Planning and Development (Taiwan).

Council of Agriculture (1995), *Agricultural Production Statistics Abstract, Taiwan District, the Republic of China*, Council of Agriculture (Taiwan).

Food and Agricultural Organization (1996a), *FAOSTAT 1996*, FAO.

Food and Agricultural Organization (1996b), *World Agriculture: Towards 2010, An FAO Study*, FAO.

Kahn, H. W. Brown, and L. Martel (1976), *Next 200 Years: A Scenario for America and the World*, William Morrow: New York.

Meadows, D. H., D. L. Meadows, and J. Randers (1992), *Beyond the Limits*, Chelsea Green Publishing Company.

Oga, K. (1996), "Sekai wa Ueruka? (World Hunger Will Happen?)," in Morishima, M., et al., *Sekai wa Ueruka,?* Nobunkyo, pp.120–175.

Thompson, R. (1996), "Shokuryo Anzenhosho no Tenbo (Forecast of Food Security)," *Asia Jiho*, February, 1997, pp. 38–59.

The Club of Rome (1970), *Seicho no Genkai* (*The Limits to Growth*), Diamond-sha: Tokyo.

United Nations (1994), *World Population Prospects*, United Nations.

United States Department of States (1991), *Brunei Background Notes*, Internet Data, The Bureau of Public Affairs.

United States Department of Agriculture (1997), *Agricultural Baseline Projections to 2005, Reflecting the 1996 Farm Act*, United States Department of Agriculture.

World Bank (1993), *The World Food Outlook*, the World Bank.

World Bank (1992), *World Development Report 1992*, the World Bank.

World Bank (1996), *World Development Report 1996*, the World Bank.