AN ANALYSIS OF THE DYNAMICS OF TECHNOLOGICAL CHANGE IN AGRICULTURE

Yoav Kislev

Technological improvements are generally conceived in economics as identical increases in productivity for all producers. Reality is more complicated--the diffusion of new technologies is generally associated with differential changes in the scale of production, with entry into promising new lines of activity, and in the exit of producers who cannot keep up with the technological pace and are forced out by deteriorating terms of trade. These are the economic processes that revolutionize the technological and social structure of the rural communities in the process of development. This paper outlines a few assumptions and findings of a theory of structural change associated with technological improvement and illustrates it with developments in the dairy and the poultry industries in Israel.

Theoretical Outline

The theory is presented in terms of the dairy industry. Equation (1) defines the density of cow distribution:

$$(1) \quad n(m,t) = N(m,t)/N^*(t),$$

where:

m ($0 \leq m \leq 1$) is the index of the level of management of the dairy operation;

$N(m,t)$ is the number of cows in year t in herds of management level m;

$N^*(t)$ is the total number of cows in the country; and

$n(m,t)$ ($0 \leq n \leq 1$) is the density of cow distribution by management level.

Let milk yield y be a function of the genetic level of the herd $G(t)$ (both measured in kilograms of milk per cow per year) and management level m:

$$(2) \quad y(m,t) = mG(t).$$

In Israel, all cows are bred by artificial insemination. It is therefore reasonable to assume that the genetic potential of all herds is the same. Cows differ in their genotypes, but these differences wash out at the herd averages. Actual, realized yield differences stem from differences in operator management abilities. The industry's milk supply will, therefore, be:

$$\begin{aligned} (3) \quad Q(t) &= \int_0^1 y(m,t)N(m,t)dm \\ &= G(t)N^*(t)\int_0^1 n(m,t)mdm \\ &= G(t)N^*(t)E(m,t). \end{aligned}$$

$E(m,t)$ is the country average management level (the average weighted by the distribution of cows by management levels.)

Income of the better farmers--those with higher management abilities—will be higher and they will tend to expand their operations; the worst farmers are will lose and have to exit. These developments will be reflected in the factor determining supply expansion, which can be seen by differentiating the second line in equation (3):

$$(4) \quad \dot{Q} = \dot{N}*\int_0^1 G(t)n(m,t)mdm \qquad \text{[expansion effect]}$$

$$+ \; \dot{G}(t)N*\int_0^1 n(m,t)mdm \qquad \text{[genetic effect]}$$

$$+ \; G(t)N*\int_0^1 \dot{n}(m,t)mdm \qquad \text{[concentration effect].}$$

The expansion effect is the increase in supply resulting from a change in the size of the national herd, leaving constant the genetic level and the distribution of cows by management level. The genetic effect is the increase in production due to genetic improvement, holding constant the size and the distribution of the herd. The concentration effect is the increase in milk production due to the shift of the production between operators of different management levels. Empirical estimates of equation (4) are presented in the next section.

Empirical Illustration

Concentration of producers is affected by the terms of trade, defined here as the ratio of the price of the product to the price of feed concentrate. Another factor which is important in determining the dynamics of the industry is the proportion of purchased inputs in total cost; this last proportion is termed the selection stress. The tighter the selection stress, the stronger the financial effect of a change in the terms of trade and the faster the adjustment process to this change. (Government intervention in the credit market--prevalent in Israel--mitigates these effects and modifies the dynamics of the industry.)

Table 1 reports the terms of trade and the selection stress in eggs, broilers, and milk production and their changes between two years—1967 and 1972. Terms of trade stayed constant in egg production, deteriorated substantially in the production of broilers, and changed slightly in the milk industry. The selection stress is the tightest in broilers; eggs are second, and milk is last.

Figures 1, 2 and 3 depict the cumulative distributions of production by efficiency levels for the years 1967 and 1972 (1971 for milk production). Efficiency, a measure of the level of management, has been defined in the dairy industry as annual yield per cow, and for the poultry industry as the number of eggs per tonne of feed (with meat from the egg production flocks converted into eggs at the rate of 1 kilogram of meat equal to 20 eggs), or the numbers of tonnes of meat per tonne of feed in broiler production. These definitions are justified by the assumption of constant marginal product to feed ratios and constant fixed costs.

Figure 1 indicates exit of the lower tail of the distribution between 1967 and 1971 (compare the broken line to the solid line) and improvement in yields in the upper tail. Average yield rose over that period from 5,039 to 5,312 kilograms per cow per annum. Though potential genetic improvement is the same in all herds, it is only the better producers that realize yield increases. The relatively low selection stress and the just slight deterioration in the term of trade (due in part at least to government intervention) permitted many of the weaker dairy operators to stay in the industry—the graphs for 1967 and 1971 coincide in the moderate efficiency zone.

Table 1: The Terms of Trade and the Selection Stress.

Product	Unit	Terms of Trade (Ratio of the price of 1 unit of the product to 1 kilogram of concentrates)		Terms of Trade in 1972[a]	Selection Stress (Ratio of outlays on purchased inputs to value of product)[b]	
		1967	1972		1967	1972
Eggs	egg	.368	.368	1.00	.68	.77
Broilers	kg	6.69	5.75	.86	.77	.80
Milk	kg	1.478	1.433	.97	.67	.68

a 1967 - 1.00
b at the sample mean

Source: Institute of Farm Income Research, Tel Aviv.

Table 2: Components of Supply Increments.

	Milk	Broilers	Eggs
Period	1960-74	1967-75	1967-75
Production increment [a](%)	110	170	36
Partition of increment [b](%)			
Total	100	100	100
Expansion	73.5	88.0	93.3
Concentration	7.4	11.9	4.4
Genetic	9.9		
Residual	9.2	0.1	2.3

Source: Kislev and Rabiner, 1979, and Michal Reiss, Master Thesis, in preparation.

a End of period minus first year over first year's level.
b See equation (4).

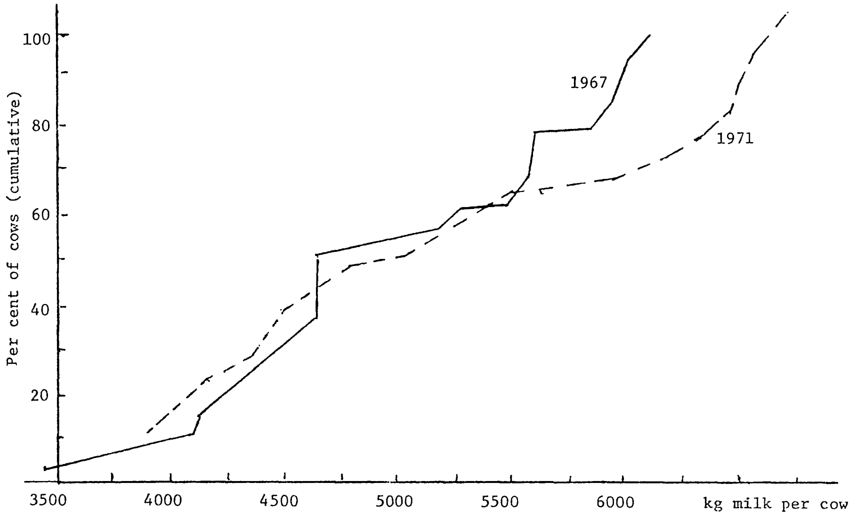

Figure 1: Distribution of Milk Production.

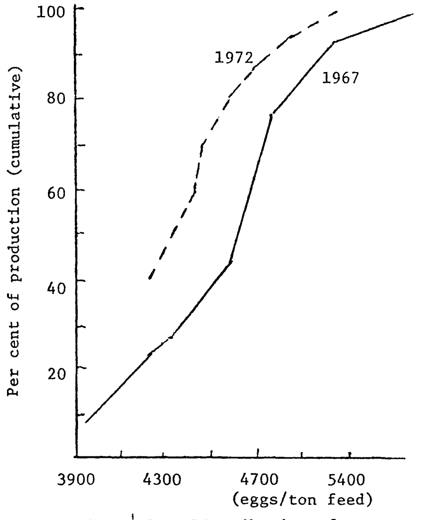

Figure 2: Distribution of Egg production.

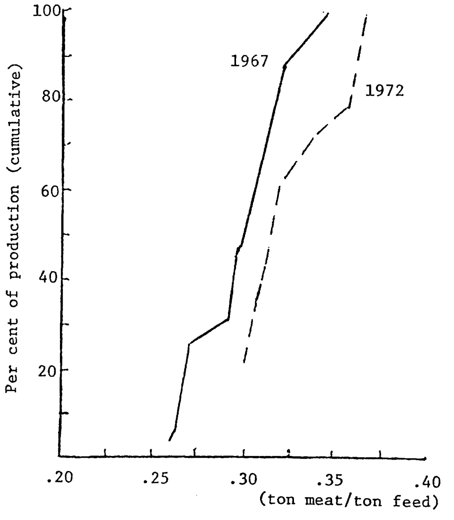

Figure 3: Distribution of Broiler Production.

The picture for the poultry industry (figures 2 and 3) is more complex and more interesting. Average productivity in the country increased in broiler production and deteriorated in egg production--the last from 4,608 to 4,488 eggs per tonne between 1967 and 1972. Examination of the graphs leads to the impression that both high and low efficiency producers left egg production and only the mediocre stayed. There was a general increase in productivity in this product. Here it also seems as if the weaker producers either exited or improved the efficency of their operation. Faster technological changes may have attracted the more efficient operators into broiler production--those who can hope to reap an appropriate rent for their abilities to be technological pioneers. These producers may have left egg production. On the other hand, the technological stagnation in egg production made this line of activity comparatively simple. Everyone can produce eggs, including producers with relatively low alternative costs. This permits the sector to operate even at low income levels, but the efficient operators--those with better alternatives--leave.

Concentration of production in the hands of the more efficient operators contributes to increased productivity. Table 2 attempts to partition supply increments in the three lines of production to the effects of equation (4). Efficiency is defined in terms of yield per cow or production per tonne of feed as in figures 1-3. The calculation will be illustrated with milk production. The national milk producing herd is divided (and this division was employed in table 2) into registered and nonregistered herds. The registered dairies are generally larger (mostly in Kibbutzim), have higher yields, and their yields—as a group--increased through time. The nonregistered herds are mostly in relatively small family operated dairies with low and stagnant yields. The share of the registered dairies grew over the last two decades, from 30 to 50 percent of the national herd (Kislev, Meisels, and Amir). This growth is the measure of concentration used in table 2.

Total milk supply in 1974 was 210 perent higher than in 1960, at the beginning of the period considered. Of this supply increment (taken as 100), 73.5 percent was due to the mere increase in the number of cows. The concentration effect was calculated as the differential growth of the registered herd times the yield differences between the registered and the nonregistered herds. The estimate is that this effect is responsible for 7.4 percent of the supply increment. The genetic effect was calculated under the assumption that the genetic process was taken from breeders' estimates prepared in progenity tests. The residual, the complement to 100 percent, can be attributed to general technological changes: improvements in husbandry, veterinary practices, and the like. The calculation can be summarized in rough terms as indicating that 30 percent of milk supply increment over the 15-year period 1960-74 was due to productivity improvements. Of these, a third was due to each of the productivity components: concentration effect, genetic effect, and more general technical change.

In the poultry industry, the expansion effect was taken as the increase in feed input times the base year product to feed ratio. Unlike the situation in milk production, estimates of genetic progress in the poultry industry have not yet been prepared. The residuals in the broiler and egg columns include, therefore, the genetic effects. These estimates of the residual technical change indicate, if we accept the method used, that there could not have been substantial genetic progress in broiler production. This finding is somewhat puzzling and will probably not be accepted by breeders who claim to have introduced several superior types during the period covered by the analysis. On the other hand, many changes in structure and equipment were introduced—mostly by the better producers—while expanding the scale of operation (part of the concentration process), and it could be that the efficiency gains resulting from these changes can be attributed to the genetics of the new lines. A better answer to this puzzle can be expected to come out of a detailed study of poultry breeding in Israel, now underway.

The empirical findings illustrate, I trust, the significance of the dynamic perspective suggested by the theoretical assumptions of the paper. The work in this area is far from completion and several extensions are worth mentioning: (a) the explict analysis of a multiproduct farming firm; (b) explicit recognition of government's role in shaping the dynamic processes in agriculture; and (c) incorporation of the effects of omitted variables, such as alternative income opportunities outside agriculture.

Reference

Kislev , Y.; Meisels, M.; Amir, S. (forthcoming) The dairy industry of Israel, in Animal Production Systems (edited by B. L. Nestel). Amsterdam, The Netherlands; Elsevier Scientific Publishing Co.