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The Simultaneous Evolution of Farm Size and Specialization: Dynamic Panel Data Evidence from Israeli Farm Communities

by

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Abstract

This paper deals with structural changes that are observed in farm sectors in many developed economies: the increase in farm size and in farm specialization. Using panel data on Israeli farm communities for the years 1992-2001, we estimate a system of simultaneous equations in which these variables are determined jointly in a dynamic setting. We employ the Arellano and Bond dynamic panel GMM algorithm for each of the equations, treating the other variables as endogenous and allowing for unobserved heterogeneity and for time trends that depend on geographical and institutional factors. The results exhibit positive and statistically significant autoregressive effects in both size and specialization. Farm size depends negatively on specialization, while specialization does not depend significantly on size. This implies that opposite to what one may conclude from aggregate data, Israeli farms expand by diversifying into additional crops and/or livestock rather than by expanding existing enterprises. Simulations show that while specialization increases in all types of communities, farm size is increasing over time in cooperative villages and decreasing over time in collective farms. This implies a gradual process that leads, in the long run, to concentration of agricultural production in a small number of large, business-oriented, family farm enterprises.

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Introduction

Farm sectors in developed countries have experienced a sharp decline in their size and importance during the second half of the 20^{th} century. For example, the number of farms in the United States has declined from 5.4 million in 1950 to less than 2 million in 1997, while the average size of farms has risen from 216 acres to 487 acres during the same period. Also, the value of farm products has increased by 250%, while the fraction of farm operators working off the farm went up from just under 40% to almost 60%. Between 1966 and 1997, the number of farms in France and Germany dropped by almost 60%, while the average farm size in these countries grew by 159% during the period. In Israel, the decline of the farm sector is visible from the early 1980s. The number of active farms dropped from 43,450 in 1981 to 25,900 in 1995, while the average size of farms increased from 9.5 hectares to 14.7 hectares during the same period.

These structural changes have been a reaction to market conditions. The global trend of decreasing terms of trade in agriculture has not skipped Israel. Figure 1 shows that the terms of trade in Israeli agriculture went down by more than 20% from 1988 to 2001. This has lead to a deterioration of income from agriculture, and at the same time alternative employment opportunities became more attractive. Figure 2 shows that during the same period, income of the self-employed in agriculture has somewhat decreased and became more volatile, while the alternative income, represented here by the income of employees in industry, has increased. In order to maintain this level of income, the self-employed in agriculture had to increase the scale of their farming operation, and this could only be achieved through the exit of other farmers. Farm exit was further facilitated by urbanization pressures. Overall, the number of self-employed in agriculture decreased from almost 50,000 in 1988 to less than 20,000 in 2001 (figure 3). Overall, the value of agricultural production has not changed significantly over the period, but it is now produced in a much smaller number of larger farms. As market conditions continue to change, so does the structure of the agricultural sector.

The purpose of this paper is to analyze jointly two important aspects of farm dynamics, namely the changes in farm size and specialization over time, and understand the linkages among them. We assume that these variables are determined simultaneously as a dynamic system of equations. We use community-level panel data for the years 1992-2001 obtained from the Israeli Ministry of Agriculture, and adopt the dynamic panel GMM estimation method of Arellano and Bond (1991).

In the next section we review the relevant existing literature and present the research hypotheses. After that we describe the data used in this study. Then we present the empirical model and the estimation strategy. The following section presents the empirical results. The last section concludes.

Literature and research hypotheses

Many studies dealing with the increase in farm size have recognized its interdependence with farm labor. The increase in farm size in developed countries was discussed and analyzed both theoretically and empirically by Kislev and Peterson (1996), Weiss (1999), Yee, Ahearn, and Huffman (2004), Kim et al. (2005), and Ahituv and Kimhi (2005). Other studies examined whether farm size and specialization are related. The empirical evidence is mixed. Pope and Prescott (1980) and Weiss and Briglauer (2000) found that farm size have a negative effect on specialization, while McNamara and Weiss (2001) and Kahanovitz et al. (1999) found that specialization is highest in both the smallest and the largest farms. Yee and Ahearn (2005) found that specialization increases farm size, but this result depends on how size is measured. Huffman and Evenson (2001) differentiated between crop specialization and livestock specialization, and found that while the association between farm size and livestock specialization was negative in both directions, size had a positive effect on crop specialization and crop specialization did not affect size significantly.

Theoretically, there are two competing hypotheses concerning the association between farm size and specialization. The association could be positive in the presence of economies of scale that make specialization more attractive on larger farms. The essence of this hypothesis is that a given quantity of inputs can produce more output if it is concentrated in a small number of farm products rather than diversified among a large number of farm products. On the other hand, the association could be negative due to the increased risk associated with larger farm production. This hypothesis implies that as farm size increases, the increased risk will induce farmers to diversify production into a larger number of farm products in order to decrease aggregate risk.

Since the two hypotheses are not contradictory, (i.e. they can both be true), we conclude that the association between farm size and specialization is theoretically ambiguous, and any empirical assessment of this association can only tell us, at a maximum, which effect, if any, is dominant. However, the two hypotheses imply different directions of causality between size and specialization. The scale economies hypothesis implies that increased specialization leads to increased volume of production, and in this case causality goes from specialization to size. The risk diversification hypothesis, on the other hand, implies that increases in size lead to decreased specialization, and in this case causality goes from size to specialization. Our empirical strategy is specifically designed to inspect the direction of causality. Before we get to it, though, we present our data set and define the variables of interest.

Data

Due to historical reasons, agricultural production in Israel is dominated by cooperatives. Motivated both by ideology and by circumstances, the early pioneers of the early 20th century set up unique forms of cooperative settlements, the two dominating types of which have been the Kibbutz and the Moshav (Kislev, 1992). The Kibbutz was a collective community in which each member produced according to his ability and consumed according to his needs. The Moshav was a 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. A third type of cooperative settlement, Moshav Shitufi, was a compromise between Kibbutz and Moshav: production was handled collectively while consumption was handled individually. Since a relatively small number of Moshav Shitufi settlements exist, we group them together with Kibbutz settlements and call them “collective farms”. Other than collective farms (43% of cropland in 2002) and Moshav cooperatives (32%), there are private family farms operating in both Jewish (10%) and Arab (15%) localities.

The data set used in this research is from an annual survey of agricultural activity that is conducted at the village level by the Ministry of Agriculture and the Central Bureau of Statistics. We have access to the data from the 1992-2001 surveys. The production data gathered is limited to the allocation of cropland to the different crops and the number of livestock. These are converted to gross value added using norms based on 1995 data. We aggregated specific crops and livestock into nine broader branches: beef, dairy, sheep, poultry, eggs, citrus fruits, other fruits, field crops and vegetables. The size of the farm is defined as the sum of value added of all nine branches, and specialization is measured by Theil's (1971) entropy index, defined as $E=1+\Sigma_{i=1...n}\,\pi_i ln(\pi_i)/ln(n)$, where π_i is the fraction of branch i in total farm output and n is the number of branches. This specialization index ranges from zero, when all crops have equal shares, to one, when there is only one crop. Both size and specialization are computed at the village level. Using the village aggregate is similar to studying an average farm in each village.

The original data set included 956 localities: 291 collective farms, 387 cooperative villages, 122 private Jewish localities and 156 Non-Jewish localities. As a rule, the data for the private Jewish localities were in bad shape and hence they were excluded from the empirical analysis. Figure 4 shows the trend in farm size over time. The upwards trend is pretty clear. The year-to-year fluctuations are mostly the result of changes in the value of vegetables. The growth of farm size is uniform across all types of localities. Figure 5 shows the trend of specialization over time, which is also positive. The change is uniform in this case as well.

Empirical model and estimation strategy

The model we chose for this research is the dynamic panel data model of Arellano and Bond (1991), which involves a Generalized Method of Moments estimation of a dependent variable as a function of its lagged value and other endogenous, pre-determined and exogenous variables, in the presence of unobserved heterogeneity. We treat specialization as an endogenous explanatory variable when we estimate size and we treat size as an endogenous explanatory variable when we estimate specialization. We also estimate the autonomous rate of change in the dependent variable over time, and the differences across regions and types of villages in this rate of change.

Specifically, the two equations we estimate for size (S) and specialization (E), respectively, are:

(1) $S_{i,t} = \alpha_0 + \alpha_1 S_{i,t-1} + \alpha_2 E_{i,t} + t \cdot D_i \alpha_3 + \mu_i + u_{i,t}$

(2) $E_{i,t} = \beta_0 + \beta_1 E_{i,t-1} + \beta_2 S_{i,t} + t \cdot D_i \beta_3 + \theta_i + v_{i,t}$

The lagged dependent variable is included as an explanatory variable to account for adjustment costs. D is a matrix of a unit vector and dummy indicators of locality attributes, including type of locality, region, and year of establishment. These are allowed to affect the autonomous trend, and hence are multiplied by *t*. μ and θ represent community-specific unobserved factors (fixed effects) that are unchanged over time, while *u* and *v* are idiosyncratic error terms.[1]

Taking first differences, equations (1) and (2) become:

(3) $\Delta S_{i,t} = \alpha_1 \Delta S_{i,t-1} + \alpha_2 \Delta E_{i,t} + D_i \alpha_3 + \Delta u_{i,t}$

(4) $\Delta E_{i,t} = \beta_1 \Delta E_{i,t-1} + \beta_2 \Delta S_{i,t} + D_i \beta_3 + \Delta v_{i,t}$

[1] Alternatively, we could have specified each endogenous variable as a function of the lagged value of the other. We preferred the current specification because as specialization increases (i.e. a farm quits a certain product), the inputs that are released are immediately used to increase production of other farm products, and if a farm increases production by engaging in an additional product, the effect on specialization will be immediate. One could think of reasons why lagged values should be included in addition to the current values, but this would have complicated our empirical analysis more than we can afford.

where $\Delta S_{i,t} = S_{i,t} - S_{i,t-1}$, and similarly for the other differenced variables. This takes care of the fixed effects. In addition, the estimation procedure corrects for endogeneity by using the Generalized Method of Moments (GMM) estimation method on each of the equations. As instruments for the endogenous explanatory variables, we use all possible lagged values of ΔS and ΔE. We correct for serial correlation by an appropriate transformation of the weighting matrix. See Arellano and Bond (1991) for further details.

The model can be estimated in one stage or in two stages. The two-stage method involves using the residuals of the first stage to compute an optimal weighting matrix, which is subsequently used in the second stage. The advantage of the two-stage method is in the efficiency of the parameter estimates. In addition, it enables to conduct the Sargan test of over-identifying restrictions, which tests for correlation between the instruments that are excluded from the second-stage model and the residuals. The disadvantage is that the standard errors of the coefficients tend to be underestimated, and this may lead to incorrect inference. We estimated each model with both methods, and as a rule, the results were not qualitatively different. In the following, we present only the one-stage estimates, mainly because for these estimates we have the ability to compute robust standard errors. We do show the results of the Sargan test based on the two-stage results. These results are not favorable in most cases, but we do not view this as a complete rejection of our model, since it was noted by Arellano and Bond (1991) that this test tends to fail too often. We also conduct the Arellano and Bond test of second-degree serial correlation in the differenced error terms. The results of this test were always favorable.

Finally, the goodness-of-fit of the model was measured by the Generalized R^2 suggested by Pesaran and Smith (1994). Note that this measure is not necessarily monotonous in the number of explanatory variables.

Results

The farm size regression results are in table 1.[2] We observe that farm size is affected positively by its lagged value, meaning that there is persistence in farm size, so that a shock to size has a lasting effect. The coefficient of lagged size is less than unity, meaning that this lasting effect vanishes over time. Specialization has a negative effect on size, meaning that more specialized farms are smaller. To illustrate this result, suppose that a farm becomes more specialized by closing down one of its branches. With the farm resources that become available it can then increase production of the other branches. Still, the overall farm size is smaller, meaning that the increase in the output of the other branches does not fully compensate for the closure of that one branch. This implies that the increased risk of specialization dominates the motive to increase production due to increasing returns.

The coefficients of lagged size and specialization are stable across the first three columns of table 1. The difference between these columns is the treatment of the autonomous change in farm size over time. The first column includes an overall time trend only, and its shows a positive trend. This confirms with the raw results (figure 4). The second column allows for a different time trend for farm size in different types of villages. The excluded group of cooperative villages enjoys an autonomous increase in farm size of 1.4% per year. On the other hand, the time trend for farm size in collective farms and in non-Jewish villages

[2] Note that we in fact estimate changes in size and specialization (equations 3-4), but treat the coefficients as their original interpretation in levels (equations 1-2).

is virtually zero. In the third column we allow for different time trends in different geographical regions. We find growth rates of close to 2% per year in farms located in the Galilee (northern part of the country), in the eastern valleys and in the south, compared to farms located in the center of the country, in the Jerusalem region or in the northern valleys. The growth in the south and in the eastern valleys can be explained by comparative advantages of climate in these regions that is brought about by technological innovations, especially in the forms of water utilization. Relative farm growth in more remote areas in general can be explained by the lack of alternative income-generating activities.

In the fourth column, we also allow for a time trend that depends on the establishment year of the village. We divide the villages into three groups: those established up to 1948 (including all non-Jewish villages), those established between 1949 and 1960 (mostly immigrant villages, lacking resources, skills and/or motivation to succeed in farming), and those established after 1960 (mostly by motivated second-generation farmers settling in remote regions and enjoying institutional support). We find that adding the establishment year trends changes the other coefficients. In particular, the coefficient of lagged farm size increases by about 50% and becomes more significant, while the coefficient of specialization loses almost two thirds of its size and becomes less significant. Also, the regional trends almost disappear, and collective farms grow at a slower rate than either cooperative or non-Jewish villages. We conclude that over and above the effects of lagged size and specialization, farm growth is mostly among cooperative villages established after 1960.

Clearly, the results indicate a multicollinearity problem with respect to village type, location and year of establishment. As a further sensitivity check we estimated the model again, excluding village type and location. The results are in the last column of table 1. We find that the effects of lagged farm size and specialization do not change much, and we now have a negative time trend for villages established before 1949, and a positive trend for villages established later. As a result, we cannot tell whether the results of column three or column five are preferred, so there remains some confusion regarding the size of the coefficients of lagged farm size and specialization, although their sign is stable across the different specifications.

Table 2 shows parallel results for specialization. We find that lagged specialization has a positive and significant effect on current specialization, and that farm size does not significantly affect specialization. These results are pretty stable across the four specifications. The first column shows a positive time trend in farm specialization, but the second column shows that this is true only for collective farms and non-Jewish villages. The third column shows that on top of the above results, specialization increases faster over time in villages established after 1960. The last column shows that specialization is increasing at a lower rate in villages located in the Galilee an in the eastern and northern valleys.

To summarize, we found that both farm size and specialization tend to increase over the sample period, where the increase in specialization puts a check on the increase in size. Size does not feed back into specialization, though. As a consequence, we expect the increase in specialization to be more pronounced over time than the increase in size. In order to illustrate this point, we present in figure 6 the results of a simulation exercise that is based on the estimated coefficients of the first column in tables 1 and 2. We derive the reduced form equations of farm size and specializations, and take as initial conditions the sample averages of these variables in the first two years of our sample. We can see that specialization is projected to increase steadily over the 30-year period, whereas size increases but at a decreasing rate, probably due to the decelerating effect of increased specialization. It seems like farm size is converging to some steady state, but this is in fact misleading. When we continue the simulation beyond the 30 years shown in figure 6, we find that specialization reaches a maximum of 100% after 130 years, and after that it no longer slows down the increase in size, and hence farms continue to grow beyond that period due to the positive time trend and its own persistence.

As the positive time trend is found to be dominant for the long run evolvement of both farm size and specialization, and recalling that we found different time trends for different types of villages, we now want to repeat the simulation exercise separately for each type of village. For this, we estimate the column-1 specifications separately for collective farms and for cooperative villages. We did not have a sufficient number of non-Jewish villages in the sample. The results appear in table 3. Regarding the farm size equation, we find that the positive effect of lagged size is similar in both types of villages, but the negative effect of specialization is statistically significant only for cooperative villages. The time trend is also significant (and positive) for cooperative farms only, as in table 1. The specialization equation results are fairly similar for the two types of villages, with a positive effect of lagged specialization and a positive time trend, with no significant effect for farm size.

The different coefficients of collective farms and cooperative villages could lead to different dynamic processes, and this is illustrated in figure 7, where simulation results for 40 years are presented. We find that specialization is higher in collective farms initially and remains higher even after 40 years, despite the fact that it is increasing in both types of villages. Farm size was initially quite similar in collective farms and in cooperative villages, but it is predicted to decrease over the years in collective farms and increase in cooperative villages. This result should be evaluated with caution, because the declining farm size in collective farms is due in part to the negative coefficient of specialization and the negative time trend, both insignificantly different from zero. But the increasing farm size in cooperative villages is based on statistically significant coefficients, and hence the widening gap in farm sizes of the two types of villages is likely to be a robust result. We conclude that the structural changes occurring in Israeli agriculture are likely to have differential effects on different types of villages, and could lead in the long run to a very different distribution of agricultural production than it is today.

Conclusion

We have estimated the simultaneous evolution of farm size and specialization in Israeli farm communities using panel data for the years 1992-2001. We found that behind the macro trends of increasing farm size and increased specialization, there are differential processes at the micro level that should not be overlooked. In particular, we found that specialization increases over the years mostly autonomously without significant feedbacks from farm size, and it is increasing faster in collective farms and in non-Jewish villages than in cooperative villages. Specialization does feed back into the evolution of farm size, mostly in cooperative villages, where it slows down the increase in farm size. Despite that, farm size increases over time in cooperative villages and decreases in collective farms. The dynamic evolution of farm size and specialization also has a geographic dimension, with farms in remote areas growing faster and specializing more slowly than farms in central locations.

Therefore, it seems like agricultural production will tend to concentrate over time in cooperative villages and in the periphery. Moreover, the process of increased specialization that leads to a decrease in size, such that the one shown in the simulation results for collective farms, could be initiated by closing down certain farm enterprises (e.g. due to negative price shocks). Instead of increasing production of other farm enterprises and utilizing size efficiencies, farm resources seem to be going elsewhere. This does not predict a bright future for agricultural production as a significant source of income in rural Israel.

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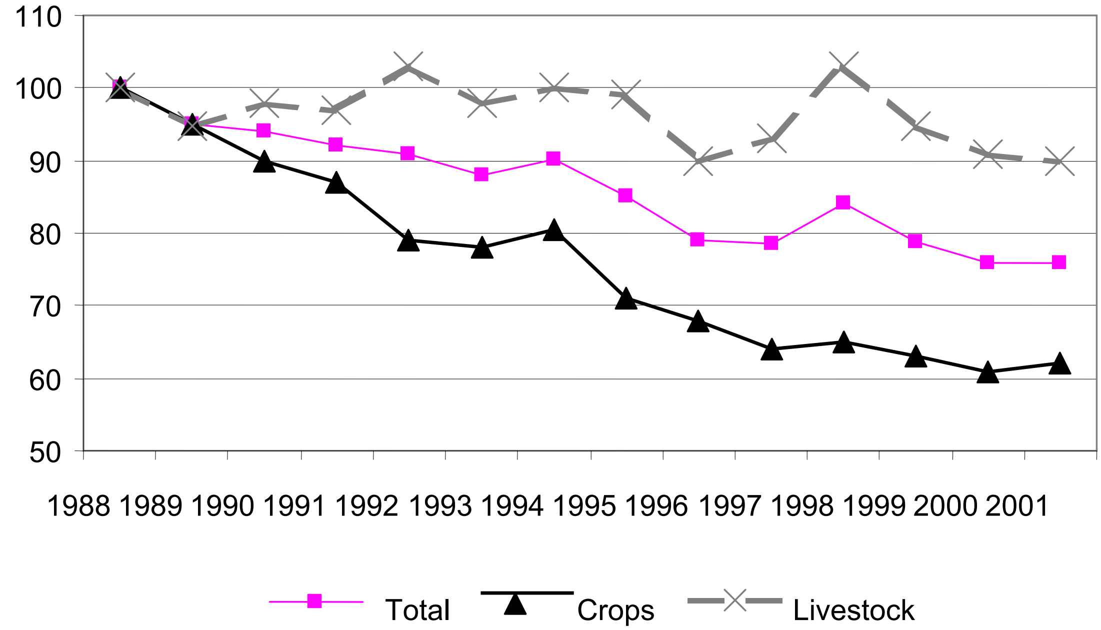


Figure 1. Terms of Trade in Israeli Agriculture

Source: Statistical Abstract of Israel (various years)

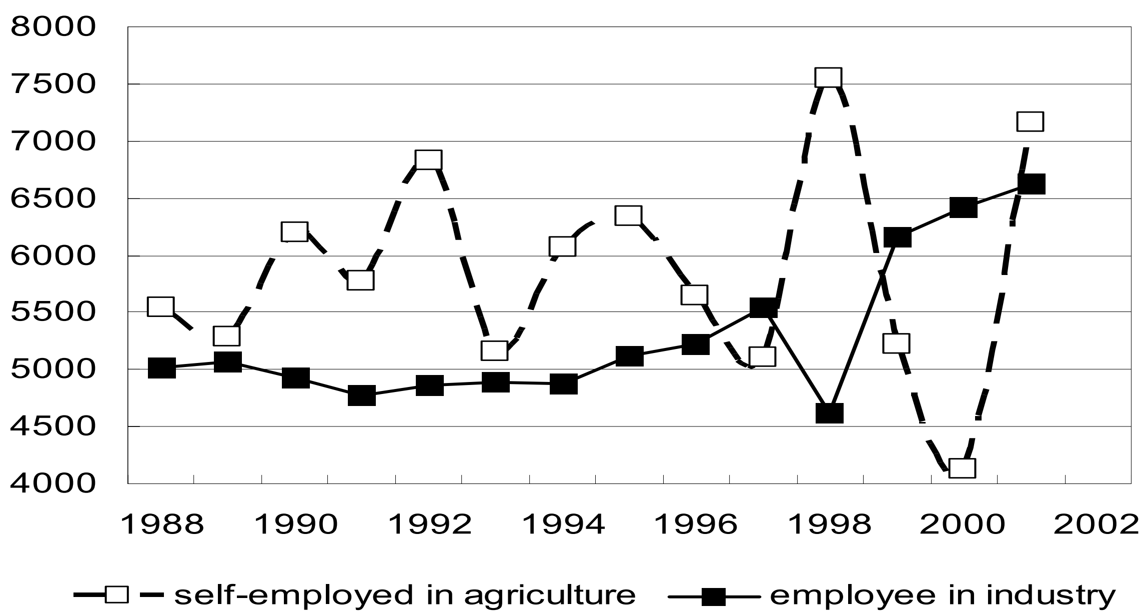


Figure 2. Monthly Income of Self-Employed in Agriculture and Employees in Industry (NIS)

Source: Statistical Abstract of Israel (various years)

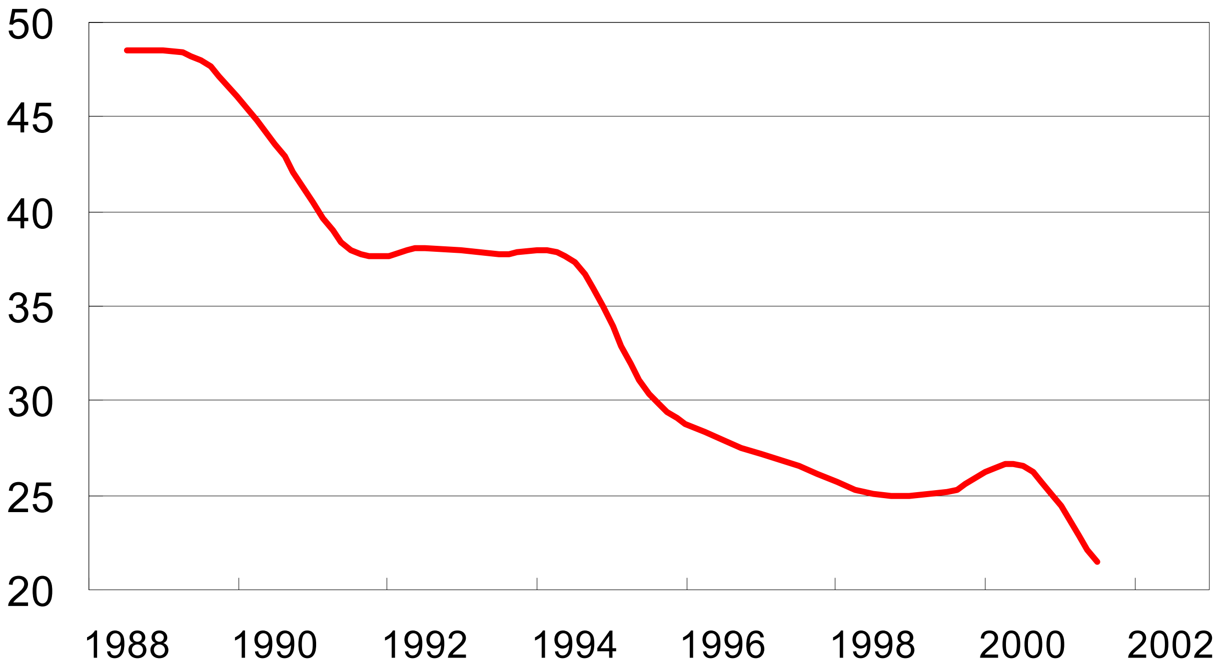


Figure 3. Number of Self-Employed Farmers in Israel (thousands)

Source: Statistical Abstract of Israel (various years)

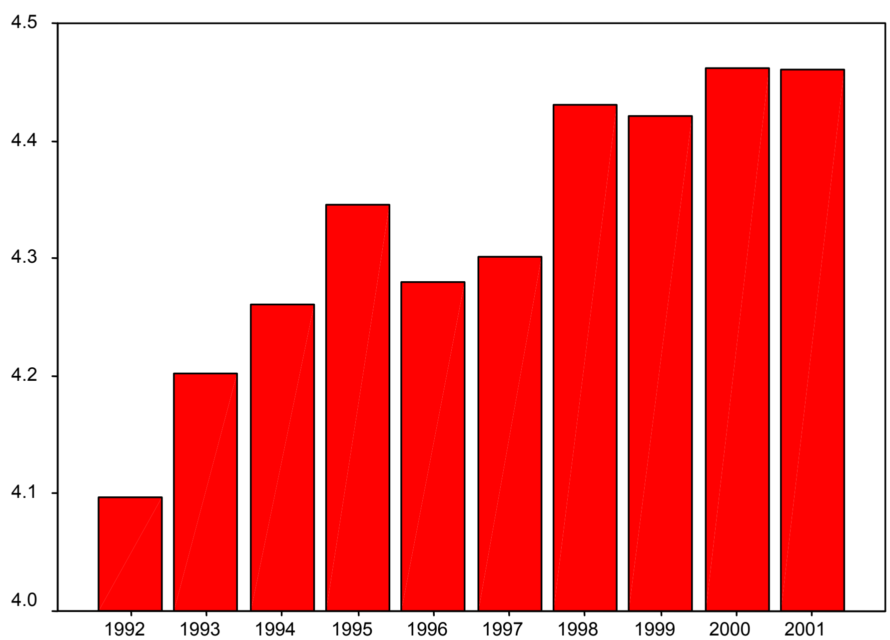


Figure 4. Trends in Average Farm Size in the Sample (Million NIS, 1995 values)

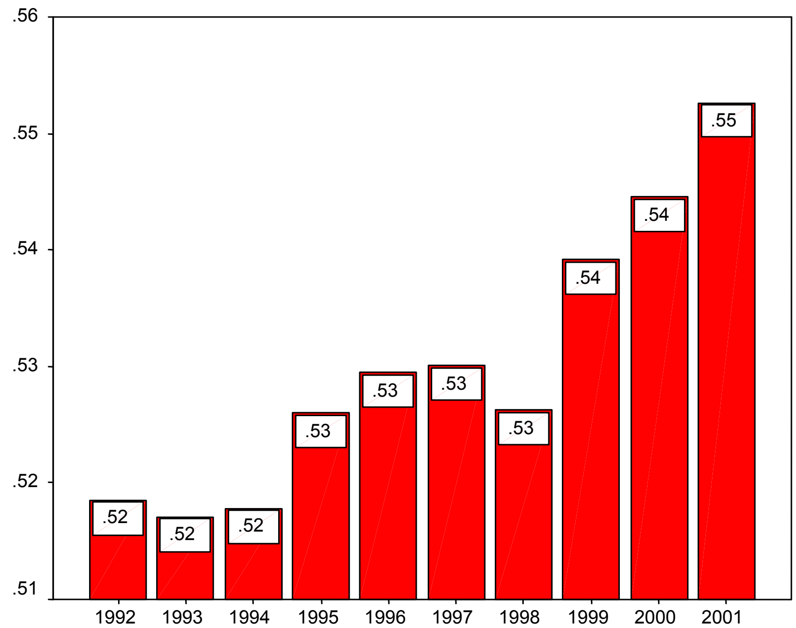


Figure 5. Trends in Average Farm Specialization in the Sample

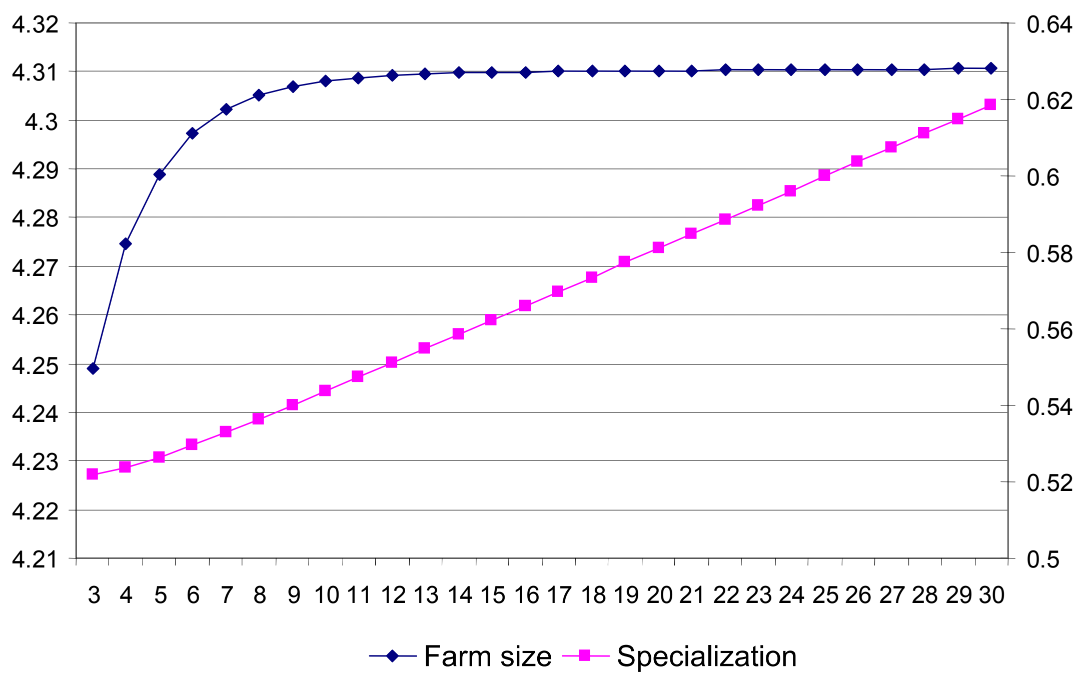
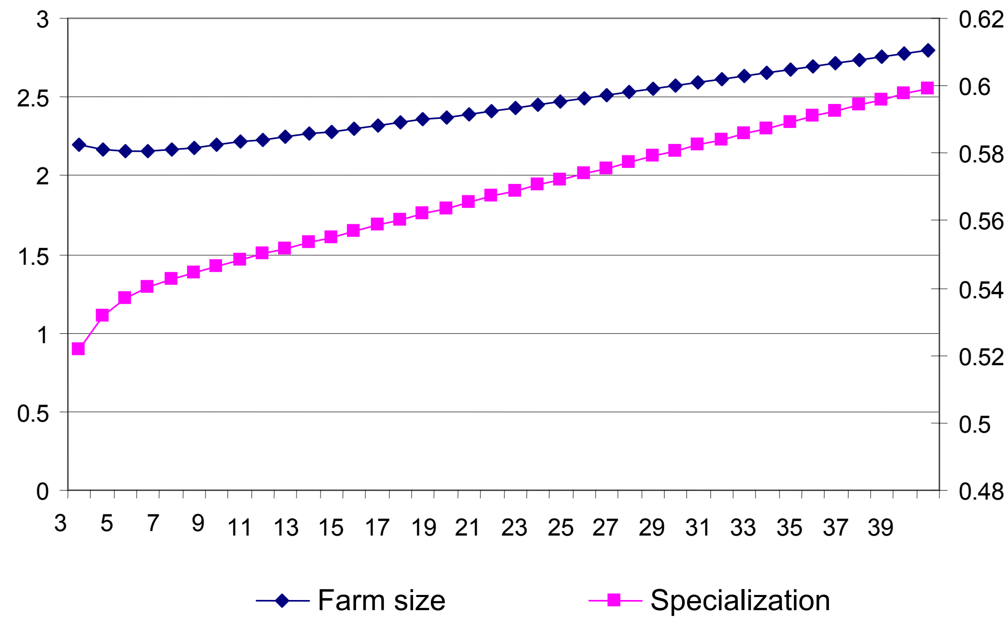


Figure 6. Simulation of Farm Size and Specialization over 30 Years

Note: Farm size and specialization are measured on the vertical axes on the left and right, respectively.

Cooperative villages



Collective farms

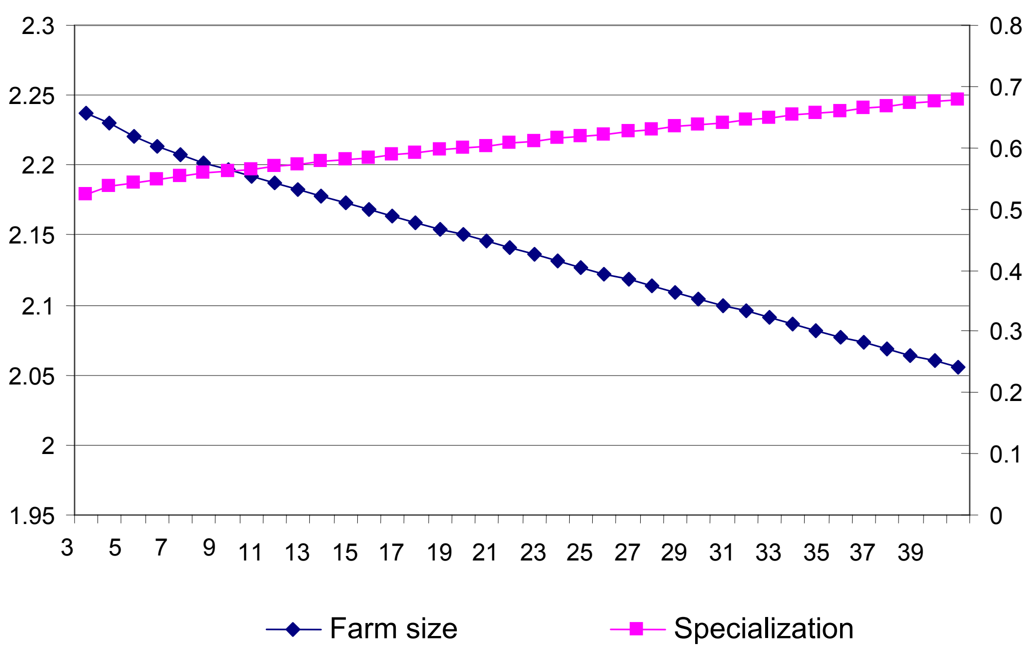


Figure 7. Simulation of Farm Size and Specialization by Village Type over 40 Years

Note: Farm size and specialization are measured on the vertical axes on the left and right, respectively.

Table 1: Farm Size Results

Variable	(1) Coefficient (T-value)	(2) Coefficient (T-value)	(3) Coefficient (T-value)	(4) Coefficient (T-value)	(5) Coefficient (T-value)
Lagged size	0.326* (1.97)	0.315* (1.95)	0.313* (1.97)	0.476** (9.27)	0.474** (8.64)
Specialization	-1.547* (-2.63)	-1.401** (-2.48)	-1.237** (-2.30)	-0.472* (-1.97)	-0.552* (-2.27)
Time	0.007* (1.92)	0.014** (2.71)	0.007 (1.58)	-0.001 (-0.32)	-0.005** (-2.50)
Collective farm		-0.014** (-2.43)	-0.016** (-2.73)	-0.007* (-2.17)	
Non-Jewish village		-0.015** (-2.39)	-0.012** (-2.50)	-0.002 (-0.40)	
Galilee			0.020* (2.26)	0.003 (0.71)	
Jerusalem			0.002 (0.40)	-0.000 (-0.03)	
Eastern valleys			0.018** (2.43)	0.003 (0.71)	
South			0.019** (2.49)	0.007* (2.02)	
Northern valleys			-0.005 (-1.08)	-0.003 (-0.91)	
Established 1949-1960				0.004 (1.24)	0.077** (2.50)
Established after 1960				0.017** (3.29)	0.022** (4.44)
Generalized R^2	0.201	0.177	0.237	0.235	0.238
Arellano & Bond test	passed	passed	passed	passed	passed
Sargan test	failed	failed	failed	failed	failed

Notes: T-test is based on robust standard errors; * Coefficient significant at 5%; ** Coefficient significant at 1%.

Table 2: Specialization Results

Variable	(1) Coefficient (T-value)	(2) Coefficient (T-value)	(3) Coefficient (T-value)	(4) Coefficient (T-value)
Lagged specialization	0.535** (7.16)	0.546** (7.40)	0.603** (9.58)	0.581** (9.23)
Farm size	-0.004 (-0.27)	0.006 (0.30)	0.010 (0.57)	0.007 (0.38)
Time	0.002** (5.62)	0.000 (0.67)	-0.001 (-1.16)	0.000 (0.45)
Collective farm		0.003** (3.53)	0.003** (3.36)	0.004** (3.93)
Non-Jewish village		0.003** (2.89)	0.004** (3.04)	0.005** (3.52)
Established 1949-1960			0.002 (1.67)	0.001 (1.22)
Established after 1960			0.003* (2.04)	0.005** (3.32)
Galilee				-0.007** (-5.55)
Jerusalem				0.001 (0.78)
Eastern valleys				-0.003* (-2.30)
South				-0.002 (-1.11)
Northern valleys				-0.003** (-2.87)
Generalized R^2	0.012	0.013	0.025	0.023
Arellano & Bond test	passed	passed	passed	passed
Sargan test	failed	failed	failed	failed

Notes: T-test is based on robust standard errors; * Coefficient significant at 5%; ** Coefficient significant at 1%.

Table 3: Results by Type of Village

Variable	Collective Farms Farm Size Coefficient (T-value)	Collective Farms Specialization Coefficient (T-value)	Cooperative Villages Farm Size Coefficient (T-value)	Cooperative Villages Specialization Coefficient (T-value)
Lagged size	0.318** (5.26)		0.315* (1.81)	
Specialization	-0.224 (-0.58)		-2.340** (-2.84)	
Lagged specialization		0.405** (4.29)		0.405** (4.00)
Farm size		0.010 (0.43)		-0.021 (-1.08)
Time	-0.000 (-0.03)	0.003** (5.42)	0.012* (2.29)	0.001* (2.06)
Generalized R^2	0.094	0.012	0.258	0.005
Arellano & Bond test	passed	passed	passed	passed
Sargan test	failed	passed	passed	failed

Notes: T-test is based on robust standard errors; * Coefficient significant at 5%; ** Coefficient significant at 1%.

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