Farm Mechanisation, Output and Labour Input: a Case Study in Thailand

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MECHANISATION is about to gain a foothold among simple farmers engaged in semi-subsistence agriculture in Thailand. Although the level of mechanisation varies widely from one region to another, it seems that the advances made in certain areas have had a significant impact on other areas and regions where farming is still carried out by traditional methods, being entirely dependent on the monsoon rains and the power of draught animals.

In the densely populated countries of Asia, such priority has generally been given to labour-intensive techniques of farming (e.g. to an adaptation of Japanese labour-intensive farming) and to the creation of more employment opportunities that certain sacrifices in terms of higher productivity have even been considered acceptable. In practice this implies that an appropriate balance has been sought between two objectives that are regarded as not necessarily compatible: maximum employment and maximum productivity. On this view it is not surprising that farm mechanisation has been somewhat discredited. It seems to me, however, that reluctance to accept mechanisation is based on false premises regarding its effects on farm employment.

The reason for this is probably that these effects have been looked at in isolation. Farming consists of a series of operations from ploughing the land to marketing the crops. Partial or selective mechanisation of a given operation will induce changes in the pattern of labour inputs in other operations. There is thus quite a good chance that, on balance, selective mechanisation will increase the total labour requirements of a unit of land. In other words, in a dynamic setting selective mechanisation may create more jobs than it eliminates. This is the major proposition that I shall try to prove on the basis of a study of methods of rice growing in the Central Region of Thailand.

[1] International Labour Office.

The rest of this paper consists of four parts. First, the pattern of diffusion of farm mechanisation will be discussed. In this part, some figures will be given on the level of farm mechanisation by region, size of holdings and tenure; the effects of mechanisation on output will be examined and an attempt made to explain the factors contributing to the higher land productivity resulting from mechanisation. In the second part the effects of selective farm mechanisation on labour inputs per unit of land will be considered, and cases will be presented in which mechanisation results in dynamic employment creation. In the third part I shall formulate a hypothetical model to illustrate the effects of farm mechanisation on output and labour input. In conclusion, the perspective for further research on the subject of technological changes in agriculture will be discussed.

Pattern of mechanisation of agriculture

According to the Census of Agriculture in Thailand, in 1963 there were 3,087,141 units of landholdings, which is almost the same as the number of farm households. Of these, only 3.3 per cent used mechanical power exclusively, 11.6 per cent used both mechanical and animal power, and 85.1 per cent depended entirely upon human and animal power.[1] The number of diesel or electric irrigation pumps is not known. As regards other farm machinery, it was estimated that there were 28,000 four-wheeled riding tractors, 4,250 crawler tractors and 2,800 power tillers in Thailand in 1968.[2]

But the level of mechanisation varies widely by region, type of machinery, size of holding and system of tenure. To begin with, therefore, it is necessary to examine these variations in an attempt to discover what factors determine the degree of popular use of different farm machines. In the following analysis no attention will be paid to whether the holders owned, leased or borrowed labour-saving equipment or were offered free use of it. Hence the number of tractors reported as being used on holdings is not necessarily the same as the total number of tractors in existence, since the same tractor might have been leased or borrowed by a number of farmers.[3] The degree of popular use of machines is therefore expressed as the percentage ratio of the number of holdings reporting the use of farm machines to the total number of holdings.

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[1] *Census of Agriculture, 1963: Whole Kingdom* (Bangkok, National Statistical Office, Office of the Prime Minister, 1965), p. 35. Holdings of less than 2 rais were excluded (1 rai = 0.16 hectare).

[2] By comparison, the number of machines of other types was insignificant: seed distributors (250), fertiliser distributors (150), harvesting machines (90) and threshing machines (250), most of which were being tried out at experimental stations (" Country study on Thailand ", ECAFE/UNIDO Fact-finding Team on Industries Manufacturing Agricultural Machinery (unpublished), p. 14).

[3] *Census of Agriculture*, op. cit., p. 10.

Regional variations in the level of farm mechanisation are shown in table I. These can be attributed to a number of factors.

First of all, the infrastructure of water utilisation must be mentioned. The Central Region includes the entire Bangkok Plain, along with the Chao Phraya, Maeklong and Prachin rivers. The construction of irrigation facilities was mostly concentrated in this region until around 1965.[1] For example in 1965, out of 9.5 million rais irrigated by state irrigation projects, 8.3 million rais were in the Central Region, while the share of the North-east Region was only 0.7 million rais.[2] The irrigation facilities are on relatively low land and the water level in distribution channels is often lower than the paddy fields. It is therefore crucial for better utilisation of irrigation water to employ diesel engines or electric motors for pumping.

TABLE I. PERCENTAGES OF FARM HOLDINGS REPORTING THE USE OF MACHINERY BY REGION AND TYPE OF MACHINE, 1963

Type of machine	Whole Kingdom	Central Region	North-east Region	North Region	South Region
Electric motors or diesel engines	7.3	24.2	1.3	5.1	0.9
Tractors	5.9	14.2	0.5	5.9	7.5
Sprayers	4.4	10.0	0.7	7.5	0.8
Threshers	1.9	3.5	0.3	4.2	0.1

Sources: *Census of Agriculture, 1963 : Whole Kingdom* (Bangkok, National Statistical Office, Office of the Prime Minister, 1965), p. 36; ibid., *Central Region*, p. 36; ibid., *North-east*, p. 35; ibid., *South Region*, p. 33.

Second, the average income of a farm household in the Central Region is much higher than in the North-east. According to a survey of income and expenditure in 1963 the average income of a farm household in the Central Region was 7,940 bahts in comparison with 3,554 bahts in the North-east.[3] Naturally farmers with higher incomes can afford farm machines more easily than those with lower incomes.

Third, the average size of holdings of arable land in the Central Region was about 23.4 rais and the proportion of smallholders with less

[1] Kaichi Aki: " On the control factors for water resources exploitation planning in south east Asian area ", in *Southeast Asian Studies* (Centre for Southeast Asian Studies, Kyoto University), Vol. 3, No. 1, June 1965, and Yoshikazu Fujioka and Yoshiro Kaida: " Irrigation and drainage in the Bangkok Plain ", in ibid., Vol. 5, No. 3.

[2] *Statistical yearbook, Thailand, 1966* (Bangkok, National Statistical Office, Office of the Prime Minister, 1968), pp. 190-191.

[3] " Income and expenditure of farmers, 1963 ", in *Statistical yearbook, Thailand, 1966*, op. cit., p. 187.

than 15 rais of land was 38 per cent, whereas the corresponding figures in the North-east were 18.5 rais and 45 per cent.[1]

Fourth, in 1963 owner-cultivators in the Central Region accounted for 75 per cent of the total, compared with 90 per cent in the North-east; of these, 16 per cent in the Central Region as against only 8 per cent in the North-east were large owner-cultivators with more than 50 rais of land.[1] It was found in a recent survey that " about 41 per cent of the farmers in the Central Plain are tenants, with 25 per cent renting the entire area and 16 per cent a portion of the land cropped " [2], whereas the number of tenants in the North-east was almost negligible. These facts imply that in the Central Region there are more large landlords and more tenants than in the North-east.

The use of farm machines by size of holdings and by tenure in the Central Region is shown in table II. That there is a positive relation between the size of holdings and the use of farm machines needs no explanation. But a word must be said about the relation between mechanisation and tenure.

An owner is defined as a holder who owns all or some of the land he farms. Cash renter means a holder who rents all the land in the holding and pays the owner solely in cash. Crop renter means a holder who pays rent on all land in the holding in the form of produce.[3] Thus defined, tenants are considerably in the minority, representing only 17 per cent of the number of owner-cultivators.

From table II one might gain the impression that tenants are more inclined to adopt innovations. The mechanisation index shows a higher value in all size-groups for tenants than for owner-cultivators. It is, however, extremely important to distinguish between traditional tenants, engaged mainly in rice growing, and highly commercialised tenants, mainly producing such cash crops as maize, sugarcane and vegetables for marketing. Although little information is available regarding highly commercialised tenants, I found during my field survey that those with large holdings are engaged exclusively in cash crop cultivation with a high degree of mechanisation. The majority of tenants, however, are traditional: about 80 per cent of the cash renters and 60 per cent of the crop renters hold less than 15 rais. It is in relation to these small tenants that a number of questions need to be clarified. For this purpose the case of Singhburi Province, where farm mechanisation has made striking progress, was examined in greater detail.

In Singhburi over 90 per cent of the area is owner-cultivated, and tenants are traditional smallholders; the owner-cultivators are, by and

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[1] *Census of Agriculture*, op. cit., *Central Region*, p. 12; ibid., *North-east*, p. 12.

[2] *Country paper, Thailand.* Joint ECAFE/ILO/FAO Regional Seminar on Implementation of Land Reform, Manila, 1-12 July 1969 (mimeographed), p. 5.

[3] *Census of Agriculture*, op. cit., p. 9.

TABLE II. TOTAL HOLDINGS AND PERCENTAGE OF FARM OPERATORS USING SELECTED FARM MACHINES, BY TENURE AND SIZE OF HOLDING, CENTRAL REGION

Tenure status of farm operator and size of holding in rais	Total holdings (1)	Electric motor or diesel engine (2)	Tractors (3)	Sprayers (4)	Threshers (5)	Mechanisation index [1] (6)
Owner	**526 914**	**22.0**	**14.8**	**10.6**	**3.8**	**51.2**
2-6	60 157	11.4	3.4	4.9	0.6	20.3
6-15	111 784	17.6	9.6	9.2	2.1	38.5
15-30	156 506	21.3	15.3	10.7	5.6	52.9
30-45	94 959	25.7	17.1	12.4	4.0	59.2
45-60	50 516	27.9	20.0	12.6	5.0	65.5
60-140	49 390	32.7	26.4	13.9	4.1	77.1
More than 140	23 602	39.7	50.4	15.4	7.0	112.5
Cash renter	**39 440**	**35.7**	**14.4**	**13.0**	**2.3**	**65.4**
2-6	11 058	24.3	5.7	8.0	0.5	38.5
6-15	11 910	35.0	12.4	16.6	1.9	65.9
15-30	8 476	39.1	17.8	17.5	5.8	80.2
30-45	4 073	45.3	21.0	9.7	1.7	77.7
45-60	1 900	51.9	24.7	10.5	2.0	89.1
60-140	1 913	53.8	35.0	9.9	0.5	99.2
More than 140	110	46.4	66.4	10.9	1.8	125.5
Crop renter	**50 264**	**41.7**	**9.4**	**5.9**	**1.4**	**58.4**
2-6	3 926	32.8	3.1	3.7	1.1	40.7
6-15	9 734	34.5	6.1	5.0	2.4	48.0
15-30	15 901	39.3	6.9	5.7	1.8	53.7
30-45	10 926	45.5	9.0	6.4	0.7	61.6
45-60	5 023	53.1	13.5	7.0	0.5	74.1
60-140	4 549	51.7	24.7	7.5	0.3	84.2
More than 140	205	46.8	54.1	8.8	—	109.7

Source: *Census of Agriculture*, op. cit.: *Central Region*, p. 36.

[1] The sum of columns 2 to 5.

large, as open-minded towards mechanisation as the tenants. It therefore seems unlikely that the traditional tenant farmers in general are more inclined to adopt mechanisation than owner-cultivators. As a matter of fact, in a considerable number of cases, large owner-cultivators lease not only a part of their land but also such machines as diesel pumps and tractors. This practice helps them in two ways: first it increases land productivity, and hence their income from rent; secondly the hire charges on the machines make it easier for them to pay off their investment in mechanisation. At the same time, it may well be that there is a greater demand for the lease of land from mechanised landowners than from non-mechanised landowners, because tractor farming is not necessarily

more expensive than buffalo-farming. The relation between land tenure and farm mechanisation is as yet far from clear and much study of this question will be needed.

At this point a few brief remarks must be made on the economy of tractor ploughing in comparison with buffalo ploughing. The average hire costs of a tractor in the Central Region are 13 bahts per rai for the first ploughing, and 12 bahts for the second ploughing. If we assume that the size of the planted area is 25 rais, which is about the average size of holdings, the cost of hiring a tractor is 325 bahts for the first ploughing only, and 625 bahts for the first and second ploughings. It is certainly true that most Thai farmers used to keep at least one buffalo as a work animal. But the working life of a buffalo is limited to six or seven years, after which it must be replaced. According to a survey in 1957, the price of a new buffalo was about 1,000 bahts, with maintenance costs of approximately 100 bahts a year.[1] Recently the price of a mature buffalo has risen to as much as 2,500 bahts, and even a young buffalo not ready for farm operations costs as much as 2,000 bahts. Accordingly, the annual cost of a working buffalo may be as high as 400 bahts, not counting the cost of fodder and of the labour for minding it. Add to this the fact that farmers also face the risk of disease or theft of their animals and it will be clear that the use of buffaloes for farming operations is not necessarily cheaper than hiring a tractor. Farmers, once they have used tractors, are therefore convinced of the economy of tractor farming. In villages in North Thailand farmers repeatedly told me that if the hire charges were as low in the North as in the Central Region they would definitely hire a tractor. In Singhburi Province too buffaloes are rapidly being replaced by tractors.

The relation between fragmented holdings and the spread of tractor farming is often misunderstood. It is widely believed that the fragmentation of holdings hinders the advancement of tractor cultivation. This is certainly not true. It does not matter how fragmented and small the plots are. Provided all the farmers in an area agree to use tractors for ploughing, the tractor can plough the land back and forth as if the land were a single large plot. Only when some of the farmers owning plots in the area oppose the use of tractors does fragmentation become an obstacle. Much the same problem arises with the utilisation of irrigation water. Thus tractor farming, along with mechanised irrigation, necessitates joint and planned action on the part of farmers.

We have seen the state of farm mechanisation in Thailand as reflected in the Census of Agriculture of 1963. There is evidence that further progress has been made. In 1961 Thailand imported 1,487 tractors; by 1967

[1] Chaiong Chuchart and Suphan Tossonthorn: *Costs and return on Korat farm enterprises, 1957* (Bangkok, Department of Agricultural Economics, Kasetsart University, 1959), p. 19.

the number had jumped to 4,036. According to informed sources, imports of tractors will be further stepped up because of increasing demand among farmers. " The present potential is estimated to be about 4,000 tractors per year with a growth rate of 5 to 10 per cent per year, in the next five years to come. The demand will also be largely dependent upon the availability of favourable credit terms by the Agricultural Co-operative Banks and other rural credit agencies, and strengthening of the existing 3,000 co-operative farmers' associations."[1] Imports of other agricultural machinery and implements have also been increasing. According to the 1966 *Statistical yearbook* of Thailand, the average value of imports of agricultural machinery and implements (excluding tractors) was 13.8 million bahts a year during the period 1956 to 1960, and rose to 22.4 million bahts a year during the period 1961 to 1965. In 1965 alone the figure reached 25.6 million bahts.

Farm mechanisation certainly offers a great incentive in its effects on output. Taking yields of rice per rai of harvested land as a dependent variable, an index of farm mechanisation was prepared as an independent variable and linear regression of those variables was run. The data for 21 of the 26 provinces in the Central Region were used[2]; these referred to transplanted rice for 21 provinces, and broadcast rice for only 18 provinces, since three did not report on broadcast rice. Assuming a linear relationship between yields per rai and the level of farm mechanisation, regressions were tested in accordance with the following equation[3]:

$$Y = a + bX$$

where Y is the yield per rai (harvested land), and X is the index of farm mechanisation. The results of these regressions are listed below:

Transplanted rice :

15-30	rais	$Y = 219.12 + 1.24X$	$(r^2 = 0.45)$
30-45	,,	$Y = 206.93 + 1.14X$	$(r^2 = 0.87)$
45-60	,,	$Y = 193.28 + 1.01X$	$(r^2 = 0.59)$
60-140	,,	$Y = 182.85 + 1.06X$	$(r^2 = 0.60)$

Broadcast rice :

15-30	rais	$Y = 153.51 + 1.33X$	$(r^2 = 0.59)$
30-45	,,	$Y = 154.94 + 1.00X$	$(r^2 = 0.45)$
45-60	,,	$Y = 146.40 + 0.98X$	$(r^2 = 0.42)$
60-140	,,	$Y = 117.85 + 1.07X$	$(r^2 = 0.53)$

[1] " Country study on Thailand ", op. cit., p. 21.

[2] Three provinces bordering on Cambodia and one province next to the Southern Region were omitted, and no information was available in one province.

[3] The *Census* of *Agriculture* states that only 12.7 per cent of the total holdings in the Central Region reported the use of chemical fertilisers. The effects of fertilisers on output may therefore be ignored.

As will be seen, transplanted rice shows a better linear relationship between land productivity and farm mechanisation; in particular the fit for the 30-45 rais size group is especially good in the case of transplanted rice.[1] For the size groups 15-30 rais and 60-140 rais as regards broadcast rice it appears that there is some positive correlation between the two variables. The constants in each size group indicate that land productivity normally declines as the size of holdings increases.

As regards the differential effects on output of farm mechanisation in the case of transplanted and broadcast rice, it is interesting to investigate changes in yields per rai by size of holding, and to compare those in a few provinces where the index of farm mechanisation is quite high with the average figures for the Central Region as a whole. For this purpose Singhburi and Angthong were chosen because of their high farm mechanisation index (144 in Singhburi, 86 in Angthong compared with an average of 59 for the 21 provinces).[2] Figure 1 shows that the average yields of broadcast rice per rai in the Central Region as a whole clearly decline as the size of holdings increases. In contrast average yields in Singhburi and Angthong change little as the size of holdings increases, although there is a difference in the level of land productivity in the two provinces. From these findings it might be said that in such provinces as Singhburi and Angthong, where farm mechanisation is relatively highly developed, yields of broadcast rice per rai are not related to the size of holdings. Accordingly, the difference between average land productivity in the Central Region as a whole and in the two provinces widens as the size of holdings increases. For example land productivity in the 30-45 rais size group is 30 per cent higher in Singhburi and 22 per cent higher in Angthong than that in the Central Region as a whole, whereas in the 60-140 rais size group it is 50 per cent or more higher in the two provinces than in the Central Region as a whole.

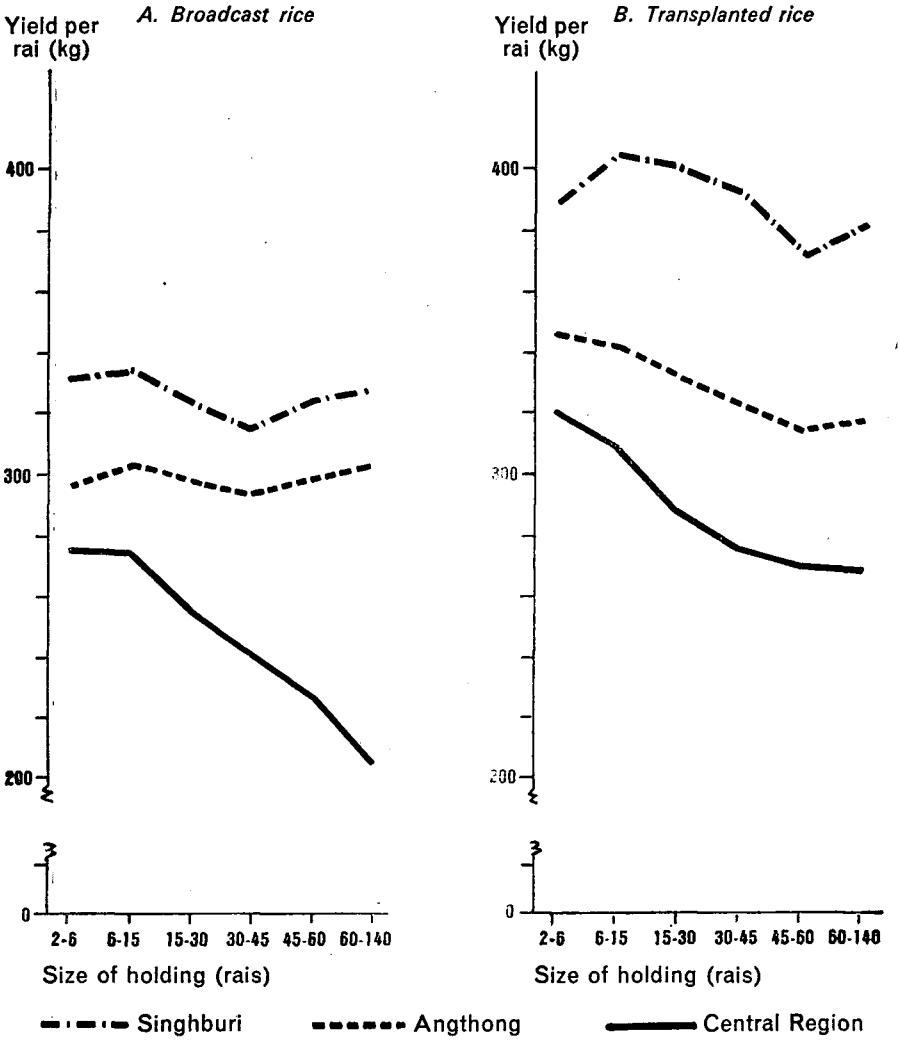
The constant efficiency of tractors in deep ploughing seems to be an important explanatory factor for higher yields. The wider the paddy fields are, the faster men and animals tire and efficiency drops. But tractors can operate day and night at the same level of efficiency. Besides, regular ploughing at fixed depths can only be done by tractor. In other words, whereas buffalo ploughing is subject to diminishing efficiency, tractor ploughing is not. This is a particularly important consideration since ploughing must be done at the right time and the suitable period is limited by rainfall: immediately after pre-monsoon rains and before the land is flooded by the monsoon rains.[3] Although the farmers I met could

[1] This point will be touched on again in the last paragraph of this section.

[2] The proportion of holdings reporting the use of chemical fertilisers was only 1.7 per cent in Singhburi and 3.5 per cent in Angthong, while the corresponding figure for the Central Region as a whole, as already mentioned, was 12.7 per cent.

[3] R. L. Pendleton: *Thailand; aspects of landscape and life* (New York, Duell, Sloan and Pearce, 1926), p. 69.

FIGURE 1. YIELDS PER RAI BY SIZE OF HOLDING, FOR BROADCAST AND TRANSPLANTED RICE, CENTRAL REGION AND SINGHBURI AND ANGTHONG PROVINCES



hardly read and write, and none of them had any vocational training, they all knew why tractor ploughing increases land productivity. They favoured tractors because they permit deep and timely ploughing, and make it less fatiguing. It is an accepted fact that soil fertility will be activated more by deep ploughing than by shallow. It is also certain that if ploughing is not deep enough, and the soil is not thoroughly broken, the

growth of roots of rice plants is hindered, resulting in less absorption of soil fertility. These two related factors are the most important in explaining the effects on output of tractor ploughing. With a given soil fertility, deep ploughing by tractors has the effect of increasing land productivity just as if additional fertilisers had been used.[1]

As regards transplanted rice, I found an interesting pattern of ploughing during my field survey. Irrigation pumps were used more frequently on paddy fields where transplanting of rice is practised. Fields under broadcast rice were more dependent on natural flooding. The full output effects of tractors could therefore not be fully realised because inefficient control of water frustrates deep ploughing. In some villages farmers used tractors for ploughing twice on broadcast fields, but on transplanted paddy fields they used them only for the first ploughing and used buffaloes for the second. There is a convincing rationale behind this practice. According to the farmers, tractors can plough deeply before the pre-monsoon rain starts but cannot be operated efficiently in breaking up the soil, particularly in the waterlogged paddy fields. The best results are therefore achieved by a combination of tractor ploughing and buffalo puddling. Because of the limits on the amount of work that can be done efficiently by the farm family of average size, it may be speculated that the optimum area of holding for this method falls in the 30-45 rais size group.

Effects of farm mechanisation on utilisation of labour force

In order to investigate the effects of farm mechanisation on labour utilisation it is first necessary to examine the traditional pattern of labour utilisation. In particular, time constraints for labour inputs and labour requirements for each operation of rice cultivation must be carefully reviewed.

Several farm economic surveys have been conducted in different years and various places, but the estimates of labour requirements they provide vary so greatly that it is not at all easy to decide which can be used as the base figure for our purpose (see table III). A further problem is that no clear distinction was made in these surveys between transplanted and broadcast rice culture. This is a serious defect since, if a survey area practises transplanting on a larger portion of paddy fields, the average labour requirements per rai is much larger than otherwise.

It is, however, commonly found that labour inputs are heavily concentrated in certain periods of the year. According to a survey in Nakorn Pathom Province, 46.4 per cent of the total inputs of labour for a year (213.7 out of 460.3 man-days of an average farm household) were used in

[1] S. Sawada: " Gijutsu Shimpo no Kōka Bunseki " [Analysis of effects of technological progress], in K. Ohkawa and S. Kawano (eds.): *Gendai Nōgyō Bunseki no Tenbō* [A review of modern agricultural analysis] (Tokyo, Taimeido, 1958), pp. 194-201.

TABLE III. LABOUR REQUIREMENTS FOR RICE GROWING, BY OPERATION
(Man-days per rai)

Operation	Region			
	A	B	C	D
Land preparation (including nursery) . .	2.5	4.5	5.5	4.2
Sowing/planting	3.9	1.7		5.2
Care	2.5	4.7	1.1	0.7
Harvesting and threshing	4.7	4.3	3.4	4.1
Miscellaneous	2.7	—	—	0.9
Total . . .	16.3	15.2	10.0	15.1

Sources: A. *Report on economic survey of rice farmers in Nakorn Pathom Province during 1955-56 rice season* (Bangkok, Agricultural Economics Division, Ministry of Agriculture, 1959). B. *A study on agricultural economic conditions of the farmers in the Provinces of Roi-Et, Mahasarakam and Karasin in 1962/63* (Bangkok, Agricultural Economics Division, Ministry of Agriculture, 1964). C. Chaiong Chuchart and Suphan Tossonthorn: *Costs and return on Korat farm enterprises, 1957* (Bangkok, Department of Agricultural Economics, Kasetsart University, 1959). D. K. Janleka: *A study of the economy of rice growing villages in Central Thailand* (Bangkok, Ministry of Agriculture, 1955).

June, July and August. About one-fifth of all working days were concentrated in July alone. Another peak appears in December and January, accounting for 30 per cent of all working days. Hence nearly 80 per cent of total working days are used in five out of twelve months.[1]

A recent publication by Professor Arb Nokajud makes the issue much clearer. In a survey of fifty-three rice cultivating households by four-week periods over the year 1961-62, he found that their pattern of labour utilisation revealed a labour shortage of about 30 per cent and 15 per cent from 17 June to 15 July and from 3 December to 30 December respectively, taking 24 workdays of 8 hours each as equal to 100 (see table IV). An interesting point of this study is that it shows that, even in the peak season of labour demand during June and July, the farm households surveyed had to spend some time on work not directly related to rice growing, though they reduced this work to the minimum. In this case, too, it is not sure how transplanted and broadcast rice were combined; but, assuming 50 per cent transplanted and 50 per cent broadcast rice, it is clear that some labour-saving techniques will have to be used if the proportion of transplanted rice is to be increased.

None of the surveys referred to makes it clear whether the farm households used any labour-saving machinery in the strict sense. It is,

[1] *Report on economic survey of rice farmers in Nakorn Pathom Province during 1955-56 rice season* (Bangkok, Agricultural Economics Division, Ministry of Agriculture, 1959).

TABLE IV. LABOUR USE PER WORKING PERSON IN FIFTY-THREE HOUSEHOLDS OF RICE CULTIVATORS, BY FOUR-WEEK PERIODS, 1961-62

(Workdays of 8 hours)

Four-week periods	Rice	Other agricultural work [1]	Minding work animals	Gainful work [2]	Domestic work	Total	Labour use rate (24 workdays per period = 100)
31 Dec.-27 Jan.	6.36	0.48	2.58	3.37	6.35	19.13	80
28 Jan.-24 Feb.	0.27	0.56	3.35	3.41	7.12	14.71	61
25 Feb.-24 Mar.	0.06	0.26	3.05	3.84	7.93	15.14	64
25 Mar.-21 Apr.	0.42	0.69	3.16	3.81	7.11	15.19	66
22 Apr.-19 May	3.26	0.88	2.91	3.48	5.67	16.20	68
20 May-16 June	10.08	0.79	2.51	1.83	4.20	19.41	81
17 June-15 July	24.44	0.37	1.74	0.79	3.82	31.16	130
16 July-12 Aug.	9.78	0.83	3.14	4.91	4.27	22.93	96
13 Aug.-9 Sep.	1.54	0.73	4.42	7.82	5.05	19.56	81
10 Sep.-7 Oct.	0.77	0.69	4.46	6.34	5.41	17.67	74
8 Oct.-4 Nov.	4.65	0.50	3.64	3.59	6.03	18.41	77
5 Nov.-2 Dec.	11.23	0.07	2.64	2.20	5.71	21.85	91
3 Dec.-30 Dec.	19.82	0.34	1.49	1.41	4.54	27.60	115
Average	**7.14**	**0.57**	**3.00**	**3.60**	**5.69**	**20.00**	**83.3**
Percentage of total time worked	36	3	15	18	28	100	—

Source: Arb Nokajud: " Thai agricultural labour: supply and demand ", in *Proceedings of the Thailand National Population Seminar*, Bangkok, 2-5 April 1968 (Bangkok, National Research Council, Prime Minister's Office, 1968), p. 432.

[1] Includes gardening, and feeding and caring for livestock. [2] Includes household enterprises such as fishing, making fishing tools, making and repairing buildings and household equipment.

however, almost certain that the sources of power and types of farm implements were traditional, e.g. buffalo ploughing, since the surveys were conducted before 1962. Hence the labour requirements revealed represent those of traditional farming techniques, and the variation among the assessments stem from different combinations of broadcast and transplanted rice. Our interest is to discover the different labour requirements per unit of land using different types of farming techniques, but the information available for this purpose is extremely limited. This is particularly true of information at the grass-roots level.

The most up-to-date assessments of labour requirements per unit of land for four different types of farming techniques are those published by the Netherlands Development Corporation (NEDECO) concerning its land consolidation project in Singhburi Province. These are shown in table V. Because no comparable estimates are available, we have to use these figures with caution until further detailed investigation throws up new data on labour requirements with different types of farming technique. The results of my interview with farmers in several provinces in the Central Region during my field surveys, however, support by and large the NEDECO estimates.

It should be noted that there is still much room for improvement in the degree of utilisation of labour in rice farming in Thailand as compared with that in rice farming in Japan. An estimate of labour requirements for transplanted rice per hectare with selective mechanisation (use of power-tillers, power-sprayers, power-threshers and engines or motors) in Japan indicates that 112.6 hours of labour input, or 14.1 man-days at the rate of 8 hours of work a day, are required for cultivating rice on 0.1 hectare

TABLE V. LABOUR REQUIREMENTS FOR RICE GROWING, BY OPERATION AND TYPE OF TECHNIQUE

(Man-days per rai)

Operation	Type of farming technique [1]			
	TB	TT	BB	BT
Land preparation (including nursery)	4.5	1.5	3.0	0.5
Sowing/planting	3.5	3.5	0.25	
Care	1.5	1.5	1.0	1.0
Harvesting and threshing	4.5	4.0	4.5	4.0
All operations	14.0	10.5	8.75	5.5

Source: NEDECO: *Project of land consolidation : Phase I* (Bangkok, Royal Irrigation Department, 1968).

[1] TB = Transplanting with buffalo farming. TT = Transplanting with tractor farming. BB = Broadcasting with buffalo farming. BT = Broadcasting with tractor farming.

of paddy field. If this level of intensivity was applied in Thailand, the labour requirements per rai for transplanted rice would be as high as 22.5 man-days, compared with the 10.5 man-days shown in table V for transplanted rice with tractor farming. Even in the case of broadcast rice, 10.1 man-days of labour per 0.1 hectare (i.e. 16.1 man-days per rai) would be required if Japan's intensive farming techniques were applied.[1] The large difference between Thai and Japanese labour requirements is mostly attributable to inputs for the care of rice: weeding, fertilising and water control. Among these, weeding gives rise to no extra costs for farmers, and they should therefore be able to use more labour for it. However, there is some doubt regarding the application of weeding alone to traditional Thai rice farming, since weeding is part of a series of operations. From the technical point of view, the major function of transplanting is to make weeding easier and more efficient. Also, one of the important functions of water supply on the paddy field is to prevent the growth of weeds. If the fields are not covered by an adequate depth of water, the weeds grow quickly, resulting in very serious damage to the growing rice. Hence, unless complementary changes are made in transplanting techniques and water control, added labour input for weeding may not bring any significant return to farmers.

Whether the use of tractors will increase labour requirements or not depends upon the farming techniques traditionally used. If the traditional combination is broadcast rice with buffalo farming (type BB in table V), labour requirements per rai will increase from 8.8 man-days to 10.5 man-days if farmers shift to transplanted rice with tractors (type TT), but they will be reduced from 8.8 to 5.5 man-days if the change is to broadcast rice with tractors (type BT). Although there are regional variations in the combination of transplanted with broadcast rice in the Central Region, it can generally be said that (except in a number of provinces adjacent to the Bangkok-Thonburi metropolitan area) about 60 to 70 per cent of paddy fields are under broadcast rice. Assuming a land utilisation pattern of 70 per cent and 30 per cent under broadcast and transplanted rice respectively, Professor Nokajud's study shows that the labour force available was fully utilised during the peak seasons, from ploughing through transplanting and harvesting. The peak-season labour requirements are thus a bottleneck to expanding areas under transplanted rice, because it is transplanting that requires the largest amount of labour, and more importantly because both the growth of young rice and the level of water in the paddy fields make it necessary to do transplanting during a limited period of time. In other words it is difficult for farmers to expand the area under transplanted rice unless their farming techniques are changed.

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[1] " Jūnen-go no Nōgyō-gijutsu " [Agricultural technology in the next decade] (Ministry of Agriculture, 1962), quoted in *Nihon no Nōgyō : Asu eno Ayumi* [Japanese agriculture: steps for the future] (Tokyo, Nosei Chosa Iinkai, 1966), p. 53.

Land utilisation patterns can therefore be improved only by tractor farming with the use of engines or motors for irrigation. The soil conditions in the Central Plain [1] are such that buffalo power is too weak for ploughing before the pre-monsoon rains soften the soil during May. Tractors, however, can plough before the pre-monsoon rains. Indeed, in the Central Region wide areas of paddy fields are ploughed by tractor at least once and possibly twice in March and April. Assuming that buffaloes are still used for breaking up the soil in many cases, the entire process of ploughing can be completed by the end of the pre-monsoon rains. This has the effect of saving about 1.6 man-days per rai (if the second ploughing is also done by tractor, the labour-saving effects will be much larger). A shift from broadcasting to transplanting accompanied by tractor ploughing will increase labour requirements for sowing and transplanting by as much as 14 times. On balance, labour requirements per rai will increase from 3.25 to 5.0 man-days. Given a number of working family members, this increased demand for labour could be met by the combined effects of labour saving by the use of tractors and of spreading peak season requirements over a longer period of time into the dry season. We can therefore conclude that tractor farming can lead to more intensive utilisation of the labour force in a dynamic setting of changing land utilisation.

Innovations are first adopted in a limited area, or by a few farmers. The number of these will steadily increase, however, until eventually the innovation has been accepted by all. In Thailand it seems to me that a sufficient number of farmers are open to innovations of this kind. " Machine power by its very effectiveness can have a great value psychologically. One of its greatest benefits has been to reduce the general conservatism and inertia of rural areas because it can take away a great deal of the drudgery and uncertainty of farming. " [2] There is indeed good reason to believe that tractor farming will open farmers' minds to further innovations, and that this indirect effect will play a significant role in the further development and diversification of agriculture in Thailand.

A hypothetical model

Our findings can be presented in a hypothetical model which might be generally applicable. In order to do this, I shall develop my argument on the following assumptions:

(1) The paddy land available for rice production is given and will be fully utilised.

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[1] Pendleton, op. cit., p. 66.

[2] *Report of the Food and Agriculture Commission, 1960* (Karachi, Ministry of Food and Agriculture, 1960), p. 107.

(2) Broadcast or transplanted rice, or a combination of the two, is planted on the paddy land.

(3) The maximum capacity of labour supply as measured by man-days available for paddy operation is given by the size of a farm household.

(4) Given a certain type of technology the labour requirements for broadcasting and transplanting operations are also given.

(5) The labour requirements for transplanted rice are larger than those for broadcast rice.

(6) Land productivity of transplanted rice is higher than that of broadcast rice.

(7) Farm operations must be performed at appropriate times and are subject to time constraints.

The findings in the previous sections support the realism of these assumptions for Thai agriculture.

From these assumptions the relationship of output and labour input for a particular pattern of land utilisation between broadcast and transplanted rice can be presented in a set of simultaneous equations:

$$N = \alpha B + \beta T; \alpha < \beta \quad \ldots\ldots\ldots \quad (1)$$

$$O = \delta B + \epsilon T; \delta < \epsilon \quad \ldots\ldots\ldots \quad (2)$$

$$\bar{L} = B + T \quad \ldots\ldots\ldots\ldots\ldots \quad (3)$$

where N = labour inputs
B = area under broadcast rice
T = area under transplanted rice
α = labour requirement coefficient for broadcast rice
β = labour requirement coefficient for transplanted rice
O = total output
δ = yield of broadcast rice per unit of paddy land
ϵ = yield of transplanted rice per unit of paddy land
$\bar{L}$ = total land available for rice production, and the bar implies that the size of land is given.

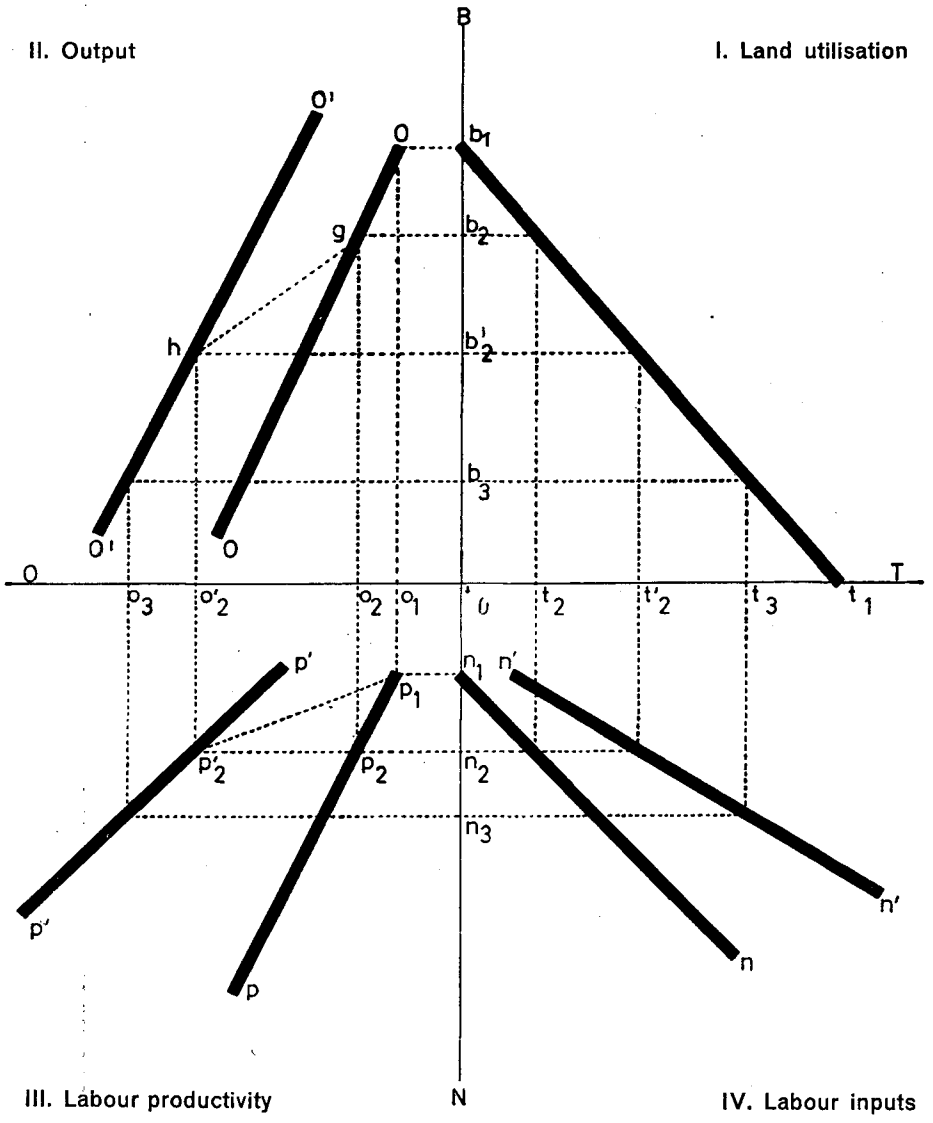
Equations (1) and (2) can be re-written as:

$$N = \alpha B + \beta (\bar{L} - B) \quad \ldots\ldots\ldots \quad (4)$$

$$O = \delta B + \epsilon (\bar{L} - B) \quad \ldots\ldots\ldots \quad (5)$$

Once a typical farm household determines the amount of land for broadcast rice, the total labour requirements, output, and labour productivity (output per man-day) are all determined simultaneously in this system. This relationship is demonstrated by a four-quadrant diagram. Figure 2 shows the relationship of these variables on the basis of an assumption that only buffalo and human labour are employed for farming

FIGURE 2. EFFECTS OF TRACTOR FARMING ON OUTPUT AND LABOUR INPUTS



operations, assuming that a set of coefficients α, β, δ and ϵ are given from the nature of traditional farming techniques. For the sake of simplicity, other factors such as fertilisers are ignored. The first quadrant explains a pattern of land utilisation, by which I mean a combination of broadcast and transplanted rice. Hence, any point from b_1 to t_1 shows a pattern of land utilisation. The line o o in the second quadrant illustrates the changes in output due to a change in the pattern of land utilisation. From our assumption $\delta < \epsilon$, output increases when land under transplanted rice increases, and the slope of the line is determined by the combined effect of δ and ϵ. Similarly, the labour inputs measured in man-days (or man-hours) are drawn in the fourth quadrant. The need for labour inputs, the slope of n'n', is determined by the labour requirement coefficients, α and β. Once output and labour inputs are known in the second and fourth quadrants, we can draw a productivity curve in the third quadrant; the marginal productivity of labour is equal to the slope of this productivity curve.

If all paddy land is used for broadcast rice, the land utilisation pattern is shown at b_1. Output and inputs of labour measured in man-days are accordingly indicated by o_1 and n_1 respectively. Since L (the total land available for rice production) is fixed, land productivity, o_1/L, can be indicated by o_1 alone. Labour productivity per man-day is given by o_1/n_1. By our assumptions 3 and 7, availability of labour inputs is limited; the maximum amount of labour available is shown at n_2. This pattern of land utilisation, therefore, underutilises the available labour force by the magnitude of n_2 minus n_1. Since fuller utilisation of family labour force adds no extra costs on the one hand, and also fuller utilisation of labour force by increasing an area under transplanted rice will increase output on the other hand, the land utilisation pattern moves from b_1 to b_2 (or t_0 to t_2) along the line $b_1 t_1$.

Provided that a set of four coefficients is determined by the given type of farming technology, in this case by traditional buffalo ploughing, the land utilisation pattern $b_2 t_2$ will fully exhaust available labour inputs. This is clear from assumptions 3 and 7. We consider this pattern of land utilisation as that making maximum use of resources available within the traditional farming techniques.

Let us now introduce a new type of farming technique, say tractor farming. This will change the set of four coefficients as follows:

$$\alpha \text{ to } \alpha'; \alpha > \alpha'$$
$$\beta \text{ to } \beta'; \beta > \beta'$$
$$\alpha' < \beta'$$
$$\delta \text{ to } \delta'; \delta < \delta'$$
$$\epsilon \text{ to } \epsilon'; \epsilon < \epsilon'$$
$$\delta' < \epsilon'$$

The result of these changes in terms of the output curve is apparent. It shifts leftward, increasing land productivity as shown by the line o'o' as compared with the line o o. Regarding the effects on labour inputs per unit of land, it is natural to expect a decline, which is shown by n'n', a new labour inputs curve. Assuming that the level of maximum availability of labour inputs, n_2, remains unchanged, the labour inputs saved by tractor ploughing will allow an increase of the area under transplanted rice. Thus, the land utilisation pattern will shift to b_2' t_2'. This will result in a sharp increase in land and labour productivity as shown by the lines g h and p_1 p_2' respectively. We consider this the output expansion attributable to the introduction of tractor ploughing.

Now we are ready to discuss the effects on labour inputs. Thus far we kept n_2 fixed on the basis of assumptions 3 and 7. The effects on labour inputs can now be worked through in relation to assumption 7, time constraints. In traditional technology depending on buffalo power, ploughing and land preparation cannot be started before the pre-monsoon rains soften the land. This usually takes place in May. The land becomes completely arid and extremely hard through the dry season months so that, at the end of the dry season, man and buffalo cannot plough it at all. Once the rain starts in May, they have to complete the farm operations of ploughing through transplanting before the paddy field gets flooded at the beginning of August. Tractor farming can, however, extend the period for farming operations into some parts of the dry season when men and animals are forced into idleness. As we have seen, tractors can plough the paddy fields twice during March and April so that even the pre-monsoon rains could be utilised for seed bed and broadcasting operations. Once the time constraints are weakened, the labour inputs can be spread over a longer period, increasing their maximum availability. In the diagram this process is illustrated by the shift from n_2 to n_3. With the new level of maximum availability of labour inputs, the land utilisation pattern of maximum utilisation of resources will be b_3 t_3, which apparently increases output as high as o_3. We consider this as the output and labour input effects of tractor farming. Since we keep assumption 1, labour input per unit of land definitely rises because of tractor farming. Both land and labour productivities are higher than those obtained through traditional farming techniques as shown by the lines o'o' and p'p'.

Conclusions

The findings in the previous section support the contention that, in a dynamic setting, selective mechanisation may create more jobs than it eliminates. In fact, " these labour-saving devices [such as tractors and diesel pumps, and medium-sized tube wells] have provided farmers with an opportunity to spread work over several seasons. As such, they have,

on balance, enabled farmers to increase the labour input to their agriculture ".[1] By and large, however, developing countries in Asia are still at the crossroads on the subject of mechanisation in agriculture. " To ignore it may be to forfeit a valuable ally in the production war. To use it properly, competent investigation and patient build-up based on experience is necessary. As with so many other aspects of progress, success is likely to depend on the planned integration with mechanisation of a number of other aids to production. Without an organisation capable of handling it in this manner, it could involve extensive disillusion and loss ".[2] It is therefore of vital importance to carry out further research on how to combine mechanisation with increasing employment for the rural labour force. For this purpose, I suggest that further research on farm mechanisation should be carried out along the following lines.

First, technological change offers a unique opportunity to overcome the constraints imposed on agriculture by natural conditions. But if this opportunity is to be seized technology must be adapted to suit special local conditions. The transferability of technology is greatly limited by the climatic and topographical conditions peculiar to each locality on the one hand, and by the ecological characteristics of the crop to be grown on the other. This is the crucial matter in the dissemination of technological change in agriculture, and explains why it is very desirable to design and develop agricultural machinery and implements specially for each country and for given localities in each country.

Secondly, a technological innovation in agriculture cannot be effectively adopted unless complementary changes take place simultaneously in the other operations involved. In other words, what is needed is a set of mutually integrated innovations. The " package programme " in India and the " do-it-yourself rice kit " in the Philippines are notable examples of this approach. Research on the dissemination of technological change in agriculture must therefore be carried out in a comprehensive manner, covering the whole series of farming activities from ploughing to the marketing of produce. This applies equally to the design and development of farm machinery and implements.

Thirdly, the effectiveness of new techniques can be demonstrated only when they have been adopted by a large number of self-employed farmers over a wide area. Examples are provided by the joint use of tractors by smallholders in the Central Plain of Thailand and the farmers' associations for the joint use of irrigation and drainage facilities in Japan and China (Taiwan). These are indivisible techniques which a group of farmers must agree to adopt before they can be effective. But even divisible techniques must be communally adopted. A single farmer may use pesticides to protect his crops; but effective pest control requires co-operation,

[1] Asian Development Bank: *Asian agricultural survey*, Vol. II (Manila), p. 798.

[2] *Report of the Food and Agriculture Commission, 1960*, op. cit., p. 110.

for pests and diseases are not confined by fences. After several years of trial and error in the Comilla Project in Pakistan, the dissemination of new technology in traditional rural areas was seen to be an organisational problem. These examples illustrate the importance of integrating changes in productive techniques with changes in institutions.

Technological change in agriculture can be effectively applied to solving the problems of underutilisation of the rural labour force. How this can best be done, however, is still open to discussion, for the aspects of the problem mentioned above have not yet been fully explored. The research and field studies required are beyond the capacity of economists alone. They demand the joint efforts of agronomists, agricultural engineers, civil engineers, sociologists and economists. But these efforts will be fruitless if farmers themselves are not directly involved. The task is daunting, but it is one that must be brought to a successful conclusion.