ECONOMIC GROWTH CENTER

YALE UNIVERSITY

Box 1987, Yale Station
New Haven, Connecticut

Center Discussion Paper No. 119

THE DIFFUSION OF AN INNOVATION IN THE ISRAELI AGRICULTURE*

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July, 1971

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A lot has been written about the process of the diffusion of innovations.[1] The contribution of the present study is based chiefly on two points. The first part of the paper is mainly a description of an innovation cycle: a comparative analysis of the rate and extent of the diffusion of a particular innovation through the various sectors of the Israeli agriculture from the highly modernized kibbutz to the tradition-bounded Arab sector. The second part is a market equilibrium analysis of the spread of the innovation.

The innovation studied is the technique of growing vegetables (tomatoes, cucumbers, peppers) under plastic covers. Fresh vegetables cannot grow unprotected in the winter in most parts of Israel; glass greenhouses are too expensive. Protective tunnels constructed from long sheets of plastic material (polyvinyl-chloride or polyethylene) supported by wood or metal frames were first tried in an experiment station in the winter of 1955/56 (the method, including, initially, the use of bamboo supporters, was introduced from Japan). The first commercial plots appeared a year later and it seems that by mid 1960's the diffusion process reached an equilibrium level.

The growing of vegetables under plastic covers requires more skill and capital than summer cultivation. Yet these obstacles were not prohibitively large as the rates of adoption, reported below, will testify, and, as a result, one could trace the diffusion process over a relatively short period of time.

Table 1

Vegetables Under Plastic Covers (dunams)

Year	Tomatoes	Cucumbers	Peppers	Total
1958/59	n. a.	50	1	(51)
1959/60	n. a.	100	3	(103)
1960/61	n. a.	300	10	(310)
1961/62	146	516	27	689
1962/63	227	458	56	741
1963/64	406	983	219	1608
1964/65	866	2415	612	3893
1965/66	2177	2999	1740	6856
1966/67	2851	3295	1634	7780

Notes:

1 dunam = 0.1 hectare = 0.25 acre.

Source:

Vegetables Production and Marketing Board, Tel Aviv.

The study covers the period of 1958/59 to 1966/67. The integration of new areas after the June 1967 war changed the market conditions in agriculture in Israel and the period was therefore not extended further.

Rate of Adoption

As mentioned earlier, the first commercial use of plastic covers was in 1956/57, at first with cucumbers. Reportedly, the areas were approximately 50 dunams (5 hectares) in 1958/59, 100 dunams a year later and 310 dunams in 1960/61.

Orderly collection of data started in 1961/62 (Table 1 and Figure 1). Roughly speaking, the total area was multiplied in 7 out of the 9 growing seasons reported. A clear deceleration in the spread of the new method appears in all three crops toward the end of the period. The decline in the spread between 1961/62 and 1962/63 was a reaction of the growers to favorable climate conditions in the first of these seasons which resulted in lower prices and income (Table 7).

Table 2 and Figure 2 survey the diffusion of the new technique by sector. Kibbutz (plr. kibbutzim)[2,3] is a communal settlement of 200 to 2,000 inhabitants in which production and consumption are collective. The scale of operation is large, permitting specialization of members in a single line of production. Many kibbutzim operate industrial enterprises and all have workshops and maintain and improve implements themselves; the level of schooling is high, 12 years is the rule and higher education

Table 2

Area Under Plastic Cover,

By Sector (dunams)

Year	Kibbutzim	Moshavim		Private	The Arab Sector	Others	Total
		Established	Young				
1961/62	117	158	188	222	-	4	689
1962/63	169	210	153	154	12	43	741
1963/64	163	291	535	565	36	18	1608
1964/65	309	884	1014	1559	94	33	3893
1965/66	386	1395	2288	1883	815	89	6856
1966/67	468	1313	3157	1960	651	231	7780

Source:

As for Table 1.

Others are mostly schools.

is prevalent; technology is advanced and capital labor ratio is high. As a result, the kibbutzim are by far the most innovative sector in the Israeli agriculture, and they were in fact among the first to adopt the plastic covers. It is perhaps also typical that the very first kibbutz to grow vegetables under plastic covers is operating a factory of plastic product. The methods of spreading the covers and erecting tunnels by machine were also developed in this same kibbutz (Ha'ogen). Despite the fact that the kibbutzim were among the first to start with the plastic technique and despite their general innovativeness their share in total area was, already in 1961/62, only 17% compared to their share in total agricultural product which is of the order of 32% (Table 3). Moreover, toward the end of the studied period the share of the kibbutzim declined to 6% of the area.

The other cooperative sector is the sector of the moshavim (singular: moshav). In the moshav, farmers operate their private enterprises individually and cooperate in marketing, purchasing of inputs and services. Capital intensity in the moshav is lower than in the kibbutz, scale of operation smaller, most farms are diversified and as a result operators manage 3-4 lines of production (field crops, livestock, orchards, etc.). As Molcho and Katz [7] found, farmers in the moshavim are significantly less innovative than in the kibbutzim.[4]

Moshavim are divided in our data to "established" and "young". The established were founded before the creation of the state of Israel in 1948

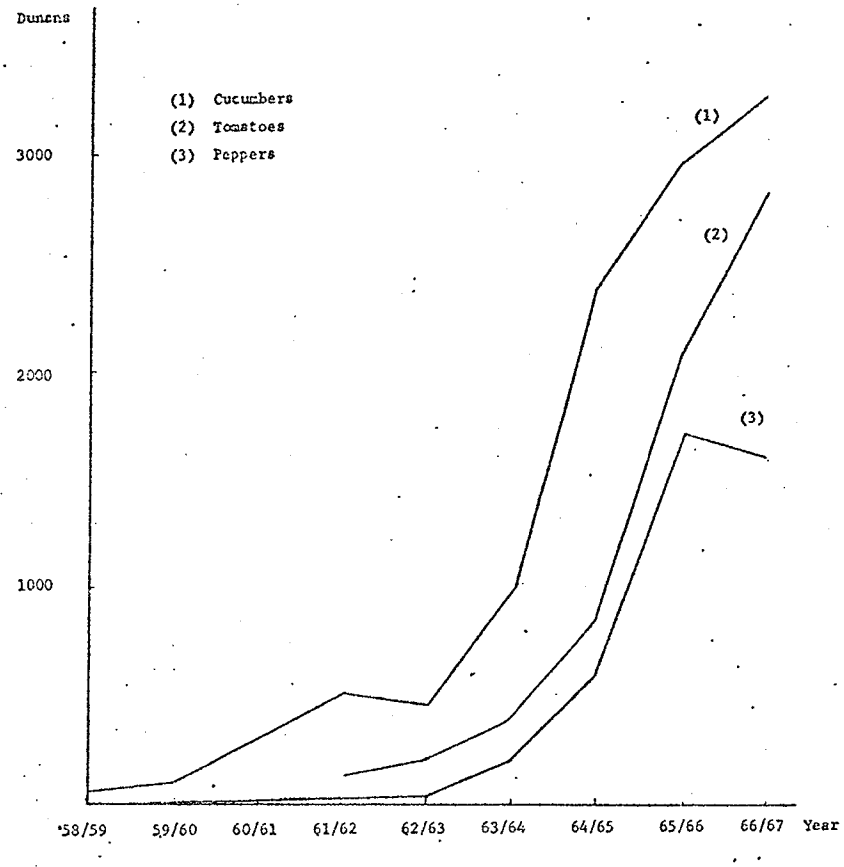

Figure 1: Area By Crop

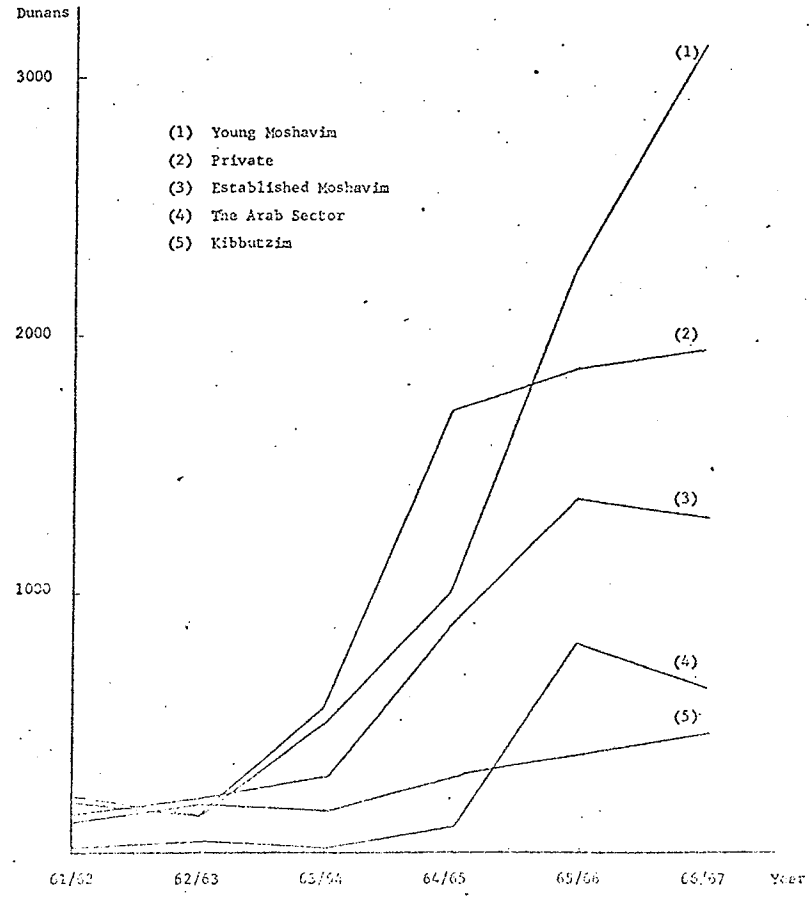

Figure 2: Area By Sector

and mostly in the 1920's and 1930's. The young moshavim were established after 1948 and by and large their members immigrated to Israel after 1948 with no prior agricultural experience and were directed from the port to the new moshav in which the state provided them with land, housing and some implements. As should be expected, members of young moshavim are generally much less innovative as those in the established ones (and were even more so in the 1950's). However, the area they cultivated was of the same order of magnitude as that of the established moshavim in 1961/62 while it was almost 2.5 times larger than that in 1966/67, indicating a faster rate of adoption in the young moshavim (Table 2).

The other interesting case is that of the Arab sector. This is the only traditional agricultural sector ("traditional" in the sense of Schultz [10]) in Israel, with very low capital intensity and highly divided land cultivated by extended families. This sector had no land under plastic covers in 1961/62 while its share in total area was, in 1966/67, higher than its share in total farm output (Tables 2, 3). Despite its disadvantages, it succeeded to adopt the new methods, with a lag of several years, and to employ the benefits of a late comer to adopt at a higher rate.

The same findings as discussed above are summarized in Table 4 which reports estimates of the sigmoidal function

$$(1) \qquad y_t = \frac{k}{1 + be^{-at}}$$

where y_t is the area (in dunams) under plastic covers in year t and k, a, b are

Table 3

Sectorial Attributes

	Kibbutzim	Moshavim		Private	The Arab Sector	Others	Average
		Established	Young				
1. Total product (10^6 IL)	357.7	126.5	290.2	204.8	71.7	38.7	1,124.5
2. Share in total product	.318	.112	.265	.182	.064	.034	100
3. Net income (10^6 IL)	113.4	28.6	75.8	60.4	27.7	13.2	327.2
4. Labor days (1000)	4535	1800	5233	4260	2330	839	18,997
5. Product per labor day (IL)	78.9	70.3	57.0	48.1	30.8	45.6	58.0
6. Net income per labor day (IL)	25.0	15.9	14.5	14.2	11.9	15.7	16.0
7. Ratio: line 6 to average	1.479	.941	.858	.840	.704	.929	1.00
8. Share of area under plastic cover 1961/62	.170	.229	.273	.322	-	.006	1.00
9. Same 1966/67	.060	.169	.406	.252	.084	.029	1.00
10. line 8 / line 2	.51	1.03	2.04	1.77	-	.18	-
11. line 9 / line 2	.19	1.51	1.53	1.38	1.31	.85	-

Source:

Lines 1-7: Ministry of Agriculture, The Five Year Plan for the Israeli Agriculture, 1966/67-1970/71. Tel Aviv, August, 1966, Vol. B, p. 129.

Lines 8, 9: Table 2.

parameters. (Since the equation for the established moshavim did not have a real value solution, the estimates for the pooled data of the total area in the moshav sector are reported.)

The parameter k is the "ceiling", the level to which the area approachs as time increases. $k/(1 + b)$ is the starting value, the estimate of the intercept. Note the low values for the young moshavim and the Arab sector. The parameter a indicates the rate of adaption,

$$(2) \qquad \frac{\dot{y}}{y} = a\left(1 - \frac{y}{k}\right).$$

Note, for example, that it is the highest in the Arab sector.

Thus, as our findings show, general features of innovativeness explain only the very first steps of the spread of the technique studied. Only a few years after its introduction, the adoption of the new technique was determined by other factors. To our judgement, the most important of these factors is the alternative cost of labor, vegetable growing is labor intensive (relative to other lines of agricultural activities) with relatively low returns to labor. Kibbutzim, and to some extent moshavim also, try, as a rule, to adhere to the principle of self-labor so as not to exploit hired employees. The private sector and the Arab sector are not limited by this principle. In the Arab sector, alternative cost of labor is often even lower than the market wage rate due to the abundant availability of family labor. Some indication of the differences in the alternative cost of labor can be deducted from line 6 in Table 3--net

Table 4

Estimated Values of the Sigmoidal Function

Equation (1)

	K	b	a	$\frac{K}{1+b}$	$*_{R}^{2}$
Tomatoes	5196	202	.998	25.7	.993
Cucumbers	3257	64	1.153	49.8	.988
Peppers	1837	3,654	2.077	.5	.979
Kibbutzim	571	15	.588	35.8	.983
Moshavim:Young	3633	233	1.257	15.5	.990
Moshavim:Total	6233	99	.979	62.3	.994
Private	1935	132	1.585	14.6	.978
The Arab Sector	852	464,580	3.850	0	.974

Notes:

$*_{R}^{2}$ correlation coefficient between the calculated and observed y values.

Estimated by the method suggested by Tintner [11, pp. 208-211].

income per labor day. Thus the extent of the spread of the new technique is negatively correlated with the alternative cost of labor, while the rate of adoption is faster for the late comers who have the benefits of learning from the experience of others. (It is interesting to note, in this connection, that the private sector is concentrated mainly in the central area of the country close to Arab villages whose inhabitants are often employed as laborers by this sector and thus have the opportunity of on-the-job training in the new techniques.)

Adoption is a process that entails testing and learning. Some try the new method and leave it, others wait for their neighbors to try it first. Unfortunately, data on individual growers are collected only for the private sector. Data for all other sectors are recorded on the village basis. In an effort to correct part of this shortcoming, a sample of 29 moshavim, which had records on the numbers of individual farmers growing under plastic covers, was collected. Some results are reported in Table 5. Note increases both in the number of moshavim and in the number of growers per moshav with area under plastic cover; these are indications of the spread of new methods. More on the trial and testing that takes place can be seen from the data in Table 6.

Table 6a records information on the village basis, Table 6b on the individual grower. Note particularly the large numbers of "leaving" even in the last years and even for a whole village. Some of those who left, it should be added, moved "ahead" to more advanced and sophisticated technologies, such as the growing of strawberries for exports.

Table 5

Sample Data

	(1) Moshavim with vegetable under plastic tunnels	(2) Farmers growing vegetables under plastic tunnels	(3) (2)/(1)
1961/62	8	10	1.25
1962/63	10	21	2.10
1963/64	16	46	2.88
1964/65	27	130	4.81
1965/66	28	222	7.93
1966/67	29	291	10.03

Source:

Own sample which covered 29 moshavim, all with plastic areas in 1966/67.

Table 6

Entry and Exit

	Numbers of growers	Area per grower (dunam)	Percentages			
			"new"	"continuing"	"returns"	"leaving"
	a. Moshavim (unit is the village)					
1961/62	26	13.3	-	-	-	-
1962/63	37	9.8	50	50	-	30
1963/64	53	15.6	52	41	7	38
1964/65	59	32.2	61	31	8	21
1965/66	91	40.5	38	55	7	24
1966/67	109	41.0	31	61	8	33
	b. Private Sector (unit is individual farmer)					
1961/62	12	18.50	-	-	-	-
1962/63	13	11.85	54	46	-	46
1963/64	14	40.36	64	36	-	57
1964/65	84	18.56	84	8	8	8
1965/66	92	20.47	38	61	1	30
1966/67	90	21.78	39	56	5	47

Notes:

"New"--were not recorded as growing previously.

"Continuing" and "leaving"--grew last year.

"Returns"--grow some time in the period before that year.

Data in Table 6a is for the whole sector of the moshavim (not just for our sample).

Equilibrium Estimates

The spread of the new technique is affected by its profitability, as has already been indicated in explaining the 1962/63 slowdown in adoption. In most innovation diffusion cases, the limit, the "ceiling" of the process, is 100% usage--planting hybrid seeds on all the maize areas, as for example in [4] . There is no such natural limit to the spread of plastic covered winter vegetables, rather its extent is determined by a market equilibrium. In this section we attempt to project a long run market equilibrium and to re-estimate the singmoidal diffusion function under the assumption of equilibrium.

The basic approach is simple. It is assumed that cost of production is fixed at some level (c_i per crop i), that quantities bought are affected by prices (own and related crops), by income and by a seasonal, monthly, factor, and that equilibrium quantities are those that will clear the markets at production costs. Once these quantities are known, the projected equilibrium areas can be calculated. These long run equilibrium areas are then reintroduced as predetermined k values in equations such as (1), and the sigmoidal diffusion function can be re-estimated, now explaining adoption as a movement toward equilibrium. What follows is a detailed presentation of this process.

The marketing season of vegetables under cover is March to June. To present demand equations, let

Table 7

Estimated Net Income (IL/dunam)

	Tomatoes	Cucumbers	Peppers
1960	1770	1146	1527
1961	2034	1552	1873
1962	1885	498	1386
1963	1196	718	2053
1964	2606	757	1719
1965	2777	803	1397
1966	1232	414	493

Notes:

The growing season stretches over fall to spring. Income occurs in winter and spring.

Calculated by using prices paid to producers in the Tel Aviv central market to compute the revenue, and Ministry of Agriculture Planning Section data for cost and yields.

i be the crop index ($i = 1, 2, 3$)

j month index ($j = 1, \ldots, 4$)

q_{it} quantity

p_{it} price

d_t disposable income (only annual data were available)

u_{it} a random component

a $\sim$ will mark logarithms ($\tilde{p}_{it} = \log p_{it}$).

The demand equations were estimated from the regression equations

$$(3) \qquad \tilde{p}_{it} = b_{io} + \sum_{\substack{k=1 \\ k \neq i}}^{3} b_{ik}\tilde{p}_{kt} + b_{i4}\tilde{q}_{it} + b_{i5}d_t + b_{it} + u_{it}$$

$$(i=1, 2, 3)$$

where b_{it} is the coefficient of the month t. The equations (3) were estimated for each crop separately; previous experiments with simultaneous estimates did not show superior results [1, 2]. The estimates are reported in the Appendix.

Equations (3) are monthly demand functions; production costs are in annual terms. For consistency one has to estimate an "average" price for each crop. This was done in the following way. First, define monthly crop share by

$$(4) \qquad \eta_{it} = q_{it} / \sum_{t=1}^{4} q_{it} \qquad (i=1, 2, 3).$$

The η_{it} values, the distributions of crop yields by month, were received

from the Agricultural Extension Service experts. Let $\bar{p}_i$, $\tilde{p}_i$, $\bar{q}_i$, $\tilde{q}_i$ stand for annual averages, arithmetic and geometric, of prices and quantities (thus $\bar{p}_i = \sum_{t=1}^{4} p_{it}/4$). From (3),

$$(5) \qquad \tilde{p}_{it} - \bar{\tilde{p}}_i = b_{io} + \sum_{\substack{k=1 \\ k\neq i}}^{3} b_{ik} (\tilde{p}_{kt} - \bar{\tilde{p}}_k) + b_{i4} (\tilde{q}_{it} - \bar{\tilde{q}}_i) + (b_{it} - \bar{b}_i)$$

$$(i=1, 2, 3, \quad t=1, \ldots 4),$$

(note that $d_t - \bar{d} = 0$). The system (5) is a system of 12 equations. It was treated as a system of 12 equations in 12 unknown--the 12 price ratios $(\tilde{p}_{it} - \bar{\tilde{p}}_i)$--by substituting in (5) the estimates of (3) for the b_{ij} values and by calculating $\tilde{q}_{it} - \bar{\tilde{q}}_i$ in a fashion similar to (4). From this solution to (5) a vector of price ratios was calculated

$$(6) \qquad \Pi = \{\pi_{it}\} = \{p_{it}/\bar{p}_i\} .$$

The ratios in (6) are estimated price ratios (a logarithmic average was used to estimate the arithmetic mean).

To estimate equilibrium quantities, we proceeded as follows. In a non-profit equilibrium

$$(7) \qquad c_i = \sum_{t=1}^{4} \eta_{it} p_{it} \qquad (i=1, 2, 3)$$

where c_i are costs per crop i.[5]

From (7) and (6)

$$(8) \qquad c_i/\bar{p}_i = \sum_{t=1}^{4} \eta_{it} \pi_{it} .$$

Projected equilibrium average prices were calculated from

$$(9) \qquad \bar{p}_i = c_i / \left(\sum_{t=1}^{4} \eta_{it} \pi_{it} \right),$$

from which one can calculate monthly projected price ($\hat{p}_{it}$) as

$$(10) \qquad \hat{p}_{it} = \bar{p}_i \pi_{it}.$$

Inserting these projected prices (for April) into the demand equations (3), equilibrium projected quantities were calculated (projected 1971/72 disposable income figures were used). Dividing by expected yields, equilibrium projected areas were reached.

These projected areas are reported in Table 8 together with the re-estimated parameters of equation (1).

Concluding Remarks

It has already been mentioned that recent changes in the Israeli economy rendered meaningless any extension of the equilibrium analysis of the last section to the period beyond 1967. As a postscript, it is, however, interesting to note that in the 1970/71 season the young moshavim grew 46.3% and the Arab sector 25.6% in the area of tomatoes and cucumbers under cover (data on peppers are not collected any more). These are substantial increases, particularly for the Arab sector, from the respective shares in 1966/67 (Table 3, line 9) and they are in line with the trends observed in earlier years.

Table 8

Equilibrium Estimates of Equation (1)

	Tomatoes	Cucumbers	Peppers
Projected Equilibrium Values:			
Total product (ton)	16,652	5,368	3,122
Area (dunams)	3,965	3,158	1,388
Regressions:			
No. of observations	5	8	7
a	.878 (7.752)	.913 (8.299)	1.131 (26.782)
b	79.2 (12.275)	207.5 (9.620)	455.0 (44.603)
$*R^2$	.960	.912	.949

Notes:

$*R^2$ correlation coefficient between the calculated and observed y values.

Estimated in the form $\log (y_t/k) = \log b - at + u_t$. Values in parenthesis are t values.

Adoption of new techniques is viewed in general as part of the modernization process, with the resulting implication that the more modernized sectors (or enterpreneurs) will adopt faster and more. The dynamics of the plastic covers innovation turned out to be more complex and involved than this simple pattern, with skills, knowledge, progressiveness and economic factors combining to determine the rate and direction of adoption.

The existing side by side of modernized, advanced and progressing sectors and traditional, hard to adjust ones often results in widening income inequalities and even destruction of the more backward part of the industry. The case studied here reveals an alternative possibility: an innovation cycle. The more advanced sector, endowed with skills and the ability to absorb new information, draws rents from early adoption. Once an innovation has been tested, and to some extent adapted to the local conditions, it may be taken over by the sectors whose comparative advantage is in lower labor alternative costs (this development should, of course, not be expected with capital intensive labor saving innovations), while the progressive sector must turn to new innovations in order to capitalize on its comparative advantages.

More than one such cycle can be identified in the Israeli agriculture (in the growing of vegetables and flowers, viniculture and sheep raising). The implications for development are clearly interesting and important and need not be elaborated upon here. Innovations will always be adopted first by the progressive sectors. To institute policies for balanced and

more equal development, we may have to know more about the nature of innovations and the conditions favorable for their sequential adoption.

Appendix:

Regression Coefficients of Demand Functions Eq. (3)

	Peppers	Cucumbers	Tomatoes
R^2	.859	.953	.820
Intercept, b_{io}	-4.285 (-1.939)	-1.7783 (-.806)	.5165 (.169)
Other crops price coefficients, b_{ik}	.0739 (.852)	.0311 (.290)	
	-.1092 (-1.080)		-1.440 (-.891)
		-.0180 (-.120)	.1689 (.845)
Own quantity coefficients, b_{i4}			-.6071 (-5.930)
		-.3307 (-13.672)	
	-.4363 (-6.294)		
Income coefficient, b_{i5}	.4231 (1.569)	.2045 (.709)	-.0987 (.229)
Month effects, b_{it}			
Feb.		.5077 (-3.665)	-.1941 (1.252)
March	-.0664 (-.665)		
April	.0213 (.167)	.2495 2.414)	-.1096 (-.623)
May	.4526 (2.370)		.0622 (.247)
June	.3389 (1.222)	-.4301 (-2.825)	-.3747 (-.992)

Notes:

Number of observations 30 (for the period 1960-1966). In parentheses are t value. Observations in February were added to the estimates.

Footnotes

*This is a revised version of the second author's Master Thesis [9]. The work on this study was financed, in part, by a grant from the United States Department of Agriculture, under P.L. 480. The writing of the present version was completed during the stay of the first author at the Economic Growth Center at Yale.

[1]The classical sociological reference is Rogers [8]; for economic studies, see, for example, the works by Griliches [4] and Mansfield [6].

[2]Included in this sector is also the sector of the moshav shitufi in which production is collective and consumption private.

[3]The historical development of the three major forms of Jewish agricultural settlements in Israel is discussed in [12]. For a somewhat popular description of the kibbutz and the moshav see [3]. [5] is an economic description of the operation of the kibbutz.

[4]Molcho and Katz also found that while in moshavim innovativeness of farm operators was positively correlated with the usually accepted personal characteristics of Innovators (modern outlook, education, young age, etc.) such a correlation was not found in their sample of kibbutzim members. Evidently, this institutional setting dominates in the kibbutzim the personal traits or requires specific definition of the character of the innovator in this sector.

[5]The c_i values were estimated by us from technical data as IL 419; - IL 853- and IL 727 - per ton of tomatoes, cucumbers and peppers, respectively.

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