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ADOPTION OF AGRICULTURAL INNOVATIONS:
THE CASE OF DRIP IRRIGATION OF
COTTON IN ISRAEL*

by

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ABSTRACT

The adoption parameters of drip irrigation in cotton growing in the collective farms sector (kibbutzim) in Israel are estimated. The classical logistic function is perfectly retrieved. The estimated parameters are then explained by a variable that represents profitability, the change in yield. In spite of the small number of data points it again appears that profitability is the major explanatory variable for the adoption of a new technology. A hypothesis of dynamic ceiling is described and estimates are drawn.

The study is aimed at estimating and explaining the parameters of the adoption process of drip irrigation in cotton by collective farms in Israel. Israel consists of more than 50% desert-type areas, with less than 200 mm. annual rainfall. In addition, water sources outside the desert areas are scarce and uncertainty prevails about their annual yield. Thus, irrigation and water use efficiency technologies go hand-in-hand as a 'must' for the development and expansion of agriculture.

The main purpose of the development of irrigation technologies is to save water, or, the equivalent, to increase the productivity of water (water saving technologies).

Like any new technology, irrigation technologies have also to go through a phase of dissemination. Therefore, as with other technologies, the driving force of the adoption is a key issue. Knowledge of the resulting rate of adoption is needed by all parties involved: the innovator, the manufacturer, and the policy-maker who is in charge of the scarce resource.

In this study a conceptual framework for the decision to adopt drip technology for the irrigation of cotton in Israel is developed and econometric analyses of time series and cross-section-time series data that identify the parameters of diffusion are presented. The model finally adopted is the one used by Griliches (1957) for hybrid corn in the U.S.A.[1]

Background

In Israel, irrigation and agricultural development are inseparable. Until the mid-1970's, irrigation by sprinklers was the dominant (90%) technology. By that time the drip irrigation technology had been developed and was disseminated for various uses, the main ones being small orchards and sensitive flowers and vegetables. Its rise in terms of acreage of field crops started only in 1977. Since cotton is the major irrigated field crop in Israel (see Table 1), the diffusion of drip irrigation in cotton is the most significant sign of its commercial widescale acceptance. By the early 1980's cotton reached its peak acreage and since then has fluctuated (responding to prices of alternative crops to its price on the world market). However, the acreage of drip irrigation continued to increase. In Table 2 one can see the dynamics of its relative share in irrigated cotton. The interesting point is the regional differences in the relative shares. In 1985 its relative share ranged approximately 30% in the Yizre'el Valley to 70% in the Negev.[2] A graphical description of these figures is presented in Figure 1, with three regions presenting the highest and smallest rates of adoption and the special case of the Ra'ananna district. Some of the reasons for the differences between areas are explained below. Table 2 also shows that the area drip under irrigation continued to expand even though the total cotton area declined. Hence, since cotton is usually grown continuously on the same land the increase in drip irrigation means the substitution of one irrigation technology, i.e., sprinklers, for another.[3] We hypothesize that the rate of substitution (and expansion) as exhibited by the regional differences in the share of drip irrigation, stem from the same reason, profitability. The profitability may be due to one or more of the following factors:

a) saving of water per unit of land
b) increase in fiber yield per unit of land (and unit of water)
c) saving in other costs (fertilization, weed control and insecticides)
d) improvement in the quality of the yield
e) introduction of marginal land, not suited to other irrigation technologies, to the production of cotton
f) better utilization of the entire water system (irrigation is not restricted to calm weather), thus also saving energy.
g) enables the use of marginal water (in terms of salinity).

Israeli agricultural magazines on the subjects of irrigation, fertilization, and cotton growing), as well as completed questionnaires distributed among growers, indicate the validity of all the above factors, and alsol that the meaningful one is the second.[4] Also on a per-region basis we were able to quantify only the second one, the increase in yield per unit of land. Production cost data indicate that in terms of profitability the increased yield is challenged by the high cost of investment in drip irrigation. In this context one finds that after some minimal acreage (5 ha), there are no economies of scale in investment and in drip utilization and that there are no regional differences in investment costs per unit of land.[5] Thus, the source of the regional differences in adoption rates can lie only in the different intensity of the seven reasons for profitability listed above. Correspondingly one can expect that the greater the relative profitability, the more rapid is the adoption and the higher (in a given year) the share of the new technology. A quick glance at the seven regions shows the Negev at the top and the Yizre'el Valley at the bottom. The outstanding high rise in the share of drip irrigation in the Ra'ananna region is due to the relatively small acreage of cotton on each farm (due to the presence of other alternatives, i.e., citrus, avocado, etc.).

The Adoption Model

Given the "on the average" profitability of drip irrigation the immediate question is why is it not adopted instantaneously by all cotton growers. The answers to this question are as follows:

1) There is a distribution of the profitability. Its magnitude changes for different soils, topographies, climates, and qualities of water and land.

2) The supply curve of capital differs for different growers. It is upward sloping at different slopes.

3) The availability, quality, and alternative use of equipment of other irrigation technologies differ for different growers.

4) Manpower shortages at the beginning and end of the growing season are not the same for all growers.

5) Sunken costs related to the technology to be substituted. The new technology enters into use as the equipment of the old one depreciates.

6) Waiting to see how the service, reliability, and availability of the equipment needed for the new technology develop.

7) Risk aversion of the expected adopters.

Disregarding the various uncertainties of a new technology, the balancing of certain parts of the benefits with the costs and difficulties of drip irrigation gives the data presented in Figure 2. The term 'marginal benefits' comprises the direct monetary net returns from the conversion of an additional hectare to drip irrigation. The term 'marginal costs' contains the indirect costs and the monetary value of the difficulties of converting an additional hectare to drip irrigation.

Hence, from the basic rule of equating the marginal benefits and marginal costs, in a static world, in year t, the grower will convert D_t^o hectares to drip. In a dynamic world the picture in year t+1 would be different from that in t. The MC is likely to be the same as or lower than that in t, since D_t^o hectares are already under drip irrigation, while the MB might move to the left, starting at the level of V_t, and its slope flattens or even moves somewhat upwards. The intersections of MC_t and MB_t $t = 1,\ldots,T$ would determine the area converted each year to drip irrigation. The conversion would stop at year S, when the following takes place: $MC_S > MB_S$ for D_S. However, in the beginning, $S = 1,2,3$ we observe that $D_{t+1} >$

D_t. One reason might be the learning process of working with drip irrigation and thus the increasing profitability of the marginal conversion, a shift of the MB upward.

This explanation does not yield a specific pattern to the series D_1, $D_2, D_3, \ldots, D_T$, nor does it identify the role of each factor in the MC_t and MB_t in the determination of D_t.[6]

Various studies of the adoption of new technologies were centered around the elements of uncertainty and risk aversion. The uncertainty might be related to natural conditions (rainfall) or market conditions (prices). Feder (1980) looks at the adoption of new technologies by farms and attempts to identify the risk aversion effect, the farm size effect, as well as the effects of credit constraints on it. Feder formulates a production function for the new technology which has a separable stochastic part. The adoption is via the usage of variable inputs. He applies the maximization of expected utility to find the effects of being risk averse on the use of the new technologies. Dynamics is not present in the model, as there are no fixed costs of adoption. Just and Zilberman (1983) extend the Feder (1980) study and correct for some of its shortcomings, e.g. the lack of fixed investment in the adoption process which tend to discourage adoption. The results of the maximization of expected utility when risk aversion is present and farm size is a constraint, are those suggested by intuition. For example (J-Z proposition 1): if the modern input is risk increasing, then larger farms tend to use more of the modern input if relative risk aversion is increasing. However, like the Feder paper, this lacks dynamic implications.

This shortage is overcome by the joint Feder, Just and Zilberman (1985) survey in which the dynamics of adoption occupies a major part. The following has been extracted from their study. They noticed that in addition to uncertainty of output, also prices (of output and inputs) may be random and their uncertainty may affect technological choice. From the static models of adoption behavior they derive hypotheses regarding the dynamic properties of the adoption process. For example, as the farmer experiences more of the innovation, his perceived distribution of technical parameters shifts over time from a lower payoff to a higher payoff. Also over time capital availability may be increased from profits on past adoption.

Their survey contains examples of studies indicating that the length of time between awareness and adoption is negatively related to the mean profitability of the new technology and positively to the variance of actual profits (Lindner et al., 1979). They recall that Fischer and Lindner (1980) allow for differences in soil quality, human capital and other factors that affect the performance of the new technology. In 1981, Fisher and Lindner extended the above risk-neutral model to a risk-averse Baysian learning model.

Empirical studies usually show that the S-shaped pattern characterizes aggregate diffusion over time. However, the parameters of an S-shaped function can be derived analytically from various diffusion mechanisms, e.g. communication (Rogers, 1969) and imitation (Mansfield 1961). It is also seen that the shape of the curve depends on the distribution of external influences (Hernes, 1976). Thus, the shape of the estimated function does not provide information on the underlying mechanism. An additional setback to the possibility of identifying the underlying process from the estimated parameters is given by Davis (1979). He shows that the presence of scale elements and the distribution of firms by size would also affect the shape of the diffusion function. Hence, the econometric estimation of the diffusion function can serve only for descriptive purposes but not for identifying the factors, reasons, and weight of each one of them in the adoption process.

The description of the adoption process has its own importance, since it provides values with which to forecast the diffusion of other innovations which have similar characteristics to farms, which are similar to those that were analyzed. In this study the diffusion function for drip irrigation of cotton in Israeli kibbutzim (collective farms) is estimated.

Data

The adoption process analyzed in this study is a continuous one at the micro level of an individual kibbutz. Micro data indicate that the decision was not a dichotomous but a quantitative one: how much land to convert each year from the old technology, sprinklers to drip. Obviously, when the decision is quantitative on the micro level, it is also quantitative on the aggregate regional level.

The Israeli cotton sector is a price taker. The price of cotton is determined in the world market and converted, after various considerations, to a fixed (by quality) price given to each producer regardless of the quantity he produces. Hence, the demand that each producer and the Israeli cotton industry faces is perfectly elastic. The level of the demand changes over time due to the fluctuations of international prices and because of domestic considerations. This determined price of cotton and the and expected prices of alternative products that compete on the limited resources (mainly water and land) and the natural conditions (varying from year to year) affect the total acreage of cotton, the total acreage converted to drip irrigation and thus the variable that is explained - the share of drip in total irrigated cotton.[7] Data on individual farms and regions indicate variations in total acreage but a continuous increase in drip irrigation and in its share. This picture might be due to the larged fixed costs of drip equipment as well as its absolute advantage over the other technologies which makes drip irrigation the shock absorber for the total level of production. Another possible reason may be related to the fact that the yield per unit of land is the greatest with drip irrigation. Thus, when reducing the area dedicated to cotton, the first to be reduced are lands with the submarginal yields, i.e. those that employ other irrigation technologies.

The socioeconomic group of adopters is quite homogeneous. Due to technological economies of scale, over 90% of the cotton in Israel is grown by collective farms (kibbutzim and large partnerships of family farms). The governmental extension service, and the extension services of the producers of drip equipment, provide free and intensive information to all growers.

Hence, lack of knowledge or its uneven distribution are not relevant for explaining differences in adoption. Over individual farms the relevant reasons for this are the relative profitability (which is also affected by nature: soil, climatic conditions, etc.) and the relative power of the management of the cotton branch in the collective decision making. While the first reason might be proxied by differences in yield per unit of land (or per unit of water or per monetary unit of inputs' basket), the second is as yet an unexplained ballpark. It apparently exists since there are huge adoption differences amongst growers in the same region. When estimating the regional adoption process we called it the farm effect.[8]

Results

The drip irrigation technology is still an innovation, but it is already challenged by new ones (water-and-labor saving technologies). There were nine observations (growing seasons) which were begun in 1977. Two adoption functions were tried: the logistic and the log logistic. In general, the first performed much better, which is probably due to the very small number of points over time, while time is the explanatory variable. Thus, only the results for the logistic function are presented.

The interpretation of the coefficients is obvious once we recall that the logistic function

$$(1) \qquad P_t = K/(1 + e^{a+bt})$$

where P is the share of drip irrigation in year t, k the saturation level and a, b the parameters, and the solution to the differential equation is:

$$(2) \qquad dP/dt = bP_t\left(\frac{K-P_t}{K}\right)$$

i.e., b determines the rate at which the gap between the saturation level and the performance is closed. In the following we present the b's for regions and farms within regions. Since K is an unknown priori, it is estimated simultaneously with b and a. All the results are presented in Table 3, in the Appendix.

As will be seen below, there are large regional differences in both $\hat{b}$ and $\hat{K}$. We follow Griliches' proposition and define a new term, $\hat{b}' = \hat{b} \cdot \hat{K}$, which further emphasizes the adoption differences (other things being constant, we expect a larger $\hat{b}'$ the larger is $\hat{k}$).[9] The last analysis in this study is the explanation of $\hat{b}'$ over regions. Regional differences in yield per hectare for drip and sprinkler irrigation is the explanatory variable DYL.. The explanation is good, although one should recall that only seve observations are available. The estimation is by ordinary least squares. The estimated equation is

$$(4) \qquad \underset{}{b'} = \underset{(.15)}{-0.212} + \underset{(0.0008)}{0.00363}\ DYL, \quad R^2 = 0.81$$

The interpretation of this result is that as the difference in yield increases by 10 kg of fibers per hectare, the product of the rate of adoption and the ceiling of adoption increases by 3.6 %. The average difference in yield is (all regions being weighted equally) 185 kg, i.e., an approximately 5 % change in the difference of yields changes b' by 3.6 %. Detailed results on the estimated diffusion functions are presented in the Appendix.

Conclusions

In spite of the short period for which the adoption process is analyzed, the data on both a micro level (a kibbutz), and a macro level, (a region), exhibit the classical pattern that has been documented in many past studies. Furthermore, the estimated parameters of the adoption function are explained well by the major motive for adoption, profitability. Our results on the economics of drip irrigation are supported by other studies, for instance the detailed one by Wilson et al. (1984). The climate of the area they analyze, viz., southern Arizona, is similar to that of the south of Israel, and cotton is the major field crop grown there. They report on possibilities of increasing the yield by up to 29 % and achieve a savings in water of up to 40 %. However, they emphasize that effective drip technology requires a more intensive application of plant, soil, engineering and economic science than is usually available. Apparently many of the kibbutzim in Israel were able to supply all these requirements, which explains the high rate of adoption of drip irrigation in cotton.

The dynamics of the system is further demonstrated in Appendix 2, which shows that the saturation level shifts upward as the new technology is further adopted. The reasons may be better knowledge and increased reliability. For researchers and developers this means that the evaluation of the potential market has to be prepared several times until the technology is well on its way, or - alternatively - a dynamic market potential is preferred, presuming the innovator is willing to exploit a new development optimally.

APPENDIX 1

The estimated equation is the transformation of the logsitic model

$$(1) \qquad P_t = K/(1 + e^{a+bt+\epsilon_t})$$

where ϵ_t is assumed to be a classical random variable. This assumption is not tested due to the small number of observations. This is also the reason for choosing ordinary least squares rather than nonlinear least squares, the underlying functional form of which is

$$(2) \qquad P_t = K/(1 + e^{a+bt}) + \epsilon_t$$

The log logistic function mentioned in the text is as equation (1) above, but instead of the term e^{a+bt} it contains the term e^{a+bLnt}. The estimated equation for (1) is therefore

$$(3) \qquad Ln(K/P_t - 1) = a + bt + \epsilon_t.$$

When dummy variables are used to capture the farm effect the estimated equation becomes

$$(4) \qquad Ln(K/P_{ti} - 1) = a + bt + \sum_{i=1}^{I} c_i D_{it} + \epsilon_{ti}$$

where D_{it} takes the value of 1.0 for all t for farm i and the value 0.0 for all other farms. We present below some of the results. As already mentioned the value of K was estimated jointly with the other parameters by intergrating various values of K and identifying the value for which R^2 is maximized (a variant of a maximum likelihood). Table 3 contains the estimates for each of the seven regions. As can be seen (even considering that we had only eight or nine observations), the fit of the logistic is perfect. In three regions we had detailed data on most of the kibbutzim that grew cotton. In the Ra'ananna region this amounted to 89 observations (11 kibbutzim) in the Galilee region to 224 observations (28 kibbutzim), and in the Hadera region to 152 observations (19 kibbutzim). For each of these regions we first estimated one diffusion function and then in a joint estimation allowed for a farm effect once on the parameter a and once on the parameter b. The conclusion is not uniform. In the Ra'ananna region we found a significant effect of the farm effect on parameter a but not on b. Also, the estimated K for the regions aggregate is the same as that estimated with the individual farm data. In the Galilee there are farm effects on both a and b and the regional aggregate K differs from that estimated from individual farm data. In the Hadera region the results are similar to those found for the Galilee region.

In the Hadera region we also estimated a diffusion function for each kibbutz (19 functions) and found a very large variance in the results. The $\hat{b}$'s range from a low of 0.24 to a high of 1.51, the $\hat{K}$'s range from a low of

0.31 to a high of 1.0, the $\hat{b}$''s from a low of 0.24 to a high of 0.75, and the R^2's range from 0.71 to a high of 0.96. We could spot the differences already by the share of drip irrigation at the first observation (1978). This ranged from zero to 24%. In 1979 the share was already positive in all regions. It is also interesting to see that for those with a positive share in 1978, their K is larger and the correlation among them between the share in 1978 and the estimated K is positive. They are also the ones with the higher R^2. Among the 19 kibbutzim four have a k = 1.0. Of the four, two own a factory which produces equipment for drip irrigation and the other two grow a relatively small acreage of cotton.

APPENDIX 2 - THE DYNAMICS OF THE SATURATION LEVEL

In the text the results of estimating the logistic adoption functions for the period 1977/78 to 1985 are reported. The adoption ceilings are those emerging from the procedure of maximum likelihood estimation. In this Appendix the hypothesis that these ceilings are not constant is verified: at least in the first stages of the adoption process one might observe an upward shift of the ceiling as the adoption progresses. Hence, as time passes, the ceiling gets higher. This is described graphically in Figure 3.

In the following we present the estimated ceilings by region for different periods of data (1977-83, 1977-84 and 1977-85, Table 4). As can be seen, the results confirm the hypothesis exhibited by Figure 3. The implied conclusions are:

(1) As long as the adoption continues the estimated ceiling is not necessarily final. It is obviously final once it reaches a natural limit, e.g. if measured as a fraction it is 1.0.

(2) The increase in the ceilings (absolute or relative) has to do with the re-evaluation of profitability. This result is not backed by statistical proof due to the lack of data.

(3) The larger is the relative profitability, the larger are the shifts and the quicker is the convergence to the final ceiling which is also relatively higher. This is proved by the corresponding differences among the various regions.

(4) In general, the viewpoint on the 'dynamics of the saturation level' is of importance no one can ignore: an innovator planning the penetration efforts should bear in mind this phenomenon in deciding on his 'plant-size', avoiding an artificially increased incentive on the part of potential competitors.

TABLE 1 - COTTON: PRODUCTION ACREAGE AND SHARE IN ISRAELI AGRICULTURE

Year	Israel's irrigated area of field crops	COTTON Total area	area in kibbutzim	Production (fibers)
	10^3 Hectares			(10^3 MT)
1955	26.5 (20.0)*	2.2		2.2
1960	43.4 (28.4)	10.5		10.6
1965	47.7 (32.6)	16.9		21.8
1970	63.7 (52.6)	32.3		35.2
1975	68.9 (52.8)	38.8		48.9
1976	69.5 (55.7)	43.4	40.6	
1977	75.7 (60.2)	51.0		64.3
1978	73.4 (65.1)	59.3		79.5
1979	75.3 (65.2)	56.9	48.4	75.1
1980	76.8 (69.7)	57.7		77.9
1981	95.0 (75.8)	59.8		91.5
1982	107.4 (76.2)	55.9	44.5	86.6
1983	102.5 (76.0)	56.8	45.4	91.0
1984	114.4 (79.4)	63.3	48.7	88.0
1985	forthcoming	65.4	49.7	99.0
1986**	" "	46.4	37.1	66.0

Source: Statistical Abstracts of Israel (Central Bureau of Statistics) and Cotton Production and Marketing Board, Israel.

* In parentheses, area of summer crops

** Estimate.

TABLE 2 - REGIONAL DIFFUSION OF DRIP IRRIGATION IN COTTON

Year	Total	Drip irrigated	Drip irrigation's share
	Cotton (Ha)		
	NEGEV Region		
1978	6075	80	.013
1979	5527	160	.029
1980	4865	400	.082
1981	5110	1200	.235
1982	5469	2014	.368
1983	5571	2859	.513
1984	6568	4119	.627
1985	5918	4162	.703
	LAKHISH Region		
1978	4800	30	.006
1979	4600	112	.024
1980	4600	280	.061
1981	4890	500	.102
1982	4717	1100	.233
1983	4663	1758	.377
1984	5300	2314	.437
1985	5938	2870	.480
	RA'ANANNA Region		
1978	2530	50	.020
1979	2600	147	.057
1980	2595	220	.085
1981	2642	311	.118
1982	2605	493	.189
1983	2675	637	.238
1984	3260	1429	.438
1985	3139	2070	.660

YIZRE'EL VALLEY

1977	10340	90	.009
1978	12540	300	.024
1979	10420	678	.065
1980	10630	878	.083
1981	1110	1415	.127
1982	7819	1522	.195
1983	8133	1491	.183
1984	8581	2129	.248
1985	8861	2619	.296

GALILEE

1977	5720	100	.017
1978	6468	330	.051
1979	7040	515	.073
1980	6795	750	.110
1981	6678	950	.142
1982	6228	1194	.192
1983	6239	1906	.305
1984	6500	2390	.368
1985	6457	3111	.482

BET SHE'AN Region

1978	6700	170	.025
1979	6900	520	.075
1980	7236	1474	.204
1981	7829	1942	.248
1982	7261	2229	.307
1983	7447	2999	.403
1984	8066	3835	.475
1985	8210	4578	.558

HADERA Region

1978	6829	100	.015
1979	6514	260	.040
1980	6031	552	.092
1981	5749	849	.148
1982	5572	1086	.195
1983	5348	1374	.257
1984	5404	2015	.373
1985	5451	2397	.440

TABLE 3 - REGIONAL LOGISTIC FUNCTIONS

Region	N	$\hat{a}$	$\hat{b}$	$\hat{K}$	R^2	$\hat{b}'$
Negev	8	-4.955 (0.13)*	0.961 (.03)	0.750	.996	0.72
Lakhish	8	-5.326 (.16)	1.061 (.03)	0.500	.995	0.53
Ra'ananna	8	-4.287 (0.20)	0.583 (.04)	1.00	.973	0.58
Yizre'el Valley	9	-3.780 (.27)	0.556 (.05)	0.400	.951	0.22
Galilee	9	-3.796 (.15)	0.523 (.03)	0.650	.981	0.33
Bet She'an	8	-3.320 (.30)	0.576 (.06)	0.750	.917	0.43
Hadera	8	-3.977 (.19)	0.727 (.04)	0.500	.985	0.36

* Values in parentheses are standard errors of the estimates.

TABLE 4 - THE DYNAMICS OF CEILINGS BY REGION

Region	Base Period 1977-1983	1977-1984	1977-1985
Negev	0.65	0.70	0.75
Lakhish	0.50	0.50	0.50
Ra'ananna	0.30	0.90	1.00
Yizre'el Valley	0.30	0.30	0.40
Galilee	0.50	0.50	0.65
Bet She'an	0.45	0.50	0.75
Hadera	0.30	0.40	0.50

FOOTNOTES

1. See also Fishelson (1984). A recent study of the choice of irrigation technologies was carried out by Caswell and Zilberman (1985). However, their study is static in the sense that they explain the share of modern technologies, drip and sprinklers, in fruit growing at one point in time by using the logit model. The main result is the identification of the cost saving effect.
2. In three regions, Yizre'el Valley, Hadera and Ra'ananna, the total area included up to 10% non-irrigated cotton until 1980; since 1980 its share has been less than 3%.
3. The changing share of drip irrigation might be the result of two effects that work in the same direction. The expansion effect, i.e., the introduction of drip, enabled the cultivation of marginal land and the utilization of marginal water in cotton production, thus leading to an increase in the acreage of cotton. The substitution effect just increases the area of drip irrigation. Both effects increase the acreage and share of drip irrigation in cotton production.
4. See Yaron and Finerman (1986), who surveyed 38 kibbutz cotton growers in the Rehovot and Lakhish regions.
5. For details, see Joseph and Segal (1985). A ranking of annual per-hectare-costs of irrigation, including returns to specific irrigation capital and auxiliary equipment, yields at the low end the linear moving-line ($165) and at the high end the drip system ($470).

A more relevant comparison (due to land topography constraints) is with various sprinkler technologies (about \$300). That is, the annual differênce in costs is approximately \$250. Given cotton prices (in 1982/83 = \$.80/pound) this means that the break even difference in yield is 140 kg/ha. It is significantly different at today's cotton prices, which are much lower.

6. As far as is known, there was no shortage of supply of drip irrigation equipment in any of the mentioned years.
7. See the study by Eckstein (1985), which explains the total acreage of cotton in Israel. The study is based upon micro data.
8. We were in possession of farm data for three out of the seven regions defined.
9. From equation (2), one can see that

$$b = (dP_t/P_t)/\frac{k - P_t}{k}$$

i.e., b is a pure number. It is the ratio between the relative change in the share (or total level) of the adopted technology and the relative distance of the actual share from its saturation level.

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