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Efficiency Implications of the Dairy Farm Policy Reform in Israel

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Abstract

The dairy branch is one of the most regulated branches of agriculture in Israel. The dairy farm policy reform, initiated in 1999, enabled Israeli dairy farmers, for the first time, to trade production quotas, and encouraged capital investments through financial incentives. The consequence was a rapid exit of producers, an increase in the size of existing producers either through purchasing quotas or through mergers, and an improvement of production efficiency and milk quality. This paper employs Data Envelopment Analysis (DEA) to estimate the changes in production efficiency, using data from the dairy farm profitability surveys of 2003, 2005, 2007 and 2009. We found that dairy farms have become larger and more efficient during the reform period. Results also suggest that scale efficiency has increased over time for small family farms. Meta Production Frontier analysis showed that relatively small Moshav farms were able to catch up with the technology used by the most efficient farms in the industry, and this may explain the gradual increase in their scale efficiency. Larger Moshav farms, on the other hand, were not able to catch up with the technology used by the most efficient farms. Continued policies aimed at further concentration of production in fewer and larger farms are not necessarily the most effective approach to increase dairy farm efficiency. Efforts should focus on helping less efficient farmers to utilize the best available production methods and adopt more efficient production techniques.

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Introduction

The dairy industry is one of the most stable and profitable branches in Israeli agriculture. As of the year 2013, the value of raw milk comprised roughly 11.5% of the value of agricultural production. Dairy products comprise a little over 1% of GDP in Israel and about 12.6% of the average monthly household expenditure, and per-capita dairy consumption in Israel is among the highest in the world (figure 1). Milk production is performed on two types of agricultural communities: Kibbutz collectives operate large dairy farms while farmers in Moshav cooperative villages operate smaller family units. Production is regulated by a quota system in order to maintain this diversified production structure. Raw milk prices are determined on a cost-plus basis in order to protect the small producers from being exploited by the large dairy processing companies which enjoy monopsonistic power. Production is also protected from international competition by a set of import tariffs and quotas. Obviously, this regime interferes with market forces and creates inefficiencies. It is also subject to international pressures as a result of international trade agreements. These factors, in addition to the need to renew dairy farm infrastructure in order to meet environmental standards, have led to a major reform, which was officially launched in 1999 (Kimhi and Rubin 2006).

The reform allowed dairy farmers to sell their production quota to other dairy farmers, under certain conditions, so that the latter could increase their volume of production. Another possibility was for dairy farmers to form partnerships and merge their farms. The incentives provided by the reform were of the carrot and stick type. The carrot was that subsidized loans and grants were provided to farmers who bought quota or formed partnerships, in order to rebuild their farms so that they meet environmental standards. The stick was that it was announced that administratively-determined milk prices will decrease by 2% annually, so that inefficient farmers could not expect to continue behaving in a business-as-usual manner. One important constraint embedded in the reform rules is that quota could not be transferred between the Kibbutz and Moshav sectors. The reason is the fear that the relatively smaller family dairy farms in the Moshav will disappear entirely if the larger and presumably more efficient Kibbutz farms will be allowed to acquire their production quotas.

The outcomes of the reform were quantitatively impressive. The number of dairy farms decreased from 1407 in 1999 to 837 in 2014 (figure 2). Average production per farm increased by 82%, and the quality of milk increased as well. Protein and fat contents increased by 6.3% and 11.2%, respectively, and Somatic Cell Count (a measure of bacterial contamination) decreased by approximately 40%. These outcomes are not unique to Israel, as the milk production quota regimes are gradually being abandoned in many advanced countries. For example, Kleinhanßet al. (2010) report a significant decline in the number of milk producers in Germany. Oskam and Speijers (1992) claim that enabling quota trade benefits the more efficient producers and promotes higher production efficiency. Réquillart et al. (2008) claim that abolishing the European quota system will lead to lower milk prices, higher production, lower farm profitability and higher consumer surpluses. Sauer (2010) shows that deregulating the quota trading system in Denmark has led to efficiency gains.

The purpose of this article is to examine the economic outcomes of the reform. In particular, we estimate the production efficiency of dairy farms and study its trend over the reform period. We also analyze the changes in efficiency by the different farm sectors

(Kibbutz and Moshav). We use data from the 2003, 2005, 2007 and 2009 waves of the bi-annual dairy farm profitability survey. The pooled data set includes 506 farm-year observations. Economic, allocative and technical efficiencies were estimated using Data Envelopment Analysis (DEA). That methodology is also used to analyze scale efficiency and, using the Meta Production Frontier approach, to examine technology gaps between sub-sectors in the sample, in particular between Kibbutz and Moshav farms.

We start by providing a general overview of the history of agriculture in modern-time Israel and its structural development. Then we describe the methodologies used to analyze efficiency. The data used for the analyses and the empirical results are presented afterwards. The paper ends with a summary and some policy implications.

Historical and institutional background

Agriculture was one of the most important foundations on which the state of Israel was established. Since the end of the 19th century, Jewish settlers in Israel saw agriculture as a channel through which the link between the Jewish people and their ancient homeland can be re-established. Cooperation has been the key to the success of settlement and agricultural production. The two dominating types of cooperative settlements have been the Kibbutz and the Moshav (Kislev 1992). The Kibbutz was a commune in which each member produced according to his ability and consumed according to his needs. The Moshav was a semi-cooperative village made of individual family farms, in which certain activities such as purchasing, marketing, and financing were handled jointly in order to exploit economies of scale in these activities (Haruvi and Kislev 1984; Schwartz 1999; Sofer 2001). A third type of cooperative settlement, Moshav Shitufi, was a compromise between Kibbutz and Moshav: production was handled collectively while consumption was handled individually. Ideologically, all three types of cooperative settlements explicitly highlighted farming as a way of life and not only as a way of making a living.

Economically, agriculture constituted a major fraction of national income and exports in particular for many years. Socially, the cooperative agricultural sector provided a generation of political, cultural and military leaders. After Israel declared its independence and masses of immigrants started pouring in, food security became one of the top priorities of the government. Many Moshav villages were established in the early 1950s, populated by immigrants, mostly in remote areas. The new settlers were provided with infrastructure and professional guidance in order to allow them to make a living off agriculture. Agricultural research was also promoted and financed by the government, and the resulting technological progress was remarkable.

In the 1970s, terms of trade of agriculture were already worsening, but the prosperity of agriculture continued thanks to the opening of export markets for fruits, vegetables and flowers. However, the inevitable decline of farming, experienced by virtually all countries during the development process, was around the corner. The reliance on exports made farmers more vulnerable to world price fluctuations and macroeconomic conditions. The unstable economic environment brought about by the high inflation in the late 1970s and early 1980s made farm income even more volatile. The large debt due to the capital investments could not be serviced adequately (Kislev 1993). The development of non-agricultural production and service industries provided an alternative source of income, especially for the high-ability farmers. Out-migration from agriculture accelerated through two complementary channels. The first channel was by farmers selling their farms to urban families seeking rural-style residence (Kimhi and Bollman 1999). The second channel was by continuing farmers seeking to supplement their income by engaging in non-agricultural activities (Kimhi 2000;Sofer 2001). These included on-farm small businesses as well as off-farm businesses and jobs, located in part in the surrounding rural area and in part in nearby urban centers.

The farm debt crisis that followed the economy-wide 1985 stabilization plan was a major accelerator of this process. Many farms became practically delinquent due to the high real interest rates and could not serve as a source of income anymore. Many cooperatives collapsed, leaving their members without the safety net and support system to which they were used for decades (Kislev et al. 1991; Schwartz 1999). Farmers were increasingly shifting to alternative income-generating activities, but at the same time, some of the more productive farms were able to acquire more farm resources and expand production. Today, in most Moshav villages only a handful of families are living off agriculture (Kimhi 2009). The Kibbutz is currently in the midst of a privatization process (Kislev 2015), although this has little impact on its agricultural activity.

Methodology

The measurement of farm efficiency is based on the assumption that farmers use as little inputs as possible in order to produce a given quantity of output (Farrell 1957). Assuming a constant-returns-to-scale technology, so that each farm chooses a given ratio of inputs, a farm that uses more inputs under a given technology than another farm is considered less technically efficient. In figure 3, a farm that produces at point A is less efficient than the farm that produces at point B, and if point B is the most efficient, the technical efficiency of farm A is measured as OB/OA. The curve SS includes all efficient input combinations that enable to produce a certain quantity of output. If the slope of PP is equal to the input price ratio, cost minimization dictates producing at point E. The cost of producing at point E is equal to the cost of point C, but output at point C is lower. Hence, the input quantity ratio is not the most efficient one, and the allocative efficiency of point A is OC/OB. The overall economic efficiency is the product of technical efficiency and allocative efficiency, and is equal to OC/OA.

The econometric literature offers two alternative empirical models to estimate production efficiency. Stochastic Frontier Analysis (SFA) uses a statistical model to separate between a permanent efficiency gap and random deviations from maximum efficiency (Aigner et al. 1977). Data Envelopment Analysis (DEA), on the other hand, is a nonparametric deterministic model that uses programming methods (Charnes et al. 1978). Both models provide an efficiency estimate for each farm in the sample (Jondrow et al. 1982). While DEA methodology was mostly challenged for its deterministic nature and for neglecting the treatment of measurement errors, the stochastic frontier approach had been mostly criticized for a-priori functional form assumptions on production technology and error distributions, but was also challenged due to heteroskedasticity arising mostly in production frontier estimation.[1] We use the DEA methodology in this paper due to its less restrictive assumptions. We proceed with an elaborated description of this methodology.

[1] For further discussion on drawbacks of each of the methodologies and the advances made since they were initially suggested see for example Parmeter and Kumbhakar (2014) for SFA, and Simar and Wilson (2011) for DEA.

Using a linear programming method, Charneset al. (1978) defined the constant returns to scale (CRS) efficient frontier as a piecewise linear unification of *J* efficient sample cases in the input-output space. Their definition requires those efficient cases to satisfy the condition $\theta_i = 1$, where θ_i is the optimal output-input mixture level derived from problem (1) solved for each firm i of the N firms in the sample.[2]

$$
\begin{aligned}
&\min_{\theta,\lambda} \theta, \\
&s.t. \\
(1)\quad &-y_i + Y\lambda \geq 0 \\
&\theta x_i - X\lambda \geq 0 \\
&\lambda \geq 0
\end{aligned}
$$

In (1), $x_i = (x_1, x_2, \ldots, x_K)$ and $y_i = (y_1, y_2, \ldots, y_M)$ are quantity vectors of inputs and outputs for the i^{th} firm, respectively. Y and X are matrices of $M \times N$ output levels and $K \times N$ input levels, respectively, representing the sample data. λ is a $N \times 1$ vector of constants λ_i. Inefficiency of each firm i in the sample is then calculated according to its distance from the efficient frontier, where smaller θ_i indicates a less efficient firm.

For further clarification, figure 4 illustrates a simple representation of problem (1), describing 3 firms producing a single output Y using two inputs X_1 and X_2 on an input plane where the axes represent amounts of input usage per one unit of output. A and B are efficient firms, and θ, the technical efficiency for the inefficient firm C, is

[2] We borrow our model description notation from (Coelli 1995).

measured with respect to the weighted linear combination of the inputs and output mixtures of firms A and B.

Relaxing the constant returns to scale assumption, Bankeret al. (1984), have introduced the convexity constraint $N1'\lambda = 1$ into problem (1), where $N1$ is a $N \times 1$ vector of ones. Solving the modified problem (2) generates the variable return to scale (VRS) efficiency frontier.

$$
(2) \quad \begin{aligned}
&\min_{\theta,\lambda} \theta, \\
&s.t. \\
&-y_i + Y\lambda \geq 0 \\
&\theta x_i - X\lambda \geq 0 \\
&N1'\lambda = 1 \\
&\lambda \geq 0
\end{aligned}
$$

This additional constraint tightens the feasible solution space, and results in technical efficiency estimates that are lower or equal to the ones derived from problem (1). The ratio of these two estimates (hereafter θ_i^{CRS} and θ_i^{VRS} for problems (1) and (2), respectively), is defined as the scale efficiency of the i^{th} firm (Banker 1984; Banker, et al., 1984). The scale efficiency score indicates by how much the input requirement can be decreased while keeping output constant, just by increasing firm size. To identify whether a firm is operating under a decreasing, constant or increasing return to scale technology, Banker et al. (1984) further defined the Non-increasing returns to scale (NIRS) efficient frontier as derived from the solution to problem (3).

$$
(3)\quad \begin{aligned}
&\min_{\theta,\lambda} \theta, \\
&s.t. \\
&-y_i + Y\lambda \geq 0 \\
&\theta x_i - X\lambda \geq 0 \\
&N1'\lambda \leq 1 \\
&\lambda \geq 0
\end{aligned}
$$

Using the above definitions, a firm i is characterized by increasing returns to scale if $\left\{\forall\, \theta_i^{NIRS} \neq 1 : \theta_i^{NIRS} = \theta_i^{CRS}\right\}$ and by decreasing returns to scale if $\left\{\forall\, \theta_i^{NIRS} \neq 1 : \theta_i^{NIRS} \neq \theta_i^{CRS}\right\}$. This classification is illustrated in figure 5 using a primitive example of a single input (X)-single output (Y) case.

Points E and A represent two firms operating in the industry, producing output levels Y_E and Y_A, using input levels of X_E and X_A, respectively. Points E' and A' are the corresponding efficient input-output mixtures proportional to the levels used by firms E and A, respectively, under a constant returns to scale assumption. In other words, the hypothesized firms E' and A' produce the same levels of outputs as the actual firms E and A, respectively, using only a fraction of $X_{E'}/X_E$ and $X_{A'}/X_A$ of inputs. Similarly, points C and B represent efficient mixtures under the variable returns to scale assumption. As can be observed in figure 5, each firm's efficiency score (θ_i^{CRS}) can be easily decomposed into two multiplicative efficient components, θ_i^{VRS} and scale efficiency ingredients, as in equations (4) and (5).

(4) $X_{E'}/X_E = (X_{E'}/X_C)*(X_C/X_E)$

(5) $X_{A'}/X_A = (X_{A'}/X_B)*(X_B/X_A)$

Following the definitions and illustration above, one can observe that the equality $\theta_i^{NIRS} = \theta_i^{CRS}$ holds for firm A, and therefore it is characterized by an increasing returns-to-scale production technology. The same equality does not hold for firm E, so we can conclude that it operates under decreasing returns to scale technology.

Finally, solving the cost minimization problem in (6), as suggested by Ferrier and Lovell (1990), produces the efficient cost frontier, and enables to derive the economic efficiency score.

$$
(6) \quad \begin{aligned}
&\min_{x_i,\lambda} w_i' x_i, \\
&s.t. \\
&-y_i + Y\lambda \geq 0 \\
&x_i - X\lambda \geq 0 \\
&N1'\lambda = 1 \\
&\lambda \geq 0
\end{aligned}
$$

In (6), w_i is the $K \times 1$ input price vector facing the i^{th} firm, and x_i^* is the cost minimizing optimal input vector. Using the results derived from problems (1) through (6) enables the full decomposition of Farrell's original efficiency definitions, i.e. for each firm i in a sample of N firms, one can identify the economic, allocative, technical, and scale efficiencies according to equations (7)-(10) respectively.

$$
(7) \qquad EE_i = \frac{w_i' x_i^*}{w_i' x_i} \text{ (economic efficiency)}
$$

(8) $AE_i = \frac{TE_i}{EE_i}$ (allocative efficiency)

(9) $TE_i = \theta_i^{VRS}$ (technical efficiency)

(10) $SE_i = \frac{\theta_i^{CRS}}{\theta_i^{VRS}}$ (scale efficiency)

Data

As mentioned above, the pooled dataset used for our analysis includes 506 observations sampled in four rounds of the bi-annual dairy farm profitability survey over the period of the dairy production industry reform, and are distributed almost evenly between the four sample years (2003, 2005, 2007, 2009). The farm profitability survey is a representative sample of the industry, where sampling weights are assigned to each observation and account for the weight of similar farms` share in population and production. All the analyses reported in this paper are based on these weights. Descriptive statistics of the variables used for the calculation of efficiency scores is reported in Table 1. We assume that the farms produce a single output - total milk - measured in liters per year.[3] The major inputs used for milk production are number of cows, feed, labor and capital.[4] All inputs are measured in physical units, allowing the interpretation of efficiency scores as potential cost savings. Input prices are calculated as the ratio between the reported farm expenses for

[3] The reasons we use total milk production and ignore factors such as milk quality, fat and protein contents, as well as meat production are described in detail in Appendix A.

[4] To maintain uniform definitions for all farms, and because information on the variation in feeding methods is not available, all feed ingredients used on the farm are converted to dry matter units (Bernard, 2007) using official normative tables of the Israeli Dairy Board (IDB). Similarly, due to insufficient information on differences in buildings and equipment, capital input is measured by the cowshed area which is highly correlated with the value of total assets used in the production process. Also, dairy farms in Israel do not practice grazing in the production process, and therefore land is an irrelevant input.

each input and the number of physical units used, where all monetary measures are expressed in 2003 prices.[5]

Table 2 summarizes population and production shares of each sector (Kibbutz and Moshav) by farm size and by year. In 2003, while Moshav farms accounted for 80% of the dairy farms, they accounted for only 40% of milk production. This is because three quarters of the milk produced by Moshav farms was produced on farms with under 200 cows, while almost all of the milk produced by Kibbutz farms was produced on farms with more than 200 cows. While the shares of the sectors did not change dramatically over the sample period, the size distributions within each sector changed quite a bit, as relatively larger farms became more dominant over time. The timing of changes is different, though, with the size distribution of Kibbutz farms changing earlier, while that of Moshav farms changing mostly in the last period.

Empirical results

The empirical analysis is conducted separately for Kibbutz and Moshav farms, due to the fact that the two sectors exhibit wide differences in size, capital structure, self and hired labor mixture, and other attributes. Table 3 shows the average efficiency scores by sector throughout the entire sample period. t-statistics for mean equality test are reported at the bottom of the table. We find that average economic, allocative, technical, and scale efficiencies are higher in Kibbutz farms than in Moshav farms for every year in the sample, and the differences are statistically significant at the 1% level for most cases, with the

[5] The only exception is the price associated with the number of lactating cows, which is a weighted value of the herd size at the beginning and the end of the year, computed according the official normative tables of the IDB.

exception of the difference in allocative efficiency in 2005. The two subsectors also differ in the time trends of the different efficiency components. Among Moshav farms, scale efficiency has increased gradually, while technical and allocative efficiency increased only between the first two sample years and remained stable afterwards. Kibbutz farms were scale efficient throughout the sample period, and their allocative efficiency scores were also close to maximal and did not change. As in the case of Moshav farms, some technical efficiency improvements are observed only between the first two sample periods.

Since scale efficiency is the major source of efficiency improvement at least for Moshav farms, figure 6 shows the mean scale efficiency by sector and herd size. It is evident that farms with 200 cows or more are scale efficient, while for smaller farms, scale efficiency increases with the number of cows, excluding the smallest Kibbutz farms in 2003, which either exited or expanded their size in later years. This is another indication for the existence of economies of scale in milk production, at least for farms with up to 200 cows, which are all Moshav farms. Interestingly, for that range of farm sizes, scale efficiency has increased over time, indicating either a positive selectivity leading less efficient farms to exit, or technological improvements that are most effective on small dairy farms.[6]

The possibility that technological improvements affected the two sectors differentially is worth further inspection. To this end we employ the Meta Production Frontier approach (Hayami 1969; Hayami and Ruttan 1970, 1971), which relies on measuring each farm's technical efficiency with regards to the entire sample population

[6] It could also be that the size distribution of farms within each size category has changed. In order to refute this explanation, we have estimated a linear regression of scale efficiency in Moshav farms on year dummies and three alternative measures of farm size (milk quota, number of cows and quantity of milk). Even after controlling for size, the positive time trend in scale efficiency was statistically significant.

frontier (i.e. the Meta Frontier), and with regards to its own subpopulation frontier, in order to calculate for each farm i the MTR (Meta Technology Ratio) score as defined in equation (11).

$$(11) \qquad MTR_i = \frac{TE_i}{TE_i^k}$$

In (11), k indicates the relevant subpopulation. The MTR score has been most commonly used to assess technology gaps between countries (O'Donnell et al., 2008; Moreira and Bravo-Ureta 2010; Latruffe et al., 2012), although some applications have also investigated intra-state group affiliation differences. For example, Lansink et al. (2002) examined efficiency gaps between conventional and organic farms in Finland. The MTR score also serves as a measure of the distance between each subpopulation's most efficient farms and their counterparts in the entire population. We first compute the MTR scores for each sample year separately in order to examine the magnitude of technological improvements throughout the reform period. Kernel density plots of the MTR scores of the entire industry, by year, are shown in figure 7. Average scores for each year are reported in Table 4, along with an ANOVA report to indicate whether the differences are statistically significant.

It is evident from both figure 7 and table 4 that significant technological improvements had occurred during the reform period. MTR scores in earlier years are more dispersed and are distributed around lower means (figure 7), and according to Table 4, these differences are also statistically significant. This indicates that distance of each farm from the Meta Frontier declines over time, and so we can conclude that the efficiency trends reported above are driven, at least to some extent, by technological improvements, although it is not the only factor.[7] Due to the observed differences in trends between the two sectors we choose to further explore the similarity of these effects on Kibbutz and Moshav farms separately. Our underlying assumption is that technology is available indistinctively for all farms, therefore a difference in MTR scores in our context should suggest some level of asymmetry in transferability of efficient production methods. We compute the MTR scores for all farms in our sample, dividing them into Kibbutz and Moshav subsectors. Kernel density plots of the MTR scores are shown in figure 8. Average scores for each size group by sector and year are reported in figure 9.

It is evident from figures 8 and 9 that the MTR score distributions in the two subsectors are substantially different. Kibbutz farms have higher MTR scores throughout the reform period. Moreover, most Kibbutz farms are concentrated around the highest possible MTR score, and this concentration increases over time (figure 8). The MTR scores of Moshav farms are much more dispersed and remain so over time. Combining this result with the earlier observation that the largest Moshav farms do not exhibit scale inefficiencies while smaller Moshav farms do, it is likely that the dairy farm industry is indeed suffering from some degree of asymmetric transferability of production methods, where the larger dairy farmers in the Moshav sector do not succeed in acquiring and utilizing the most efficient methods used by their counterparts in the Kibbutz sector. As can be observed in figure 9, the larger Moshav farms indeed have the lowest average MTR scores, which means they are located the furthest away from the most efficient

[7] We deduct the effect of technological improvements from the scale efficiency scores of each farm using either the average MTR score for each year, or each farm's MTR score as calculated with respect to its own year frontier. In both approaches, the trend in scale efficiency for small Moshav farms remains, although it becomes less gradual (see Appendix B).

farmers in the industry. These results therefore support our previous suggestion that the increasing time trends in scale efficiency exhibited by relatively small Moshav farms might be correlated with farmers' adaptation to their changing environment through technology adoption, or that small Moshav farmers succeed in utilizing modern and more efficient production methods, as opposed to larger farmers in the same sector.[8]

However, there exists one other possible explanation for the observed scale efficiency trend. The fact that the number of farms in the industry decreases over the reform period indicates that it is perhaps the extensive margin, rather than the intensive margin, that is driving our results. In other words, it is likely that those leaving the industry over time are the relatively inefficient producers. We rebut this possibility by identifying a similar scale efficiency trend for a subgroup of farms in our sample which were observed in more than one year (Appendix C). This implies that at least part of the increase in scale efficiency is attributed to technology improvements.

Summary and policy implications

In this paper, we have analyzed efficiency changes among dairy farms in Israel during a period of a major structural reform that was administered in the sector and allowed dairy farmers, for the first time, to either sell their production quota for a decent price or acquire additional quota. We differentiated between Kibbutz collective farms and Moshav family farms because they are very different in size and because quota transactions between these two subsectors are prohibited. We found that the dairy industry in the later years of the

[8] It should be noted that MTR scores increase over time even among the relatively large Moshav farms, but the increase was still insufficient to catch up with the MTR scores of the smaller farms.

reform is composed of larger and more efficient farms compared to the earlier years. Despite that, efficiency is still quite variable, and there is scope for further improvements.

We also found that scale efficiency has improved over time, mostly among the relatively small Moshav farms. To examine the suggestion that technological improvements are responsible for the increase in scale efficiency rather than selective exit of farms from the industry, we compared MTR scores that measure the relative efficiency with respect to a subsector compared to the industry as a whole. The results imply that the relatively small Moshav farms were able to catch up with the technology used by the most efficient farms in the industry, and this may explain the gradual increase in their scale efficiency. Larger Moshav farms, on the other hand, were not able to catch up with the technology used by the most efficient farms, although they did show efficiency improvements over the years. The difference between the adaptability of the larger and smaller Moshav farms may be due to management practices. Perhaps the increase in farm size as a result of the reform was too fast for the average individual dairy farmer to handle.

We conclude that continued policies aimed at further concentration of production in fewer and larger farms is not necessarily the most effective approach to increase dairy farm efficiency. In addition to that, efforts should be made to help less efficient farmers to utilize the best available production methods and adopt more efficient production techniques.[9]

[9] A similar conclusion was found in a study of the dairy farm industry in Ontario, Canada (Weersink et al., 1990), which exhibits some similarities to the Israeli dairy farm industry, in terms of its quota regime and quota mobility restrictions.

References

Aigner, D., Lovell, C. K., Schmidt, P., 1977. Formulation and Estimation of Stochastic Frontier Production Function Models. J. Econometrics 6, 21–37.

Banker, Rajiv D., 1984. Estimating Most Productive Scale Size Using Data Envelopment Analysis. Europ. J. Op. Res. 17(1):35–44.

Banker, R.D., Charnes, A., Cooper, W.W., 1984. Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis. Man. Sci. 30, 1078-1092.

Bernard, J. K., 2007. Measuring the Dry Matter Content of Feeds. UGA Extension Publications – SB 58, Athens, Georgia. Accessed July 2017, available at http://extension.uga.edu/publications.html

Charnes, A., Cooper, W.W., Rhodes, E., 1978. Measuring the efficiency of decision making units. Europ. J. Op. Res. 2, 429-444.

Coelli, T. J., 1995. Recent Developments in Frontier Modeling and Efficiency Measurement. Aus. J. Ag. Econ. 39(3):219–45.

Farrell, M.J., 1957. The Measurement of Economic Efficiency. J. Royal Stat. Soc. CXX, Part 3, 253-290.

Ferrier, G.D., Lovell, C.A.K, 1990. Measuring Cost Efficiency in Banking: Econometric and Linear Programming Evidence. J. Econometrics 46, 229–245.

Haruvi, N., Kislev, Y., 1984. Cooperation in the Moshav. J. Compar. Econ. 8, 54-73.

Hayami, Y., 1969. Sources of Agricultural Productivity Gap among Selected Countries. Am. J. Ag. Econ. 51(3), 564–575.

Hayami, Y., Ruttan, V.W., 1970. Agricultural Productivity Differences among Countries. Am. Econ. Rev. 60(5), 895–911.

Hayami, Y., Ruttan, V.W., 1971. *Agricultural Development: An International Perspective*. Baltimore: John Hopkins University Press.

Hemme T., 2006. IFCN Dairy Report 2006. International Farm Comparison Network, IFCN Dairy Research Center, Kiel, Germany. Accessed July 2017, available at http://ifcndairy.org/ifcn-products-services/dairy-report/

Jondrow, J, Lovell, C.A.K., Materov, Ivan S., Schmidt, P., 1982. On the Estimation of Technical Inefficiency in the Stochastic Frontier Production Function Model. J. Econometrics 19, 1982, 233-238.

Kimhi, A., 2000. Is Part-Time Farming Really a Step in the Way Out of Agriculture? Am. J. Ag. Econ. 82, 38-48.

Kimhi, A., 2009. Heterogeneity, Specialization and Social Cohesion in Israeli Moshav Cooperatives. J. Rural Coop. 37, 124-136.

Kimhi, A., Bollman. R., 1999. Family Farm Dynamics in Canada and Israel: The Case of Farm Exits. Agri. Econ. 21, 69-79.

Kimhi, A., Rubin, O.D., 2006. Assessing the Response of Farm Households to Dairy Policy Reform in Israel. Discussion Paper No. 15.06, Rehovot: The Center for Agricultural Economic Research.

Kislev, Y., 1992. Family Farms, Cooperatives and Collectives. In G.H. Peters and B.F. Stanton, eds., *Sustainable Agricultural Development: The Role of International Cooperation*, 520-530. Aldershot, England: Dartmouth.

Kislev, Y., 1993. Experience with Collective Action and Cooperation in Agriculture in Israel. In C. Csaki and Y. Kislev, eds., *Agricultural Cooperatives in Transition*, 269-290. Boulder, Colorado: Westview Press,

Kislev, Y., 2015. Agricultural Cooperatives in Israel: Past and Present. In A. Kimhi and Z. Lerman, eds., *Agricultural Transition in Post-Soviet Europe and Central Asia after 25 Years: International Workshop in honor of Professor Zvi Lerman*, Studies on the Agricultural and Food Sector in Transition Economies No. 79, Leibniz Institute of Agricultural Development in Transition Economies, pp. 175-191.

Kislev, Y., Lerman, Z., Zusman, P., 1991. Recent Experience with Cooperative Farm Credit in Israel. Econ. Develop. Cult. Change 39, 773-789.

Kleinhanß, W., Offermann, F., Ehrmann. M., 2010. Evaluation of the Impact of Milk Quota – Case study Germany. Working paper 07/2010 at the Institute of Farm Economics. Braunschweig, Germany: Johann Heinrich von Thünen-Institute.

Lansink, A.O., Kyosti, P., Backman, S., 2002. Efficiency and Productivity of Conventional and Organic Farms in Finland 1994–1997. Europ. Rev. Ag. Econ. 29(1), 51–65.

Latruffe, L., Fogarasi, J., Desjeux, Y., 2012. Efficiency, Productivity and Technology Comparison for Farms in Central and Western Europe: The Case of Field Crop and Dairy Farming in Hungary and France. Econ. Sys. 36(2), 264–278.

Moreira, V.H., Bravo-Ureta, B.E., 2010. Technical Efficiency and Metatechnology Ratios for Dairy Farms in Three Southern Cone Countries: A Stochastic Meta-Frontier Model. J. Prod. Anal. 33(1), 33-45.

O'Donnell, C.J., Prasada Rao, D.S., Battese, G.E., 2008. Metafrontier Frameworks for the Study of Firm-Level Efficiencies and Technology Ratios. Empi. Econ. 34(2), 231–255.

Oskam, A.J., Speijers, D.P., 1992. Quota Mobility and Quota Values: Influence on the Structural Development of Dairy Farming. Food Policy 17, 41-52.

Parmeter, C.F., Kumbhakar, S.C., 2014. Efficiency Analysis: A Primer on Recent Advances. Found. Trend. Econometrics 7(3-4), 191–385.

Réquillart, V., Bouamra-Mechmache, Z., Jongeneel, R., Penel, C., 2008. Economic Analysis of the Effects of the Expiry of the EU Milk Quota System. Final Report prepared for the European Commission Project Contract 30-C3-0144181/00-30. Institut d'Economie Industrielle (IDEI), Université Toulouse, France.

Sauer J., 2010. Deregulation and Dairy Production Systems: a Bayesian Distance Function Approach. J. Prod. Anal. 34, 213-237.

Schukken, Y.H., Wilson, D.J., Welcome, F., Garrison-Tikofsky, L., Gonzalez, R.N., 2003. Monitoring udder health and milk quality using somatic cell counts. Vet. Res. 34(5), 579-596.

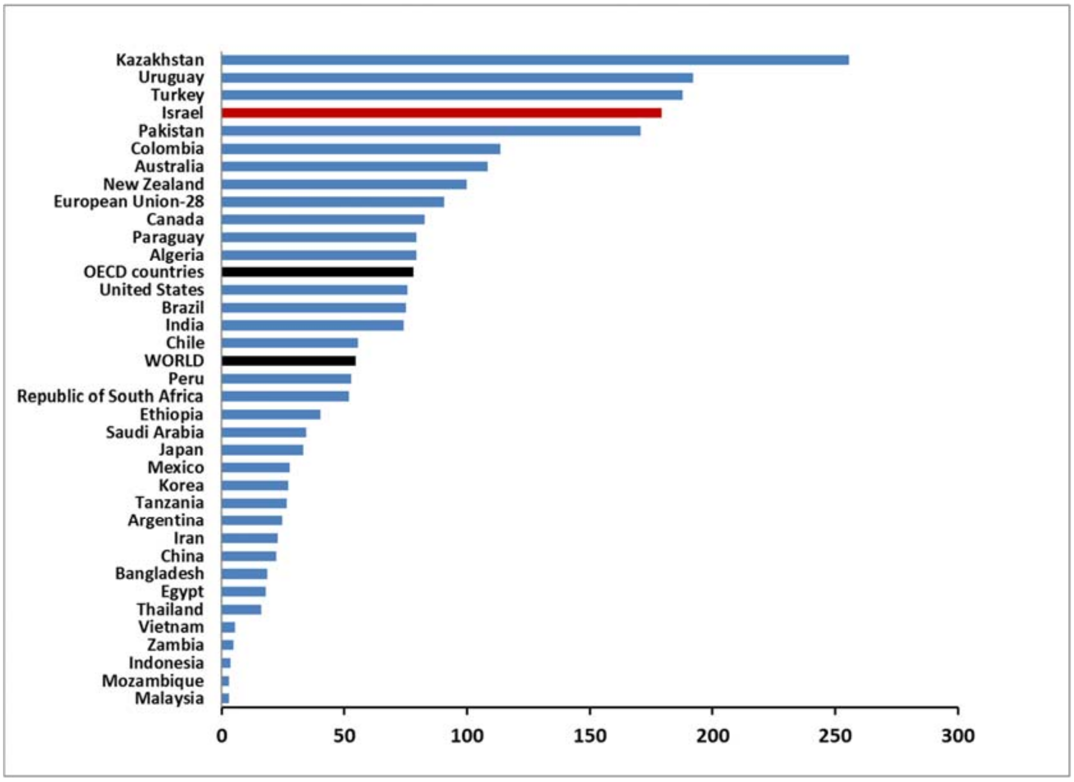
Schwartz, M., 1999. The Rise and Decline of the Israeli Moshav Cooperative: A Historical Overview. J. Rural Coop. 27, 129-166.

Simar, L., Wilson, P.W., 2011. Estimation and Inference in Nonparametric Frontier Models: Recent Developments and Perspectives. Found. Trend. Econometrics 5(3-4), 183–337.

Sofer, M., 2001. Pluriactivity in the Moshav: Family Farming in Israel. J. Rural Stud. 17, 363-375.

Weersink, A., Turvey, C.G. , Abdulahi G., 1990. Decomposition Measures of Technical Efficiency for Ontario Dairy Farms. Can. J. Ag. Econ. 38, 439–456.

Figure 1: Annual Per-Capita Raw Milk Consumption (kg, 2014)



Source: OECD - FAO Agricultural Outlook

Figure 2: Structural Changes in Milk Production during the Reform

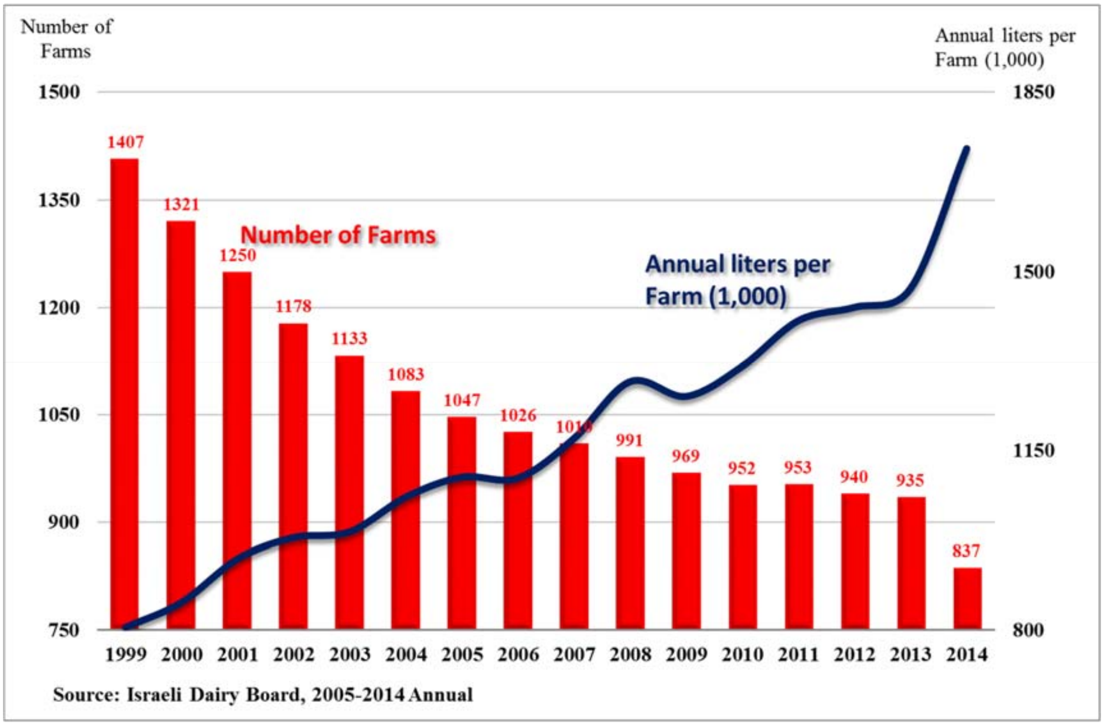


Figure 3: Demonstration of Efficiency in the Inputs Plane

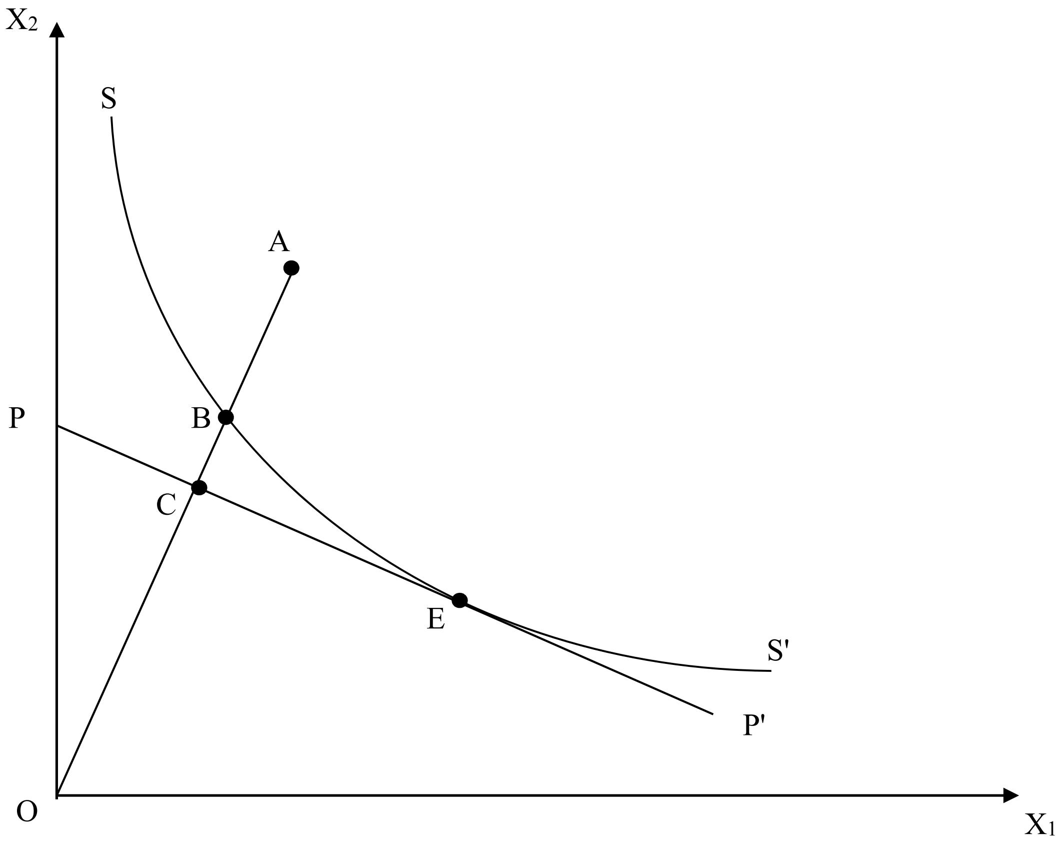


Figure 4: Efficiency Measurement and Unit Isoquant in the Input Plane

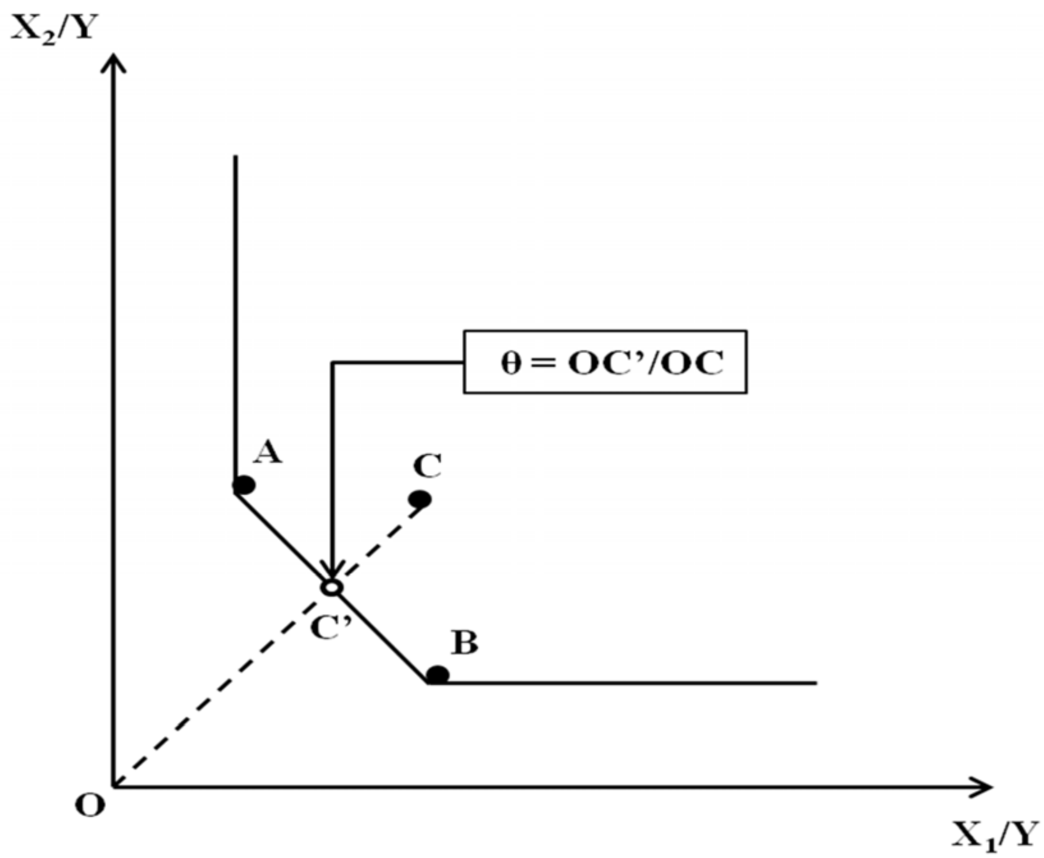


Figure 5: Identification of Return to Scales Technology Affiliation

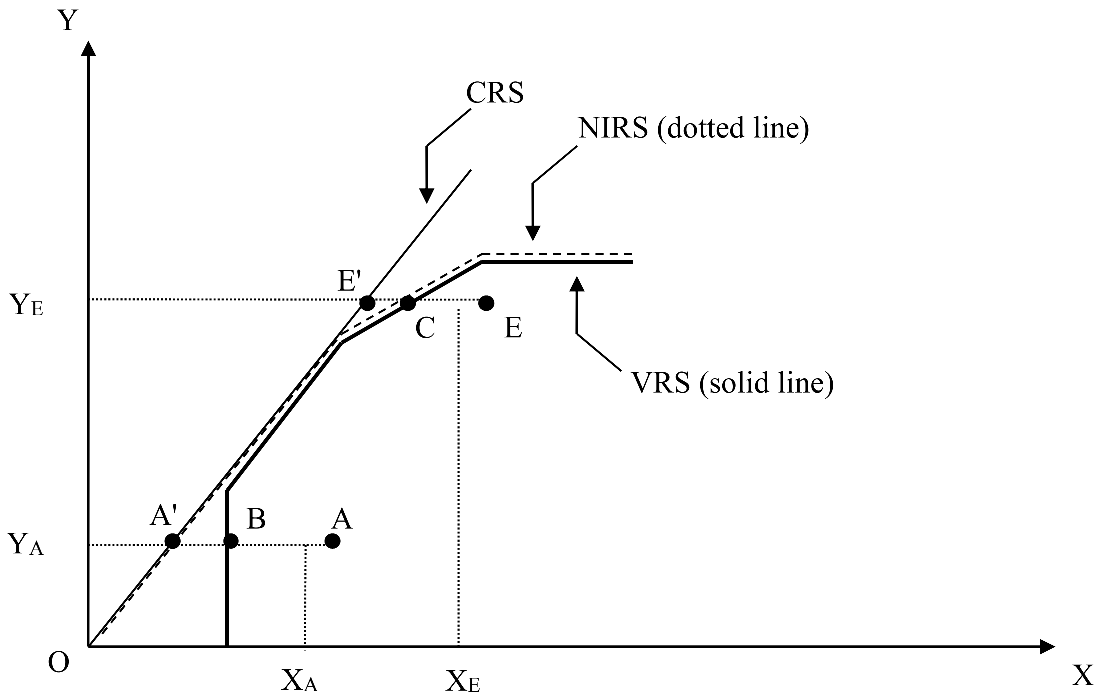
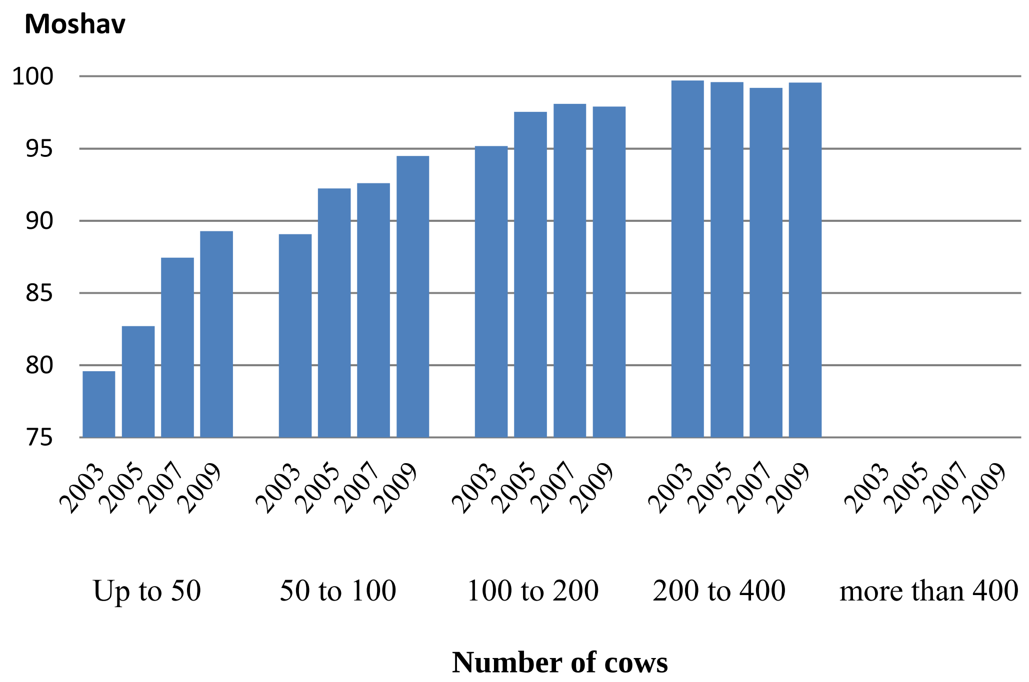


Figure 6: Average Scale Efficiency by Sector, Number of Cows, and by Year



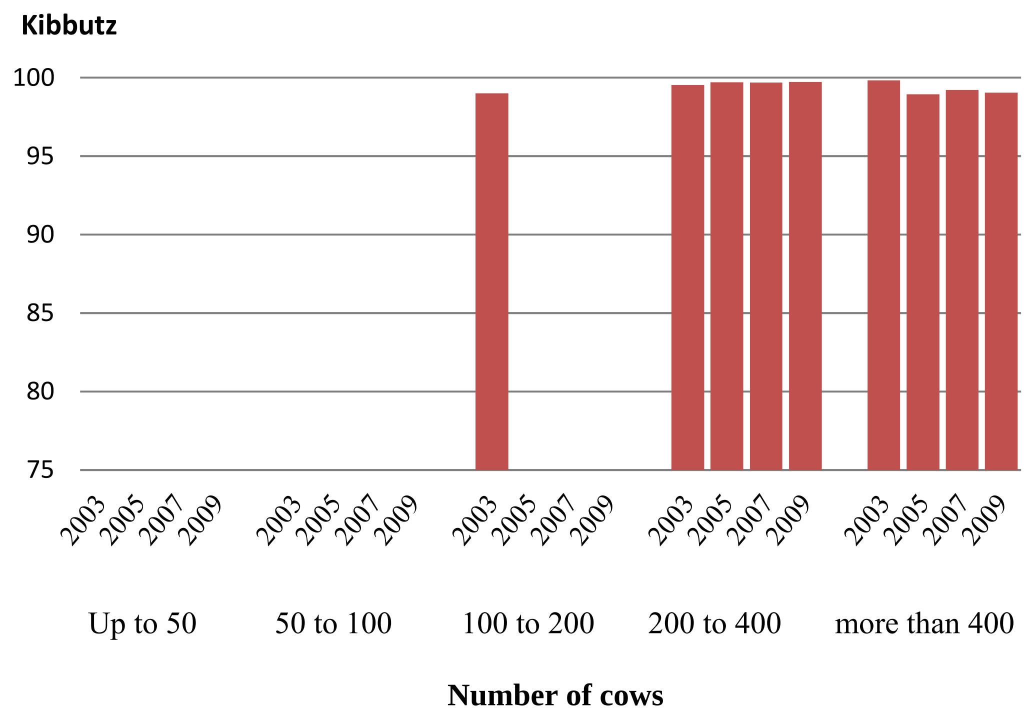


Figure 7: Meta Technology Ratio Density by Year

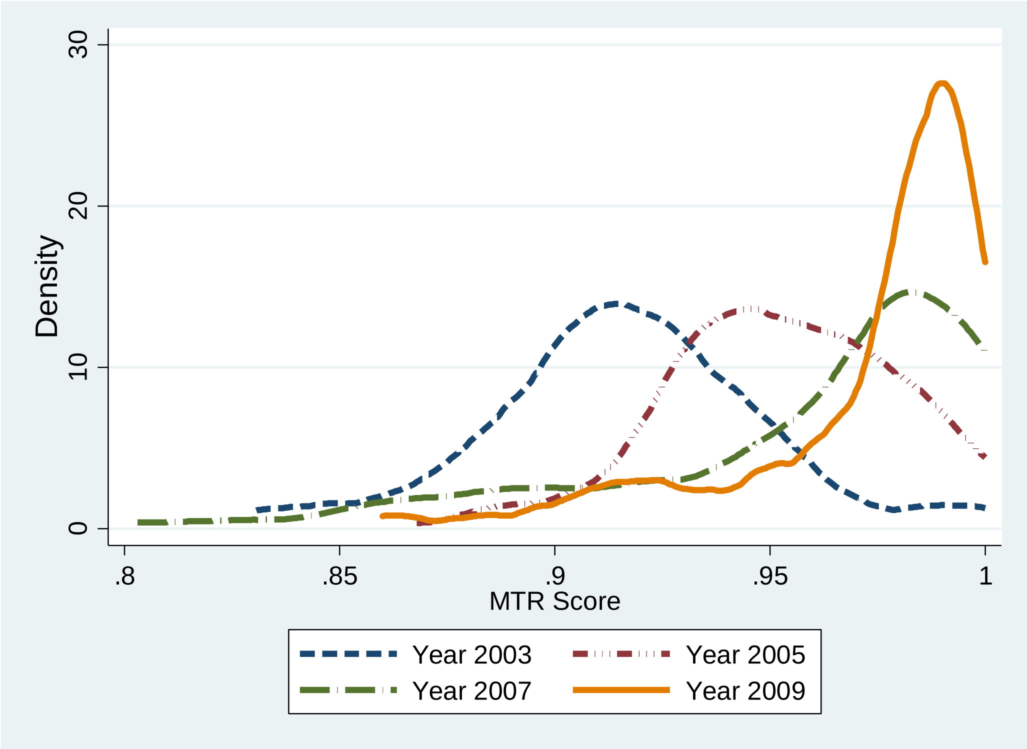


Figure 8: Meta Technology Ratio Density by Sector and Year

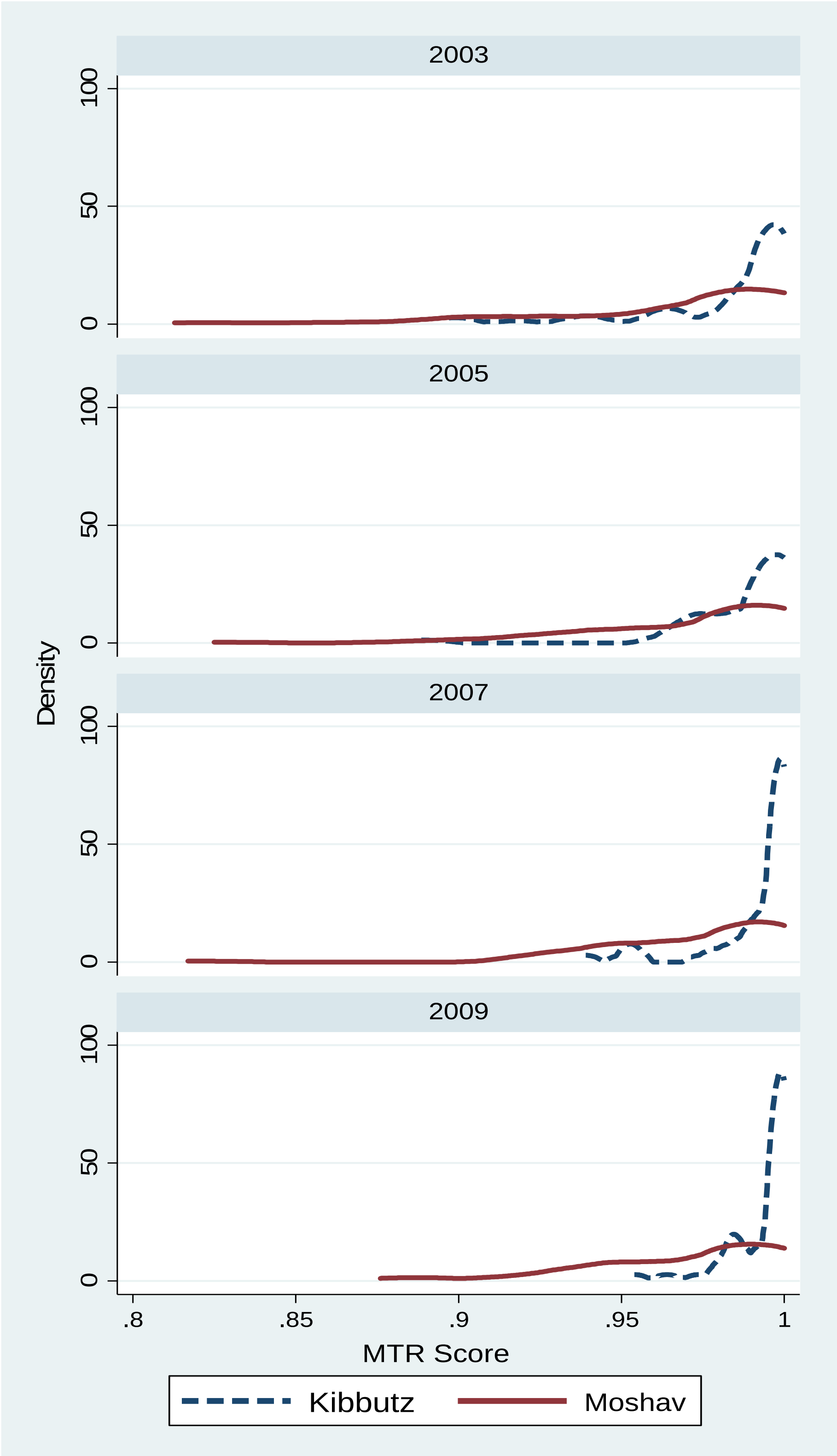
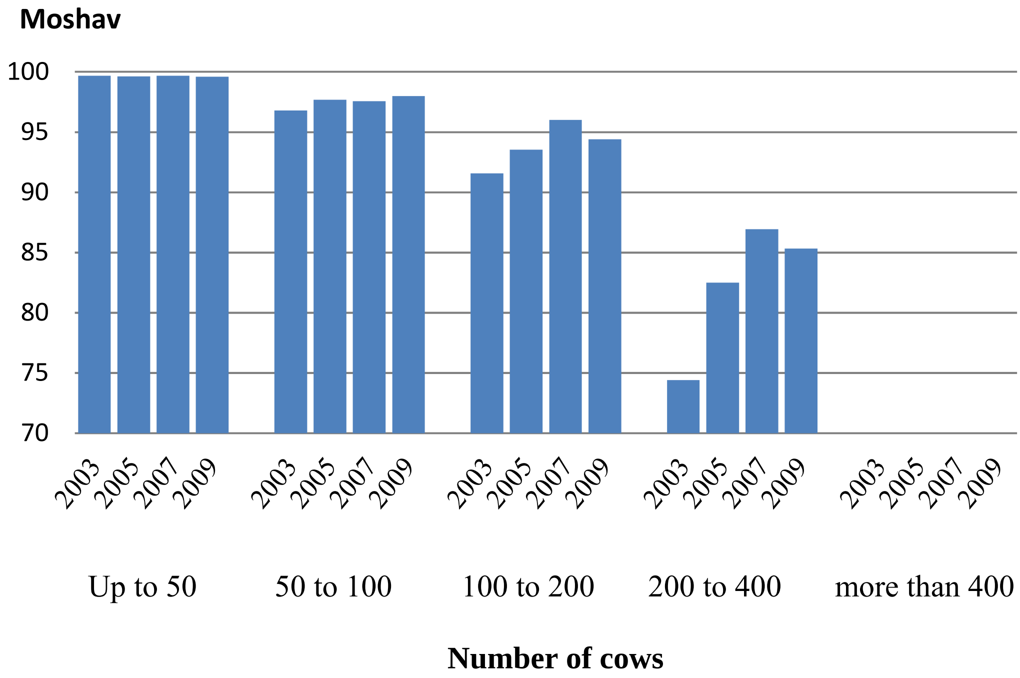


Figure 9: Average MTR Scores by Sector, Number of Cows, and by Year



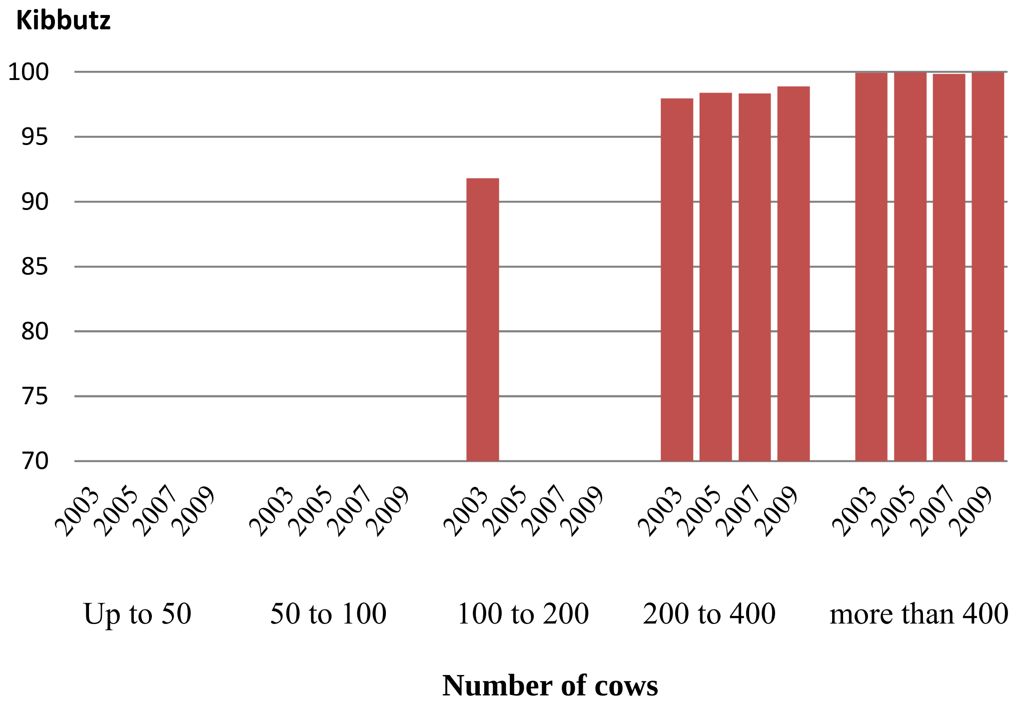


Table 1: Descriptive Statistics

Variable	Units	Mean	Std.
Output (*y*)			
Total Milk	liters/year	1,182,381	1,415,012
Input Factor (x_i)			
Cows		115	125
Labor	days/year	989	870
Sheds (Capital)	m^2	3,296	3,428
Feed (DM)	kg/year	1,140,804	1,286,642
Input Price (w_i)			
Cow Price	\$/cow	1,844	238
Labor Price	\$/day	78	14
Capital Price	\$/ m^2	8	5
Feed Price	\$/kg	0.11	0.014

Table2: Population and Production Shares by Sector, Herd Size and Year

	2003		2005		2007		2009	
Herd Size	Pop.	Prod.	Pop.	Prod.	Pop.	Prod.	Pop.	Prod.
Moshav								
Up to 50	32%	10%	42%	14%	39%	13%	19%	6%
50 - 100	39%	21%	33%	20%	36%	20%	42%	19%
100 - 200	8%	9%	7%	8%	9%	10%	19%	18%
200 - 400	—	—	—	—	—	—	1%	2%
Subtotal	80%	40%	81%	41%	84%	42%	82%	45%
Kibbutz								
100 - 200	0.5%	1%	—	—	—	—	—	—
200 - 400	17%	49%	16%	44%	10%	29%	13%	30%
400+	2%	9%	2%	14%	5%	28%	5%	26%
Subtotal	20%	60%	18%	58%	16%	57%	19%	55%

Table 3: Average Efficiency Scores by Sector and Year

	2003	2005	2007	2009
Moshav				
SE	86	88	91	94
TE	83	86	84	87
AE	93	94	94	93
EE	77	81	79	81
Kibbutz				
SE	99.6	99.6	99.5	99.5
TE	87	90	91	92
AE	96	95	95	95
EE	83	85	87	88
Mean (Moshav) - Mean(Kibbutz) t-statistic				
SE	-9.93	-8.19	-7.81	-6.73
TE	-3.72	-4.04	-8.16	-5.23
AE	-3.85	-0.88	-2.27	-3.70
EE	-5.76	-4.15	-8.90	-6.41

Table 4: Average MTR Scores by Year

Year	2003	2005	2007	2009
Average MTR Score	91.33	95.67	94.24	96.58
Analysis of Variation				
	SS	MS	F(3,502)	R^2
Model	0.2	0.668		
Year Effect	0.75	0.0015		
Total	0.95	0.0019	44.47	0.21

Appendix A – Analysis of different outputs in the Israeli dairy production industry

Dairy farming is usually considered as a multiple output production process. Common output indicators, in addition to the quantity of milk, include the quality of milk produced, measured in Somatic Cell Count (SCC, fat and protein contents. and the quantity of meat produced is another output. The following analysis examines the importance of these output indicators for the case studied here.

With respect to quality, unfortunately we do not have information in our data set that will allow us to differentiate between farms` milk quality. However, when we examine official publications by the Israeli Dairy Board (IDB) we find that a few years after the initiation of the reform, and specifically for the years that are included in our analysis, the industry had become relatively homogeneous in terms of quality, and that the majority of producers comply with IDB regulations and produce at the highest tiers of quality demanded. These regulations are well aligned with those of Europe, the United States and Canada (Schukken et al., 2003). In order to support this argument, Table A.1 depicts the trends in SCC in the Israeli dairy production industry. The first three columns report the aggregate SCC levels for each of the two sectors in the industry, and the national average, respectively. The last column reports the coefficient of variation of SCC levels. It is noticeable that starting from 2002, variation in quality had decreased immensely. The fourth and fifth columns report the threshold for high quality milk administered by the IDB, and the rate of farmers` compliance, measured as the share of total milk produced that is considered high quality. As implied before, the level of compliance reported in the fifth column suggests that the majority of the milk produced in the industry is at the highest level of quality, we therefore believe that ignoring quality variation in our sample is not causing serious biases.

Table A.1: Somatic Cell Count Trends in the Israeli Dairy Production Industry

	1,000 cells/mL				Percentages %	
Year	Kibbutz	Moshav	Average	IDB High Quality Threshold	Production Share in High Quality Tiers	CV
1996	332	515	395	-	-	34.3
1997	287	440	339	-	-	33.5
1998	303	462	357	-	-	33.1
1999	300	451	352	-	-	31.8
2000	259	396	305	-	-	33.4
2001	259	338	284	350	-	21.0
2002	248	277	258	350	-	8.3
2003	241	265	249	300	-	7.2
2004	224	239	230	300	-	4.7
2005	203	230	215	300	92.2	8.9
2006	193	201	196	290	92.2	3.0
2007	210	231	218	280	87.8	7.0
2008	207	218	211	280	91.5	3.8
2009	193	201	196	280	94.8	3.0
2010	200	204	202	280	99.5	1.4
2011	218	220	219	280	99.2	0.6
2012	223	216	220	280	97.0	2.3
2013	220	216	218	300	95.0	1.3
2014	223	219	221	300	93.6	1.3

Source: Israeli Dairy Board, 2005-2014 Annual Reports

Table A.2 reports the share of milk sales in total dairy farm income for the period 2005 - 2014. It is evident that income share of milk sales had remained stable at about 90 percent of farm income. Hence, dairy farming in Israel is highly reliant on milk production. We therefore feel confident with ignoring meat production in our analysis.

Table A.2: Milk Sales Share of Farm Income in the Israeli Dairy Production Industry

Year	Milk Sales Share of Farm Income (in Percentages %)
2005	92.9
2006	90.5
2007	90.5
2008	90.5
2009	90.9
2010	88.7
2011	90.9
2012	90.4
2013	90.6
2014	90.7

Source: Israeli Dairy Board, 2005-2014 Annual Reports

Other common indicators of milk quality are fat and protein contents. Specifically, given the quota system that prevails in the Israeli dairy production sector, a tradeoff between quantity and milk ingredients could be an important factor in farmers` strategic behavior, and therefore should be considered in the efficiency analysis. In order to examine this claim, we compute the Energy Corrected Milk (ECM) indicator (Hemme, 2006) and compare the DEA efficiency scores generated under the two approaches (i.e., ECM quantity output versus the original scores calculated based on the uncorrected milk quantity). Table A.3 reports the correlation coefficients between the two sets of efficiency indicators. It is apparent from the comparison that both approaches yield scores which are highly correlated with each other.

Table A.3: Correlation coefficients between DEA scores from a quantity output and ECM output estimations

ECM	Quantity Only			
	TE	AE	EE	SE
TE	0.9628			
AE		0.9688		
EE			0.966	
SE				0.9944

We further examine these similarities using a second stage regression approach, which is usually used to identify efficiency determinants (Ray, 1985; Kalirajan, 1991). In our case, however, this approach is only utilized to examine if there are any profound differences between efficiency scores for the two types of output considered. We use farm characteristics such as geographic region, management structure, size (as represented by the farm's production quota in liters), and the sample year as our explanatory variables. Table A.4 reports the results of that second stage regression. It is evident from looking at the estimation results that the differences between the estimated coefficients are negligible. We therefore conclude that accounting for the tradeoffs mentioned earlier between milk quantity and ingredient contents, are presumably a non-significant source for inefficiency differences among dairy farmers in Israel.

Table A.4: Second stage regression analysis comparing DEA scores sensitivity to output measure chosen

	Quantity Only				ECM			
Coefficient	TE	AE	EE	SE	TE	AE	EE	SE
Constant	0.832 ***	0.923 ***	0.766 ***	0.84 ***	0.819 ***	0.92 ***	0.751 ***	0.833 ***
Quota (10^6 Liters)	0.012 ***	0.004 **	0.015 ***	-0.002	0.01 **	0.006 ***	0.014 ***	-0.004
Kibbutz	0.008	0.004	0.012	0.116 ***	0.003	0.006-	0.003-	0.122 ***
Partnership	-0.038 ***	-0.001	-0.037 ***	0.06 ***	-0.025 **	0.006-	0.028- ***	0.063 ***
Year 2005	0.028 **	0.006	0.033 ***	0.016	0.042 ***	0.0066	0.047 ***	0.021
Year 2007	0.015	0.0091	0.023 **	0.036 ***	0.037 ***	0.006	0.042 ***	0.046 ***
Year 2007	0.045 ***	0.0002	0.044 ***	0.058 ***	0.06 ***	0.002	0.059 ***	0.068 ***
Center	-0.001	0.012	0.009	0.015	-0.001	0.014 *	0.01	0.011
Mountains	-0.022	0.007	-0.015	0.032 **	-0.027 *	0.007	-0.019	0.036 ***
Valleys	-0.011	0.009	-0.001	0.022 **	-0.013	0.0084	-0.005	0.024 ***
North	0.04 ***	0.017 **	0.053 ***	0.0007	0.042 ***	0.018 **	0.056 ***	- 0.0017
F (10,495)	15.24 ***	4.66 ***	21.04 ***	46.67 ***	10.29 ***	4.36 ***	15.83 ***	39.96 ***
R^2	0.2069	0.068	0.258	0.4479	0.1993	0.0555	0.2502	0.4409

*** indicates significance at 1%, ** indicates significance at 5%, * indicates significance at 10%

Appendix B – Analyzing Efficiency Trends for Small Moshav Farms, Scale Efficiency Corrected for Technology Improvements

We illustrate the trends in scale efficiency for the small family farms in the sample using a deducted efficiency score. Two options are explored, scaling using the yearly average MTR score, and each farm's own MTR score as computed with respect to the matching sample year frontier. Figure B.1 shows the yearly average scale efficiency for that group of producers after correcting for technological improvements. As it appears from the figure, the illustration reveals that while the trend has weakened, there is still a noticeable difference between the early period of the reform (years 2003 and 2005) and the later period (years 2007 and 2009). A regression analysis is also reported in Table B.1 to support this last statement.

Figure B.1: Average Corrected Scale Efficiency for Small (Up to 50 Cows) Moshav Farms

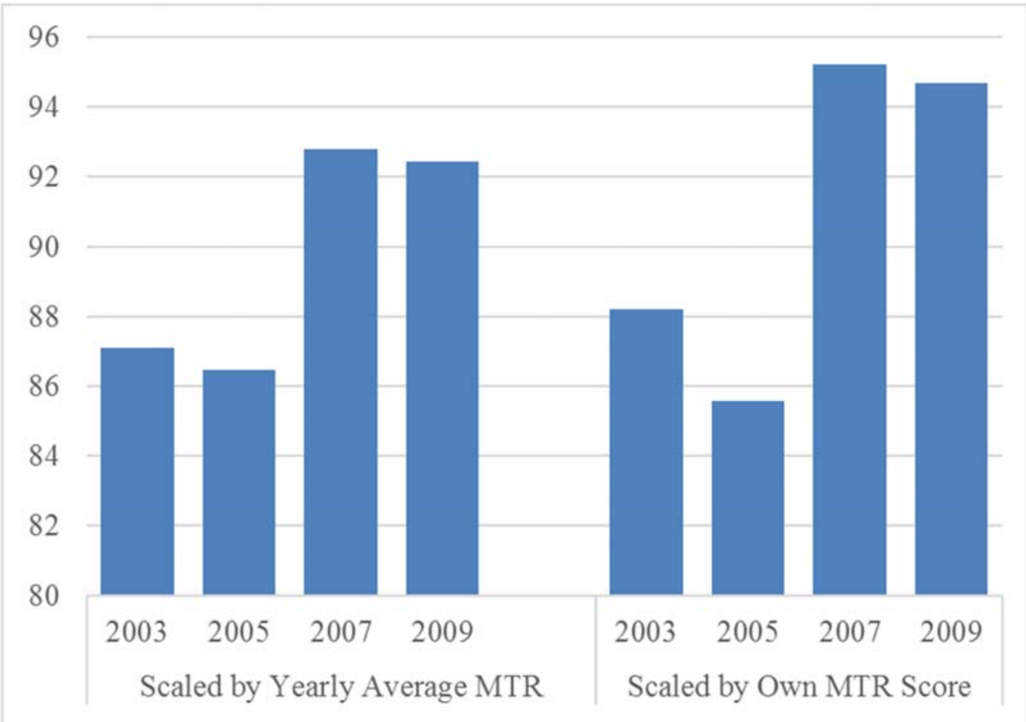


Table B.1: Regression Analysis of Corrected Scale Efficiency for Small Moshav Farms

Coefficient	Scaled by Yearly Average MTR	Scaled by Own MTR Score
Constant	0.871 ***	0.882 ***
Year 2005	-0.0067	-0.026
Year 2007	0.056 **	0.069 **
Year 2009	0.053 **	0.064 *
F(3,81)	4.22 ***	6.31 ***
R^2	0.1416	0.1855
Coefficient (Year 2009) - Coefficient (Year 2007) F(1,81)	0.04	0.11

*** indicates significance at 1%, ** indicates significance at 5%, * indicates significance at 10%

Appendix C – Efficiency trends for repeated observations in the sample

As mentioned earlier, our sample is a pooled data set compiled from bi-annual farm profitability surveys conducted by the IDB. We identified 111 farms which were resampled throughout the period of the entire sample. Observations vary in the number of repetitions and in the year (or years) of resampling, Table C.1 presents the distribution of farms accordingly.

Table C.1: Repeated Observation Distribution

	2003	2005	2007
Sampled Twice			
with 2005	18		
with 2007	16	16	
with 2009	13	16	10
Sub-Total		**89**	
Sampled Three Times			
with 2005 and 2007	4		
with 2005 and 2009	3		
with 2007 and 2009	5	9	
Sub-Total		**21**	
Sampled Four Times		**1**	
Total		**111**	

The small number of observation within each group challenges any statistical inferences, we therefore aggregate observations according to number of repetitions, ignoring the specific year combination. Average efficiency scores for the different efficiency indicators along with a suitable mean comparison test are presented in Table C.2. Figures C.1 and C.2 that follow show the Kernel density of each efficiency indicator for the two repetition groups.

Table C.2: Average Efficiency Scores for Resampled Observations, by Number of Repetitions

	SE	TE	AE	EE
Sampled Twice				
First Appearance	96.15	85.54	94.97	81.25
Second Appearance	97.14	88.22	94.34	83.23
Mean (First) - Mean (Second) t-statistic	-2.52	-3.55	1.54	-2.65
Sampled Three Times				
First Appearance	96.15	87.61	95.45	83.65
Second Appearance	97.85	89.46	95.4	85.38
Third Appearance	98.3	90.6	94.44	85.61
Analysis of Variation F-statistic	1.36	1.00	0.67	0.41

The efficiency mean comparison presented in Table C.2 demonstrates that the efficiency improvement trend that was observed earlier for the entire sample, prevails for this group of repeated observations as well. However, for the group of farms that were resampled three times the differences are insignificant. The same observations are supported by the density figures below, where for most efficiency indicators we can observe a shift to the right of the densities for farms which were sampled twice.

Figure C.1: Kernel Density of Efficiency Indicators by Sampling Sequence for Observations Sampled Twice

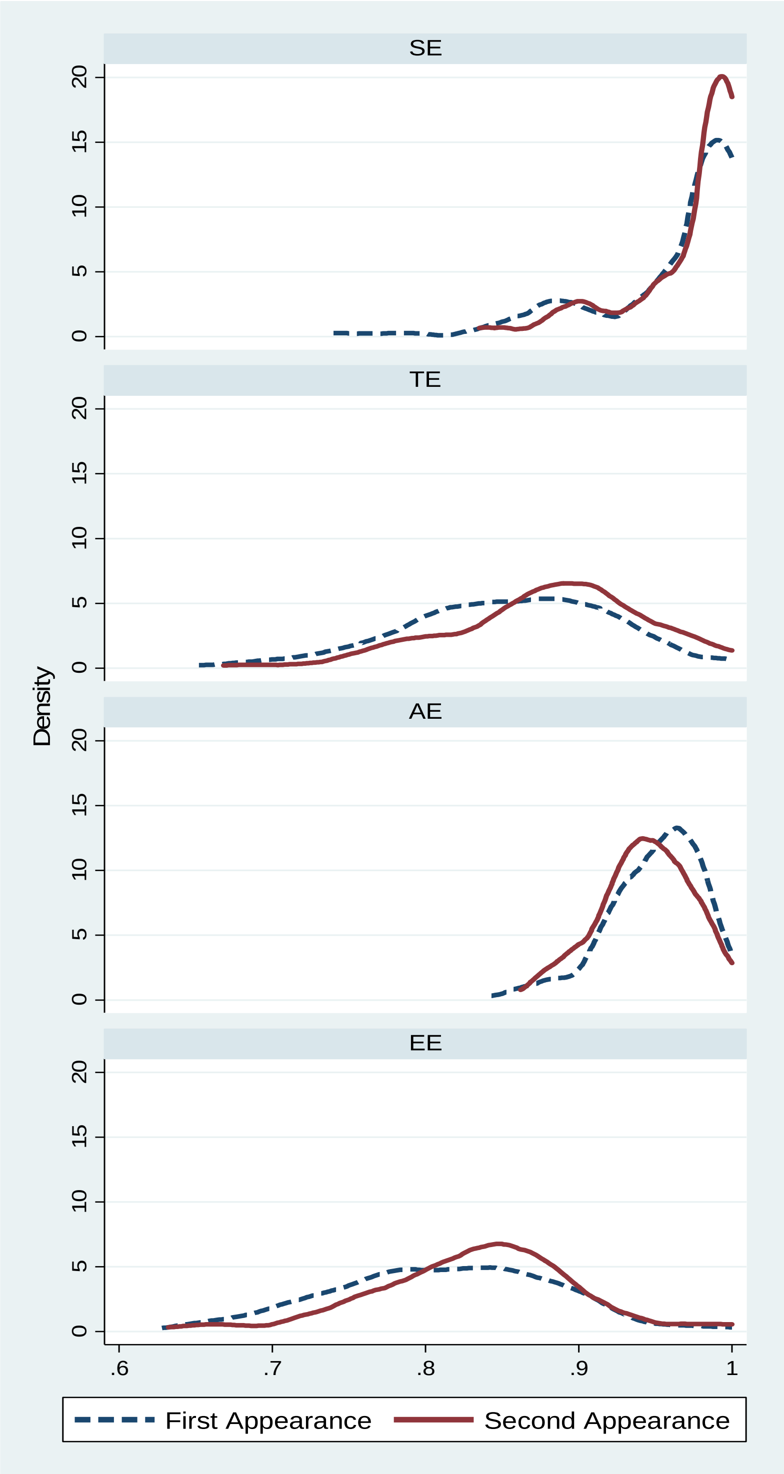


Figure C.2: Kernel Density of Efficiency Indicators by Sampling Sequence for Observations Sampled Three Times