Vol XXI
No. 1

ISSN 0019-5014

JANUARY-
MARCH
1966

INDIAN JOURNAL OF AGRICULTURAL ECONOMICS

INDIAN SOCIETY OF
AGRICULTURAL ECONOMICS,
BOMBAY

PROMOTION AND ASSESSMENT OF TECHNOLOGICAL CHANGE *IN INDIAN AGRICULTURE*

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Technological change in agriculture consists of adoption of farming techniques developed through research and calculated to bring about diversification and increase of production and greater economic returns to the farmer. Use of fertilizers, pesticides, improved seed and improved implements and contour bunding for conservation of moisture and soil are examples of such techniques. Introduction of irrigation in new areas is also a very important technological change, although it is being practised as a part of traditional agriculture for a long time. Speedy and extensive introduction of technological change is now recognized as the crucial factor in India's agricultural development. It is not yet fully realized, however, that such change must bring a substantial and assured gain, that is, of the order of 50, 100 or 200 per cent on his investment, in order to induce the tradition bound farmer accustomed to working with a narrow margin and not prepared to risk these margins for small gains to accept technological change. This means that critical studies on the economics and social and institutional implications of the technological change are essential in recommending new practices to farmers. In the present paper, the work being done to promote and assess technological change in Indian agriculture is proposed to be summarised with special reference to the contribution of the Institute of Agricultural Research Statistics.

The three stages related to the introduction of new practices among farmers are the research needed for developing these practices, the verification of the feasibility and profitability of these practices under farming conditions and their demonstration and other extension work required for persuading farmers to adopt them. A great deal of experimental research is in progress in the country at various experimental stations and institutions with the object of evolving new practices and improving the efficiency of their utilization. Considering the vast size of the country and heterogeneity of conditions, such centres are relatively few. They also work at a level of management which is much superior to that of the average farming in the country. These reasons make it essential to test the results achieved at these centres on a representative sample of farm land under actual farming conditions in order that the extension worker can recommend these practices to the farmers with confidence. The Institute of Agricultural Research Statistics makes a contribution to this initial research by collaborating with agricultural scientists in designing their research investigations on statistically sound lines and in helping them for a critical interpretation of the results through proper statistical analysis of the data. An important task of considerable magnitude

that the Institute has undertaken is building up a national index of field experiments in which are summarised individually all agronomic experiments conducted at State and Central experimental farms and research stations by diverse authorities. The first series of 17 volumes cataloguing the results of over 8,000 field experiments conducted during the year 1948 to 1953 have been published already and the next set of volumes for the years 1954-59 comprising some 12,000 experiments is in press. The Index provides a wealth of scientific information to agricultural research workers. The Institute itself has been exploiting this material and other available evidence for calculating response rates for various production aids such as fertilizers, irrigation, contour bunding, etc., for all-India and for States individually. These rates termed yardsticks are being used extensively in planning for agricultural development. In the next stage also, that is, in verifying the results of research under actual farming conditions, the Institute has taken a lead by designing a country-wide programme of simple fertilizer trials located on a sample of farmers' land in each region. The objective is to estimate the additional return obtained from various fertilizers when applied to different crops grown in the manner the farmer normally grows them, so that the results can be extended immediately for application by the farmer under his existing cultivation practices. This approach has provided not only a firm verification of the gains that the farmer may expect from fertilizer use but has provided him a convincing demonstration of these gains. This programme has expanded gradually to cover about 160 districts during 1963-64 with about 15,000 trials on several important crops. It was from these extensive fertilizer trials that a net expected gain of Rs. 100 to 140 was estimated from the use of 30 lb. N/acre on rice and irrigated wheat respectively and a net gain of Rs. 50 to 60 from application of phosphate on these crops, the investment on fertilizers being Rs. 50 on nitrogen and Rs. 45 on phosphate. The Indian farmer has to pay about the highest price for fertilizers in the world and consequently attractive as the gains from the use of fertilizers are on the food crops of rice and wheat, they are far short of the relative gains made by the Japanese farmers on rice and by the American or British farmers on wheat. The programme of trials on a sample of farm land is being extended to other improved practices like improved seed, pesticides, irrigation, etc.

The Institute participates actively in assessing the spread of improved agricultural practices that are being propagated among farmers by extension agencies in the States. In this connection, two series of sample surveys are being conducted by the Institute, one in selected districts where introduction of chemical fertilizers has made some headway and the other in the districts under the Intensive Agricultural Programme. This programme comprises of concentrated efforts to increase agricultural production through adequate supplies, credit and extension work. The surveys in Intensive Agricultural Programme Districts are repeated annually while those in other districts are repeated every five years. These surveys provide valuable data on the spread of improved agricultural practices among farmers in different areas, association between different practices and limiting factors affecting the extension of these practices. Each survey is carried out on a sample of 800 to 1,000 farmers' holdings selected per district by using modern sampling techniques. Information on various aspects of manuring and other agronomic practices is collected by careful enquiry from the farmers concerned twice a year, once in *kharif* and again in the *rabi* season. Visits to fields are made when necessary as a check on information provided by the farmers.

It is a common belief that the major fraction of fertilizers consumed in the country is applied to commercial crops. Data collected from these surveys do not support this belief. It will be seen from Table I that about 75 per cent of both nitrogenous and phosphatic fertilizers are applied to foodgrain crops in these districts, the only exception being Meerut (Uttar Pradesh) and Ferozepur (Punjab) districts where the greater proportion of fertilizers go to non-food crops, namely, sugarcane and cotton. The reason for the wrong belief that

TABLE I—PERCENTAGE CONSUMPTION OF NITROGENOUS (A/S OR EQUIVALENT) AND PHOSPHATIC (SINGLE SUPER PHOSPHATE) FERTILIZERS FOR FOOD AND COMMERCIAL AND OTHER CROPS

District	Year	Nitrogenous Fertilizers		Phosphatic Fertilizers	
		Food crops	Other crops	Food crops	Other crops
1	2	3	4	5	6
Thanjavur	1963-64	100	—	100	—
West Godavari	,,	75	25	87	13
Shahabad	,,	90	10	86	4
Raipur	,,	100	—	100	—
Aligarh	,,	81	19	80	20
Ludhiana	,,	75	25	81	19
Pali	,,	72	28	67	33
Mandya	1962-63	74	26	71	29
Surat	,,	56	44	74	26
Sambalpur	,,	89	11	99	1
Alleppey	,,	88	12	97	3
Palghat	,,	98	2	100	—
Bhandara	,,	100	—	100	—
Barabanki	,,	76	24	72	28
Coimbatore	1961-62	67	33	100	—
Varanasi	,,	76	24	—	—
Krishna	,,	75	25	94	6
Meerut	1959-60	19	81	—	—
Ferozepur	1957-58	37	63	100	—

bulk of the fertilizer is applied to cash crops arises from the fact that a larger proportion of the area under these crops receives fertilizers whereas in the case of foodgrains, a smaller proportion of the area is generally fertilized. But since the total area under foodgrains is itself very large, *i.e.*, about 80 per cent of the total cultivated area, as compared to cash crops, the total consumption of fertilizers on the former is very much greater than on the latter. With the present attractive foodgrain prices, there is no fear that the consumption of chemical fertilizers on commercial crops will be increased at the expense of foodgrains. Although the proportion of area under foodgrains receiving fertilizers is generally rather small, it will be seen from Table II that in several districts, especially in South, the greater proportion of the rice crop is already receiving nitrogenous fertilizers and, in a couple of cases, phosphatic fertilizers as well. Examples are Thanjavur, West Godavari, Shahabad, Mandya, Coimbatore, Barabanki and Krishna. The use of fertilizers on wheat and other foodgrains is lagging behind that of rice but even here, Ludhiana provides an outstanding example. Another interesting fact brought out in this connection is that nitrogenous fertilizers are much more popular than phosphatic fertilizers, as is to be expected from their relative economics.

TABLE II—PERCENTAGE AREA BENEFITED BY NITROGENOUS AND PHOSPHATIC FERTILIZERS FOR VARIOUS SIZE-GROUPS OF HOLDING

District	Crop	Percentage Area Benefited by							
		Nitrogenous fertilizers (as A/S or equivalent)				Phosphatic fertilizers (as single superphosphate)			
		Less than 2 hectares	2-4 hectares	Above 4 hectares	Pooled over all holdings	Less than 2 hectares	2-4 hectares	Above 4 hectares	Pooled over all holdings
1	2	3	4	5	6	7	8	9	10
Thanjavur (1963-64)	Rice (*Kuruvai*) ..	53	51	65	56	19	33	33	27
	Rice (*Samba*) ..	43	45	62	50	37	47	61	48
	Rice (*Thaladi*) ..	64	63	74	66	15	36	53	28
West Godavari (1963-64)	Rice (1st crop) ..	47	49	59	56	8	14	19	17
	Rice (2nd crop) ..	88	87	83	84	30	46	56	51
Shahabad (1963-64)	Rice ..	37	53	66	59	16	28	41	34
	Wheat ..	23	31	39	34	15	19	29	25
Raipur (1963-64)	Rice ..	9	20	31	24	4	14	21	16
Aligarh (1963-64)	Maize ..	23	24	33	27	0	2	2	1
	Wheat ..	13	34	61	42	0	3	6	4
Ludhiana (1963-64)	Maize ..	—	47	60	59	—	9	23	22
	Wheat ..	—	71	80	81	—	23	51	51
Pali (1963-64)	Maize ..	—	20	4	8	—	0	2	2
	Wheat ..	—	3	4	4	—	2	*	1
Mandya (1963-64)	Rice ..	73	63	74	70	67	59	67	64
	Ragi ..	16	7	10	9	14	6	9	8
	Sugarcane ..	77	79	64	68	75	72	59	62
Surat (1962-63)	Rice ..	—	19	14	16	—	10	2	4
	Jowar ..	—	4	3	3	—	1	1	1
	Cotton ..	—	4	8	7	—	0	1	1
Sambalpur (1962-63)	Rice (Autumn) ..	2	1	2	2	2	1	1	1
	Rice (Winter) ..	3	1	4	3	2	1	3	3
Alleppey (1962-63)	Rice (1st crop) ..	6	8	4	6	3	9	4	5
	Rice (2nd crop) ..	5	13	18	12	1	11	19	9
	Rice (3rd crop) ..	16	27	38	31	3	20	30	23
Palghat (1962-63)	Rice (1st crop) ..	6	25	33	27	0	0	4	2
	Rice (2nd crop) ..	9	29	54	41	1	1	7	5
Bhandara (1962-63)	Rice ..	13	14	22	18	2	5	14	9
Coimbatore (1961-62)	Rice ..	54	50	57	54	—	—	—	—
Barabanki (1962-63)	Rice ..	51	62	46	54	—	—	—	—
	Wheat ..	26	33	24	29	—	—	—	—
Krishna (1961-62)	Rice ..	57	64	70	53	66	60	63	64
Meerut (1959-60)	Wheat ..	7	8	10	8	—	—	—	—
	Sugarcane ..	26	46	45	41	—	—	—	—
Varanasi (1961-62)	Rice ..	22	32	56	32	—	—	—	—

* Percentage less than 0.5.

TABLE III—AVERAGE RATES OF APPLICATION OF NITROGENOUS AND PHOSPHATIC FERTILIZERS IN KG. PER HECTARE

District	Crop	Average rate of application of nitrogenous fertilizers (in terms of A/S or equivalent) (kg./hectare)	Recommended dose of A/S (kg./hectare)	Average rate of phosphatic fertilizers (in terms of single superphosphate) (kg./hectare)	Recommended dose of S.S.P. (kg./hectare)	Average rate of A/S expressed as % of the recommended dose	Average rate of S.S.P. expressed as % of the recommended dose
1	2	3	4	5	6	7	8
Thanjavur	Rice (*Kuruvai*)	99	168	149	168	59	89
	Rice (*Samba*)	80	168	139	168	48	83
	Rice (*Thaladi*)	93	168	157	168	55	93
West Godavari	Rice (1st crop)	141	112	253	210	126	120
	Rice (2nd crop)	170	168	178	210	101	85
Shahabad	Rice	40	240	67	240	17	28
	Wheat	74	220	58	204	34	28
Raipur	Rice	68	112	84	138	62	61
Ludhiana	Maize	148	272	111	222	54	50
	Wheat	136	247	104	123	55	85
Aligarh	Maize	59	230	66	230	26	29
	Wheat	60	92	48	92	65	52
Pali	Maize	106	224	231	224	47	103
	Wheat	78	224	136	224	35	61
Mandya	Rice	164	168	155	207	98	75
	Ragi	73	84	80	111	87	72
	Sugarcane	594	1261	423	521	47	81
Surat	Rice	135	224	134	140	60	95
	Jowar	92	112	29	140	82	21
	Cotton	100	112	70	140	89	50
Sambalpur	Rice (Antumn)	92	188	79	125	49	63
	Rice (Winter)	92	188	76	125	49	61
Alleppey	Rice (1st crop)	79	N.A.	253	N.A.	N.A.	N.A.
	Rice (2nd crop)	95	N.A.	98	N.A.	N.A	N.A.
	Rice (3rd crop)	84	N.A.	180	N.A.	N.A.	N.A.
Palghat	Rice (1st crop)	109	170	—	205	64	—
	Rice (2nd crop)	217	226	49	205	96	24
Bhandara	Rice	65	224	70	140	29	50
Coimbatore	Rice	70	154	182	210	45	87
Barabanki	Rice	68	280	—	—	24	—
	Wheat	81	280	—	—	29	—
Varanasi	Rice	46	218	—	—	21	—
Krishna	Rice	70	154	182	210	45	87
Meerut	Wheat	56	163	—	—	34	—
	Sugarcane	105	653	—	—	16	—

Note: N.A. = not available.

The year of enquiry for the various districts is the same as given in Table II.

A break-up of the proportion of the area fertilized, according to the size of the farmer's holding detailed in Table II, shows that farmers with larger holdings use chemical fertilizers more extensively, *i.e.*, on a greater proportion of their cultivated area as compared to those with smaller holdings. Where, however, fertilizer use has become quite extensive, even smaller holdings apply fertilizer on nearly the same scale as the larger holdings. The second crop of rice in West Godavari, rice and sugarcane in Mandya district and rice in Coimbatore district provide examples of this latter phenomenon. When fertilizer is introduced in a district initially, it is the larger farmer who can afford the capital and the risk for utilizing it and it is only after the other smaller farmers see his profitable experience that they are induced to follow him.

Another aspect of the same phenomenon is to be found in the caution that the farmers exercise towards adoption of the recommended rates of fertilizer application. A comparison of the actual and recommended rates of application of nitrogenous and phosphatic fertilizers on rice and other important crops in various districts is made in Table III. It will be observed that generally in the districts where use of fertilizers is well-established, the farmers adopt a rate of application approaching the recommended rate as in West Godavari, Mandya, Coimbatore, Krishna, etc., but in several other districts, farmers apply fertilizers at half the recommended dose or even less. The situation in relation to fertilizer use is improving very rapidly both in respect of the area covered as also in the increased rates of application as revealed from the repeated surveys in some of these districts. The changes are shown in Tables IV and V.

TABLE IV—PERCENTAGE AREA BENEFITED BY NITROGENOUS AND PHOSPHATIC FERTILIZERS

District	Crop	Year	Percentage Area Benefited by	
			Nitrogenous fertilizers	Phosphatic fertilizers
1	2	3	4	5
West Godavari	Rice	1954-55	27	10
		1963-64	63	25
Raipur	Rice	1958-59	14	—
		1963-64	24	16
Coimbatore	Rice	1954-55	22	2
		1961-62	54	—
Barabanki	Rice	1956-57	22	—
		1962-63	54	—
	Wheat	1956-57	25	—
		1962-63	29	—

TABLE V—AVERAGE RATES OF APPLICATION OF FERTILIZERS (KG./ HECTARE)

District	Crop	Year	Nitrogenous fertilizers (in terms of A/S or equivalent)	Phosphatic fertilizers (in terms of single super-phosphate)
1	2	3	4	5
West Godavari	Paddy	1954-55	91	95
		1963-64	151	215
Raipur	Paddy	1958-59	55	17
		1963-64	69	84
Coimbatore	Paddy	1954-55	173	106
		1961-62	202	104
Barabanki	Paddy	1956-57	80	—
		1962-63	68	—
	Wheat	1956-57	62	—
		1962-63	81	—

Fertilizer use is dependent on the availability of adequate moisture supply in the soil either through ample rainfall or irrigation. It is because of this limitation that use of fertilizer is more widespread on crops like rice and sugarcane which are grown either in heavy rainfall areas or with irrigation. As has been indicated earlier, irrigated wheat responds to fertilizers even more profitably than rice and it is important that farmers growing irrigated wheat should be induced to use fertilizers on a much greater scale on this crop.

Evolution of improved varieties of crops has been perhaps the most important research programme of agricultural departments over several decades and, as a result, the entire sugarcane area in the country has been saturated with improved seed. Improved seed of cotton has also covered a considerable proportion of the cotton growing area but progress with foodgrains has been heterogeneous as can be seen from Table VI. There are still several districts where only a small proportion of the area under rice or wheat is covered by improved seed. An important point in connection with the use of improved seed that has emerged from the surveys in the districts with Intensive Agricultural Programme is that it is only with seed directly obtained by the farmer from some authorized institution that he gets the benefit of the expected increase in yield from that seed. This is brought out in Table VII.

TABLE VI—PERCENTAGE AREA UNDER IMPROVED SEEDS : 1964-65

District	Paddy	Wheat
Thanjavur	52	—
West Godavari	61	—
Shahabad	21	25
Raipur	7	—
Aligarh	—	85
Ludhiana	—	95
Pali	—	19
Mandya	64	—
Surat	38	—
Sambalpur	16	—
Alleppey	13	—
Palghat	27	—

TABLE VII—AVERAGE YIELD (IN QUINTALS) PER HECTARE ACCORDING TO SOURCE OF SEED USED OF IMPROVED VARIETIES : 1964-65

District	Crop	Average Yield (in quintals) per Hectare			
		Own source	Government/ Co-operative Society	Registered seed grower	Others
1	2	3	4	5	6
Thanjavur	Rice (*Kuruvai*) ..	17.2(181)	17.7(10)	18.8(24)	17.2 (73)
	Rice (*Samba*) ..	18.3(179)	19.9(10)	18.9(25)	15.8 (81)
	Rice (*Thaladi*) ..	15.5(169)	19.0(13)	18.7(31)	16.5 (68)
West Godavari	Rice (1st crop) ..	16.6(162)	16.4(45)	19.9(9)	14.9 (83)
	Rice (2nd crop) ..	14.9(117)	18.4(52)	15.5(22)	15.3(108)
Shahabad	Rice ..	13.4(139)	14.7(18)	14.2(24)	14.3 (77)
	Wheat ..	7.2(124)	11.4(26)	11.9(15)	7.7 (88)
Raipur	Rice ..	12.0(288)	12.7(6)	—	12.5 (14)
Aligarh	Wheat ..	16.3(157)	16.9(153)	—	23.2 (59)
Pali	Wheat ..	10.4(159)	11.7(32)	—	10.7 (27)

Note : (1) Average yield has not been presented as the number of observations was less than 5. (2) The figures in brackets indicate the number of observations on which the average yield is based.

The difference in yield for the same variety of seed is as much as 3 quintals per hectare or more according to the source of the seed. It is necessary that institutional arrangements should be strengthened to provide the farmer with improved seed of guaranteed quality, so that he can renew his seed at frequent intervals, say, every 3 or 4 years. An important aspect of development of improved seed is that the research in the past was confined to securing seed capable of giving a small increase in yield of 10 or 15 per cent under existing agronomic conditions which did not include any use of fertilizers. With extension of fertilizer consumption, the necessity of developing seed specially responsive to fertilizer application and other favourable agronomic practices has become urgent and plant breeders are now engaged in evolving such varieties through hybridization. With the availability of this new type of seed, the efficiency of fertilizer use in India which is rather low at present as compared to other countries will also increase.

Various diseases and pests of crops are responsible for a loss in agricultural production. Surveys carried out by the Institute indicate that on rice and wheat crops, this loss would be of the order of 10 to 15 per cent at least. With increasing use of fertilizers, there is some evidence to show that crops will also attract more pests and diseases and the use of insecticides and pesticides will become increasingly important. While there is a consciousness of the need for using chemicals for protection of crops from pests and diseases, their actual use in the field has not made much headway, as will be seen from Table VIII based on the results of the surveys conducted by the Institute. Only in West Godavari district is there anything like a substantial area under rice being covered by plant protection measures. The economics of these measures also need careful study.

TABLE VIII—PERCENTAGE AREA BENEFITED BY PLANT PROTECTION CHEMICALS : 1964-65

District	Paddy	Wheat
Thanjavur	12	—
West Godavari	43	—
Shahabad	1	0
Raipur	5	—
Aligarh	—	0
Ludhiana	—	0
Pali	—	3
Mandya	5	—
Surat	3	—
Sambalpur	3	—
Alleppey	19	—
Palghat	11	—

Among improved agricultural implements, the iron plough is the only implement which has been accepted by farmers on any considerable scale. Here too, it is the larger farmer who adopted the iron plough to a greater extent than the smaller farmers as seen from results in Table IX.

TABLE IX—PERCENTAGE OF USERS AND NON-USERS OF FERTILIZERS HAVING IRON PLOUGH

District	Year		Holding-size (hectares)			
			Less than 2 hectares 0-1.99	2.00-3.99	4.00 and above	Overall
Barabanki	1956-57	Users	1	6	31	5
		Non-users	—	3	22	2
		Overall	1	6	28	4
Ferozepur	1957-58	Users	80	80	93	91
		Non-users	65	77	88	85
		Overall	67	78	89	87
Meerut	1959-60	Users	22	21	35	27
		Non-users	3	8	13	7
		Overall	8	14	26	16
Varanasi	1961-62	Users	6	7	17	8
		Non-users	2	3	19	3
		Overall	3	4	18	5
Coimbatore	1961-62	Users	10	15	22	14
		Non-users	1	2	10	4
		Overall	6	8	15	9
Krishna	1961-62	Users	6	4	5	5
		Non-users	—	—	—	—
		Overall	4	3	4	4

Another interesting finding incorporated in this table is that in each size-group of holding, farmers who use fertilizers also use the iron plough to a greater extent than others who do not use fertilizers. A similar result was found in relation to pumping sets for lift-irrigation in the Coimbatore district where such irrigation is practised on a considerable scale. These results are shown in Table X.

TABLE X—PERCENTAGE OF USERS AND NON-USERS OF FERTILIZERS HAVING PUMP SETS

District	Year		Holding-size (hectares)			
			Less than 2 hectares 0-1.99	2.00-3.99	4.00 and above	Overall
Coimbatore	1961-62	Users	17	38	46	30
		Non-users	6	11	23	15
		Overall	12	24	35	22

Two general conclusions underline the results presented above; one is that it is farmers with larger holdings who can more readily adopt technological change which then seeps down gradually to farmers with smaller holdings. The second is that independently of the size of holding, farmers who accept one improved practice also accept other similar practices more readily than farmers not employing any improved practice. It would appear from this that if extension efforts are concentrated on the most important improved practice, namely, fertilizers, which a very large proportion of farmers can adopt profitably under their present methods of cultivation, then they will also be induced to adopt other improved practices like plant protection, improved implements, etc.

BENEFIT-COST EVALUATION OF TECHNOLOGICAL CHANGE IN AGRICULTURE

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INTRODUCTION

A benefit-cost evaluation of technological change in agriculture seeks to relate the economists' theory of decision-making with that of the social psychologist. In other words, it attempts to link the social influences on choices faced by the consumer and producer with the principle of maximization, the function to be maximized being the present value of benefits minus costs. For purposes of benefit-cost appraisal, technological change in agriculture must be understood as the entire process, starting from investments which result in the flow of goods and services that make the introduction of change possible to the actual introduction of the change at the field level.

The benefit-cost models[1] that have been constructed are basically simple and require very elementary disaggregation of the variables. Their major contribution lies in sharply bringing into focus some of the important variables associated with decision-making.

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1. Some of the important contributions are : John V. Krutilla and Otto Eckstein : Multiple Purpose River Development, John Hopkins Press, Baltimore, 1957; P.O. Steiner, "Public Investments in the Water Resource Field : Choosing Among Alternatives," *American Economic Review*, Vol. XLIX, 1959, pp. 893-916; J. Margolis, "The Economic Evaluation of Federal Water Resource Development," *American Economic Review*, Vol. XLIX, 1959, pp. 96-111 ; Stephen Marglin: Approaches to Dynamic Investment Planning, North Holland Publishing Company, Amsterdam, 1963 ; Martin S. Fieldstein, "Net Social Benefit Calculations and Public Investment Decision," *Oxford Economic Papers*, New Series, Vol. 16, No. 1, March, 1964, pp. 114-131.