ECKHARD RAPELIUS and ADOLF WEBER

*The World Agricultural Input Industries as Factors of Rural Change**

INTRODUCTION

To increase food production per caput agricultural input industries play an increasing role. They are key factors of rural change in a dynamic world of population and income growth. They determine the welfare of rural and other people all over the world. Agricultural economists have acquired the skills to assist decision-makers in identifying and analysing the pertinent problems at the farm and at the agricultural sector level. However, the increasing international dimension and the economics of the agricultural input industries have to be properly understood. Otherwise, they become a burden and not a benefit to the farming community.

Agricultural input industries provide agriculture with seed, feed, water, agricultural chemicals and farm machinery. Some inputs are locally bound, like seed and water, and others are ubiquitous goods. They can be produced, transported and applied almost everywhere. In this study we intend to deal only with the latter category: chemicals and machinery. To be detailed enough on a worldwide basis we only treat the nitrogen and tractor industries. In section two the characteristics of these industries are considered. Sections three and four explain the international dimension and development of nitrogen and tractor production. In section five the main conclusions are drawn and proposals are made.

The key working hypothesis in our study is that poor factor endowments and smaller domestic markets are unfavourable for nitrogen and tractor production. Such production tends to increase the price of agricultural inputs. We assert that the basic tendencies of economies of scale in nitrogen and tractor production can be observed throughout the world regardless of the economic system. Whether nitrogen and tractors should be produced domestically or imported has to be judged in any well thought out development policy designed to increase food production.

* The research on which this paper is based was partly supported by the Sonderforschungsbereich 86: Weltwirtschaft und Internationale Wirtschafs-beziehungen.

2 CHARACTERISTICS OF THE TRACTOR AND NITROGEN INDUSTRY

Minimum size. Both industries use a sophisticated technology. In the establishment of a new plant, technical and economic reasons require a minimum size. The minimmum size in each industry varies according to site, costs of capital and material inputs, requirements for skilled labour, infrastructure and other factors. For a tractor plant built by a producer of autocars or a big multi-national firm to gain a strategic entry into an expanding market it reduces the minimum size to begin production. FAO [6, p. 203, 235] assumed in 1969, that the respective plants should not produce less than 10,000 tractors annually or 150,000 tons of nitrogen. Other authors claimed in 1972 and 1975[3,9] 20,000 tractors or 300,000 tons of nitrogen should be the minimum size. Further, there is evidence that economies of scale as well as production as in distribution in both industries are the most decisive element in reducing costs: the larger the plant the lower the average cost per unit of output.

Capital requirements. To establish a new plant heavy capital requirements are necessary. A tractor plant with an annual output of 20,000 tractors in 1968[7], (p. 47) needed a capital outlay of 142 million US$ (thereof 53 per cent for production and 47 per cent for wholesale distribution). The investment costs for a nitrogen plant of 300,000 t with the necessary facilities (storage, replacement parts etc.) have been estimated in 1975 to be 100 million US$[10] (p. 6). In the meantime inflation may have increased the reported absolute capital requirements.

Operating costs. In the nitrogen industry capital and maintenance costs account for 50 per cent. A crude analysis of the operating costs per unit of output reveals that raw materials (e.g. natural gas, coke, coal, oil) to be processed are a decisive cost item. Assuming a 100 per cent level of utilization of an ammonia plant and low prices for the natural gas used to derive hydrogen, the percentage for raw materials reaches 28 per cent and with higher prices 39 per cent.[5] Other sizeable parts of costs are energy and water, but labour costs only account for 5 per cent. Depending on the annual output level in the tractor industry the costs for material are about 70 per cent, 15 per cent for capital and 15 per cent for labour.[7] (p. 198) Labour costs increase comparatively in the tractor industry, because the costs of the distribution system and services after the sale have to be included.

Different risks of market entry. Despite similarities in both industries some differences are important to note. They mainly concern the transfer of knowledge and productive capacity, the type of decision-makers involved, and the risk-sharing between them. In the nitrogen industry selling the licence to apply the technical process, the engineering and the final construction of the plant might be done by three different firms. Even if selling the licence, the engineering and the construction of the new plant would be done by one firm the market risks of selling the plant's nitrogen output is completely separated from the original supplier of the

technology. In the tractor industry the owner of the licence and the final operation of the plant is in the hand of the same firm in market economies. The risk of building an inappropriate and inefficient plant or of having misjudged the initial size and growth of demand will be therefore assumed by the tractor firm investing abroad. That means that in the nitrogen industry there is no institutionalized risk-sharing between the foreign contractor and the domestic nitrogen producer. The funding is initiated and done very often by government bodies. This might be detrimental to farmers, because at later stages an internationally non-competitive nitrogen plant might be unduly protected beyond the infant stage by tariffs, quotas, or subsidies to mask an earlier defective decision. If the tractor firm's capital was exclusively provided by the foreign firm the need to protect the domestic market against international competition might not be similarly the government's obligation.

The sequence of establishing nitrogen and tractor industries. The challenge to establish both industries is in each country dictated by the size and growth of the respective demand. In a general classification, there are two types of agriculture. In the first type, people, who earn their livelihood from agriculture, are increasing absolutely in numbers. In the second type, the agricultural labour force decreases absolutely and relatively. The first is the situation in most developing countries, the second in industrial countries. The first group of countries has fast increasing land prices. They have to favour land productivity by augmenting fertilizer application. Industrial countries have to cope with fast rising prices of agricultural labour. They therefore emphasize labour saving and support simultaneously land saving technologies. The unlimited divisibility of fertilizer permits application at the lowest level of labour productivity. However, to repay the capital outlay for the smallest tractor a minimum level of labour productivity is required. Developing countries with domestic markets of sufficient size have in any defendable growth strategy for agricultural input industries to recognize that the nitrogen industry has to precede the tractor industry given that land prices increase faster than the prices of labour.

3 STRUCTURE AND DEVELOPMENT OF THE WORLD'S NITROGEN INDUSTRY

The distribution of the various size classes of nitrogen plants is shown in Table 1. The smaller plants are mainly situated in developing countries. Plants with more than 300,000 tons of capacity were in 1975 exclusively in industrial and oil exporting countries (Map 1). The trend to build larger plant sizes continues. Until the sixties the production of ammonia was considered a rather mature technology. Since then the large-scale ammonia plant has become technically feasible.

The history of plant sizes in a German chemical company in Graph 1 shows this dramatic increase. A classical Haber-Bosch plant in 1913 had

an annual capacity of 1,320 tons N. Since then, the size of newly established technical units of ammonia plants has grown to 54,000 tons in 1956. But due to recent technical innovations the capacity reached 429,000 tons in 1972. The energy consumption per tons of ammonia dropped from 88 GJ to 33 GJ as well as the investment decreased per unit of output. Nitrogen complexes surpassing the million tons combining several technical units have already been erected or are in the planning stage.

The history of the world's nitrogen production shows – compared to tractor production – a higher growth (Graphs 2(a) and 2(b)). The larger industrial countries lose their market share gradually. Economies of scale and competition among firms will assist them to stabilize nitrogen prices despite rising energy prices. This situation compares very favourably with the high prices farmers have generally to pay in developing countries when nitrogen mostly comes from small and technically old-fashioned plants.[9] (p. 72) Rising energy prices and the lack of possibilities to exploit similar economies of scale do not facilitate the task of keeping fertilizer prices down.

Economies of scale in nitrogen production continue beyond 300,000 tons. At present, 150 plants of this size could satisfy the world's nitrogen demand and could even meet the expected growth in demand until the year 2000. Nowadays, the domestic market is big enough in only 29 countries (out of 152) to host a nitrogen plant of desirable size. Only one country in South America, two in Africa and four in Asia (excluding China, India, and Japan) have a sufficient market size.

To avoid a total dependency on the world nitrogen market governments with small domestic markets tend to favour the erection of nitrogen plants. A contractor of a nitrogen plant will sell any desired size of plant. But he does not share the risks of marketing the production. On the other

TABLE 1 *Distribution of size classes of nitrogen plants*

Worlda 1973

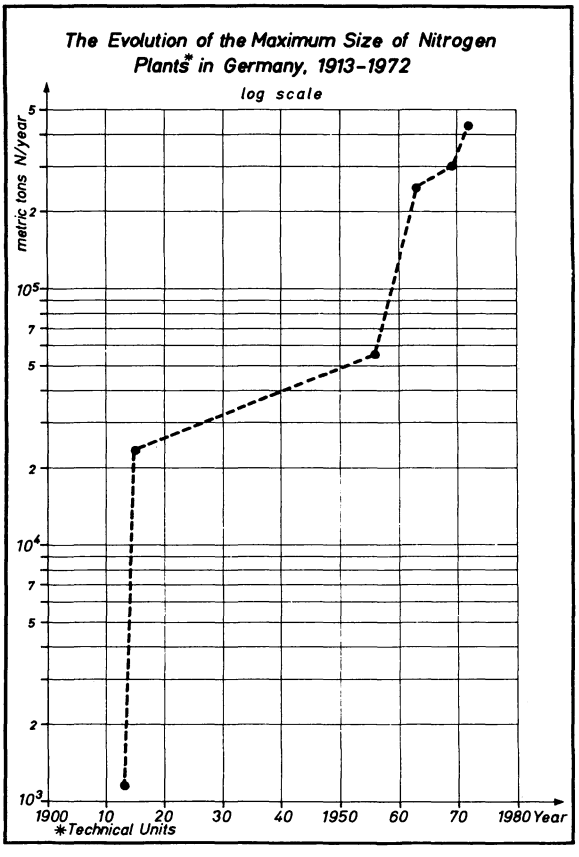
Plant Capacity in 1,000 tons N(p.a.)	Number of plants
> 700	2
501–700	4
401–500	12
301–400	23
< 300	324
	365

a Without China, North Korea and other non-reporting countries.
Source: The British Sulphur Corporation. World Fertilizer Atlas 1973.

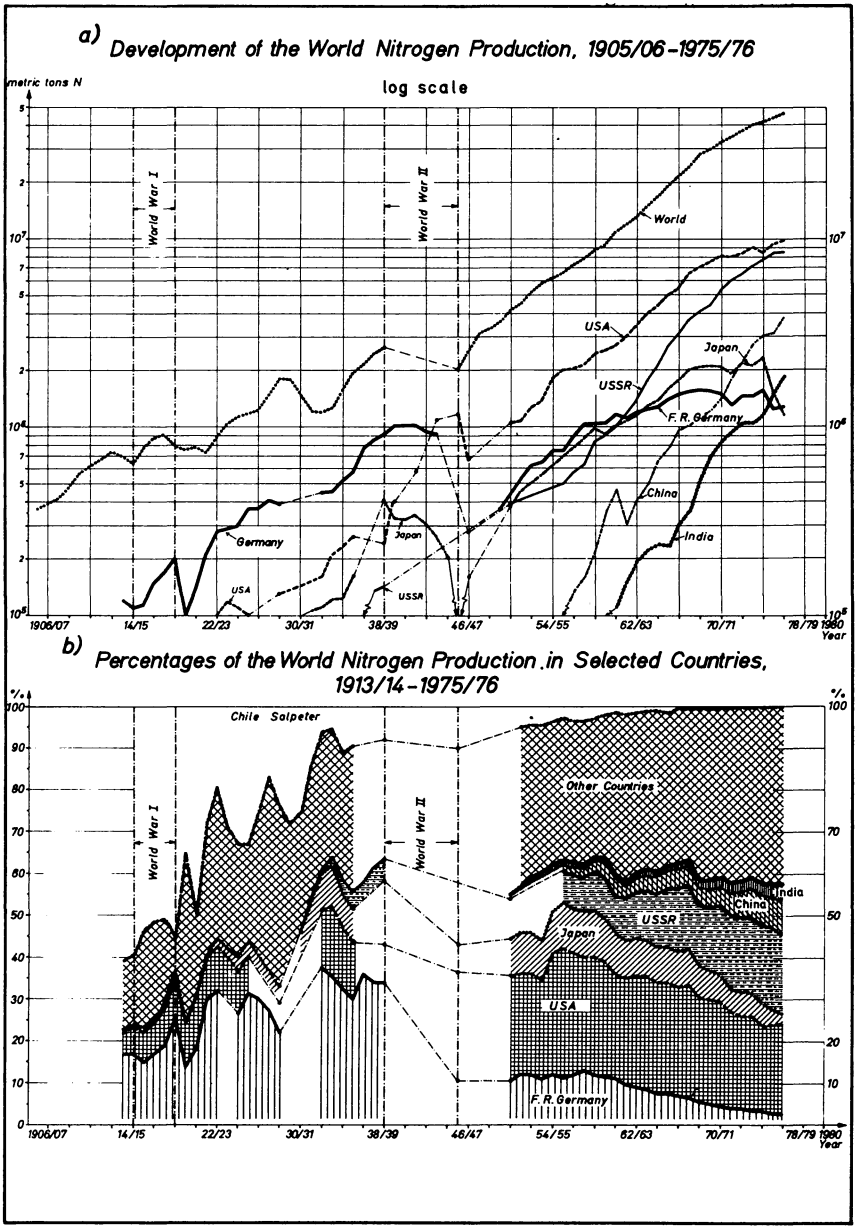
MAP 1

Location of the Twenty Largest Nitrogen Plants in the World, 1976

GRAPH 1


The Evolution of the Maximum Size of Nitrogen Plants* in Germany, 1913-1972
log scale
metric tons N/year
5
2
10^5
7
5
2
10^4
7
5
2
10^3
1900
10
20
30
40
1950
60
70
1980
Year
*Technical Units

GRAPH 2

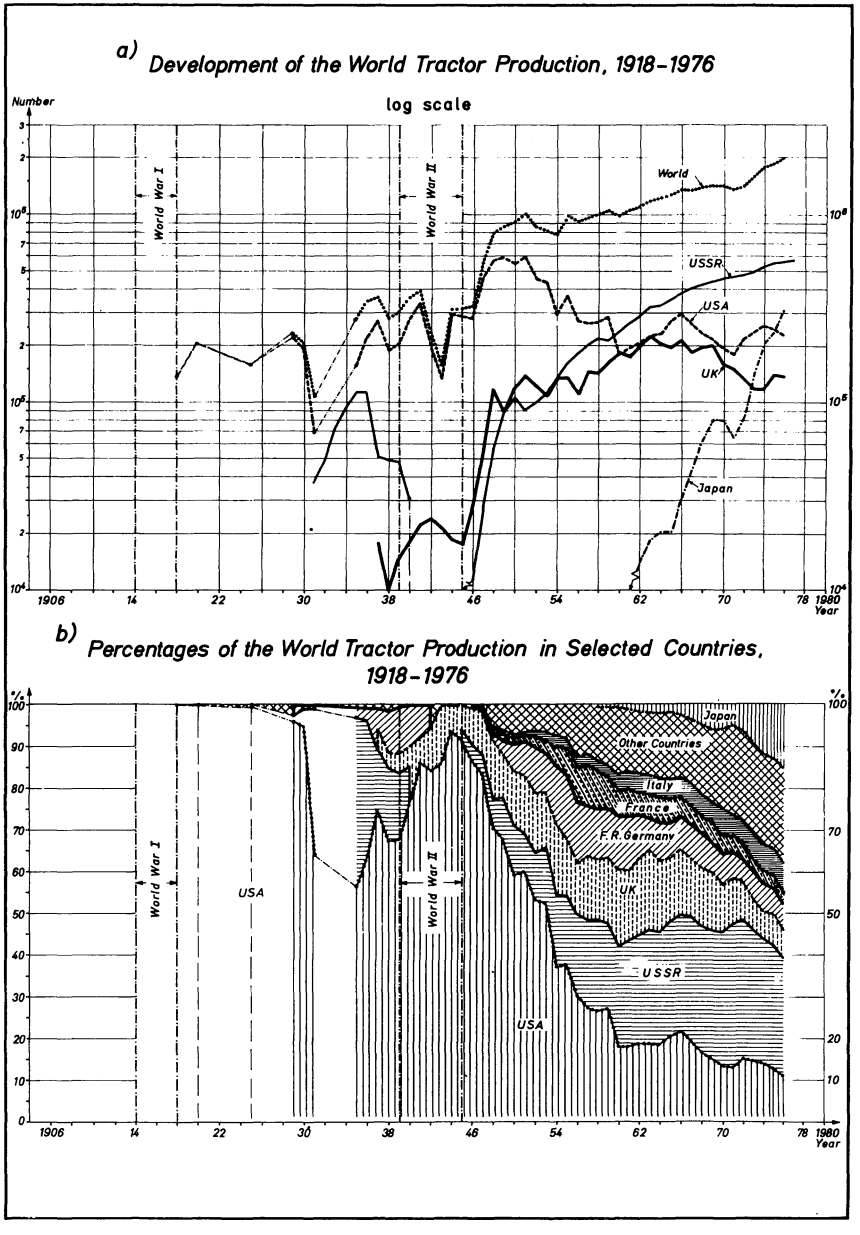

a) Development of the World Nitrogen Production, 1905/06-1975/76
metric tons N
log scale
World War I
World War II
World
USA
Japan
USSR
F.R. Germany
China
India
Germany
1906/07
14/15
22/23
30/31
38/39
46/47
54/55
62/63
70/71
78/79
1980
Year
b) Percentages of the World Nitrogen Production in Selected Countries, 1913/14-1975/76
%
Chile Salpeter
Other Countries
India
China
USSR
Japan
USA
F.R. Germany

MAP 2

Location of the World Tractor Industry (without Europe, but including European Regions of the USSR), 1977

Location of the European Tractor Industry, 1977

GRAPH 3


a) Development of the World Tractor Production, 1918-1976
Number
log scale
World War I
World War II
World
USSR
USA
UK
Japan
Year
b) Percentages of the World Tractor Production in Selected Countries, 1918-1976
%
USA
Japan
Other Countries
Italy
France
F.R. Germany
UK
USSR
1906
14
22
30
38
46
54
62
70
78
1980

hand the separation of functions may facilitate and encourage bilateral and multilateral financing. Thus it fortifies the tendency that plants which are too small will be erected. Heavy subsidization programmes are very often the consequence, because farmers need economic incentives to increase food production. Careful economic analysis by independent engineers and agricultural economists could help to evaluate the benefits and costs of building a plant. Further the world market can hardly be considered a rescuer for the surplus nitrogen, because the established large scale producers can offer lower prices and manage better the needed marketing logistics in foreign markets.

4 STRUCTURE AND DEVELOPMENT OF THE WORLD'S TRACTOR INDUSTRY

The locations of the main tractor plants are shown in Map 2. The plants are concentrated in the main crop areas of industrialized countries or in large countries like India and China. The world's tractor industry is composed of about 130 plants in 90 locations in 35 different countries.* Eleven locations are reported for North America, 22 for the USSR, six can be found in the UK and West Germany, five are in India, Italy and China. 10 European countries only count for one tractor producing location.

In 1976 the average yearly output of a tractor plant was 15,000 units. The difference in size of the annual output of tractor plants within and between countries is marked. We find the largest plants in industrialized countries. They may reach an annual output of nearly 100,000 tractors (like in the UK or the USSR), but many plants produce less than 5,000 tractors or below the minimum size. If they do not produce a very specific tractor for a small group of customers or sell in a protected national market they can hardly be considered efficient producers, because they lack the possibility of exploiting economies of scale available to large plants.

If we assume for an extremely rough calculation a world of free trade among countries and three versions of plant size, two questions arise: what would be the theoretically needed number of plants to satisfy a yearly demand of 1.83 million tractors, as in 1976, and how many countries would be involved in producing tractors for replacement? Assuming plant sizes of 10,000, 20,000 or 100,000 tractors, the world would need 183, 92 or 18 plants respectively. In 1976, out of 178 countries only 31 countries produced more than 10,000 tractors, 21 countries more than 20,000 tractors and only six countries produced more than 100,000 tractors for the domestic market and for export.

It would be wrong to argue that the difference between actual plant and

* Many locations have more than one tractor plant, therefore the number of plants exceeds the number of locations. Countries only assembling tractors or producing less than 1,000 tractors are excluded.

potential plant sizes should be eliminated in the future by implementing only the largest plants. Many other factors have to be considered. Large tractor plants in industrial countries are the result of a long development process, where the demand density and the logistics of production and marketing permit the attainment of such sizes. The observed differences between actual and potential sizes are however an indication of how difficult it is in an international framework to start production with a plant which is too small.

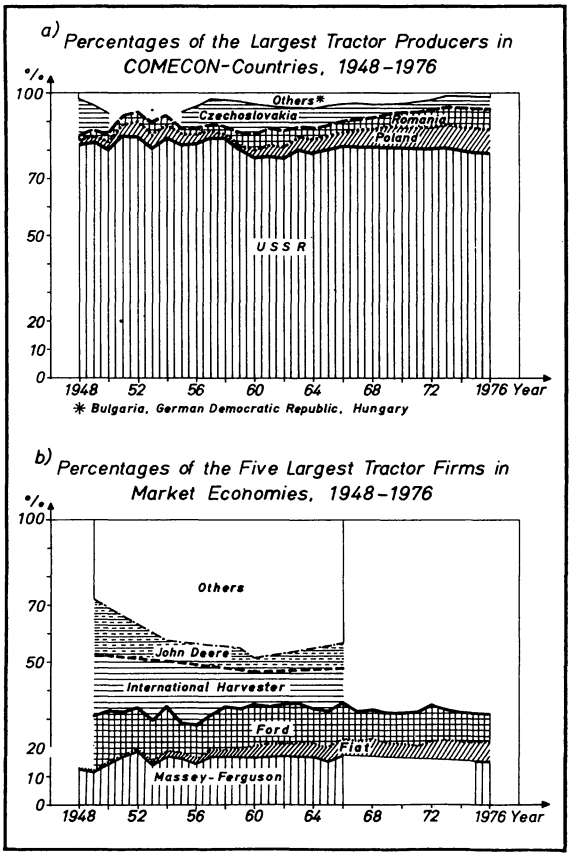
Graphs 3(a) and (b) reveal that total tractor production increased since World War II. Single countries enter tractor production through the stages of growth, saturation, and decline at different points in time. The decline of tractor production occurred in the USA in the early fifties and in the UK in the seventies. The USSR seems to have entered the saturation phase now. The recent stormy growth of Japan's tractor production demonstrates the effects of fast rising prices for labour in agriculture. They induce a fast increasing demand for tractors in a comparatively large domestic market. Countries or firms which do not share such favourable take-off conditions have to pay the price if they begin tractor production too early.

In the planned economies of Eastern Europe the USSR has the dominant position with a share of 80 per cent (Graph 4a). The economies of scale in tractor production are independent of the economic system. Therefore, Bulgaria, the German Democratic Republic and Hungary may give up tractor production one day by mutual agreement. In open market economies many small tractor plants which pioneered several decades ago have had to be closed due to powerful international competitors. The largest firms have plants in several countries. Production and distribution to meet specific demands can be tailored at international scale. Despite their tradition and their superiority in research, marketing, and full-line programmes, the combined total market share of the largest five international tractor firms has certainly not increased (Graph 4b) since Japanese firms entered the market in the sixties. Observations show that market prices for tractors between the industrial and the developing countries differ sharply.[4,6] Governments in countries with higher tractor prices tend to protect tractor production unduly against international competition. To make things worse, in promoting mechanization many governments create credit programmes to facilitate tractor purchases, which further increase the total costs of agricultural mechanization.

5 CONCLUSIONS

In general the production process is economically efficient, if the factors of production – labour, capital, raw materials, energy – are applied in proportion to their marginal costs. Since the availability and cost of these four factors vary between rich and poor countries and the proportions the

GRAPH 4


a) Percentages of the Largest Tractor Producers in COMECON-Countries, 1948–1976
%
100
70
50
20
10
0
Others*
Czechoslovakia
Romania
Poland
USSR
1948
52
56
60
64
68
72
1976 Year
* Bulgaria, German Democratic Republic, Hungary
b) Percentages of the Five Largest Tractor Firms in Market Economies, 1948–1976
%
100
70
50
20
10
0
Others
John Deere
International Harvester
Ford
Fiat
Massey-Ferguson
1948
52
56
60
64
68
72
1976 Year

factors have in production are technically quite fixed, industrial countries can generally produce nitrogen and tractors at lower costs. Due to the larger size of the domestic market industrial countries additionally benefit from large economies of scale in production and distribution. Among the more agriculturally oriented countries and disregarding factor price differences those countries with a small domestic market would have the highest disadvantage in producing nitrogen and tractors.

Decision-makers at national and international levels in and for the main agricultural input industries have to recognize that there is an unavoidable link between pricing agricultural inputs and the capacity of farmers to produce economically and efficiently. Due to the smallness of the indigenous markets governments who have to cope with internationally higher prices for domestically produced nitrogen (fertilizer, pesticides etc.) and tractors very often implement agricultural credit programmes. But they have to differentiate among the importance of agricultural input industries. The divisibility of fertilizer permits the tailoring of credit to satisfy the smallest demand. The yield and rural employment increasing character of fertilizer application has an unequivocal positive effect. On the other hand, tractors and agricultural machinery need a certain level of productivity. The yield increasing effects are certainly less than those of fertilizer, the employment effect to rural peoples might be negative under very unfavourable conditions (e.g. bimodal structure of agriculture). At low levels of agricultural productivity credit programmes to reduce fertilizer prices are therefore a more appropriate instrument to the welfare of rural people than credit programmes for tractors. The Japanese example shows how powerful the demand becomes when the time of using tractor power has come.

What can be done to exploit the economies of scale more fully in developing countries with small domestic markets to reduce farm input prices in an international framework? Several options are open. One would be free trade to enhance competition between agricultural input firms in order to provide farmers with cheaper inputs. Another course of action would be that smaller countries agree on regional integration projects to reach a sufficient market size. Agricultural economic and agri-business studies could serve as useful tools to assess the potential and constraints of regional integration versus national projects. However, we would stress that developing countries with large domestic markets even without regional projects have the possibility to enter fertilizer and tractor production.

The knowledge of designing, managing and operating agricultural input industries at several levels is very scattered. It is not an easily accessible public good. To use the agricultural input industries as factors of rural change more research with an international dimension is required. This might be considered as the final raison d'être for having undertaken this investigation.

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DISCUSSION OPENING – ALLAN N. RAE

When I read the title of this paper, I expected to hear discussion of the manner in which the world agricultural input industries had acted as the agents, or determining agents, of rural change. That is, I expected a broad, international coverage of the major input industries and examples of the various ways in which the evolution of these industries had determined, moderated or accelerated rural change. And because the focus is on rural change, I expected discussion to centre on the influence of the input industries on such things as the level and distribution of rural incomes, rural employment, farm structure, resource use and productivity. Since the input industries are often involved in selling new technology, the latter's importance in determining rural change, e.g. unemployment, surplus production, low incomes and so on, could have been covered. I would also have thought that the market structure of at least the major input industries would be important, e.g. its effect on pricing behaviour. Energy prices and their resultant rural effects are an obvious example.

However, I must confess that the paper disappointed me somewhat. It chose to concentrate on only two input industries; those supplying nitrogen and tractors. It then went on to develop a hypothesis that I would have thought obvious – that such industries possess economies of size, so that if established in regions where such economies cannot be achieved, then the costs of these inputs will be higher than if size economies in

production were achieved. In my opinion, that tells us little about the impact of the world input industries on rural change. The authors appear critical of past efforts to establish nitrogen and tractor plants in developing countries with only small domestic markets. Because production costs will likely be high, various forms of assistance will be required, and they are critical of "undue" protection of tractor production in developing countries.

I think there is another question that is the really interesting one, namely: "Why do countries, even in well thought out development programmes, decide to construct small scale nitrogen or tractor industries?" If the developing country's objectives include the boosting of rural activity and the conservation of foreign exchange, then the construction of such small-scale industries may not be a bad idea. And of course, they are acting no differently than the industrialized countries (i.e. the large-scale input producers) who protect their agricultural *output* industries. I would have liked the paper to include a cost–benefit analysis of establishing small-scale input plants in developing countries, which aim to boost rural activity and save foreign exchange – it would surely be useful to know just how great or small the welfare losses really are, since economic efficiency is not the only consideration of policy makers.

In their paper, the authors suggest possible welfare gains and losses, e.g. the yield and employment-increasing effects of fertilizers and maybe negative employment effects of mechanization, but some evidence of these gains and losses in a benefit–cost framework would have added greatly to the paper.

Two of the solutions put forward by the authors are the freeing of international trade in such inputs, and market and production integration by the small countries. But given the political realities and uncertainties of today's world, such suggestions are rather simplistic and do not, in my opinion, get us very far.

GENERAL DISCUSSION – RAPPORTEUR: F. BONNIEUX

The following points were raised in the general discussion:

Was too much emphasis being placed on tractors and chemicals as agents of rural change?

Does tractor production necessarily require large investment? (cf. paper by Khan, p. 88.)

What policies are needed to correct the undesirable developments described in the paper?

To what extent might LDCs substitute organic fertilizers (manure) for those inorganic fertilizers which require large inputs of energy?

Multi-national companies might not necessarily set up plants in a country in order to take advantage of an internal demand; but merely to take advantage of cheaper labour there.

There was also a question regarding the comparability of data on tractor units.

In reply, the authors agreed that other agents of rural change were important but felt that the tractor and fertilizer industries needed special attention because of the large amounts of capital involved and perhaps wrongly allocated in LDCs. There was also some evidence that low investment tractor production was not always successful. They felt that while some degree of substitution by manure was possible, much of this was ruled out by the high nutritive requirements of the new high-yielding varieties of plants. Regarding comparability, only four-wheel tractors of 10 hp and over were included in the analysis (which therefore excludes garden tractors). Unfortunately horse-power data are not available on a world basis.

Participants in the discussion included Judith Heyer, A. Mohammad, Caleb W.W. Wangia, Heinrich Niederboster and Joseph Klatzmann.