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Farm size, productivity and returns to scale in agriculture revisited: a case study of wine producers in South Africa

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Abstract

The inverse relationship between farm size and productivity has almost become a 'stylised fact' in the economic development literature. Most of the studies contributing to this preception have been flawed by methodological shortcomings and the request is that these studies be treated with caution. Using recent farm survey data from the wine producing areas of the Western Cape of South Africa, this study attempts to overcome some of the methodological problems, distinguishing between partial and total productivity measures. Using data envelopment analysis, most of the wine grape producers were found to operate under constant returns to scale. Co-operative membership seemed to overcome the economies of scale associated with processing and marketing. The inverse relationship between farm size and both land productivity and total factor productivity is weak, not consistently negative and differs between regions. Thus, caution must be used when advocating rural development policies based on the inevitability of an inverse relationship existing in all sectors and production regions of agriculture.

Keywords: Farm; Wine; Productivity

1. Introduction

Is another paper on the relationship between farm size and productivity necessary? Since Sen (1962) observed an inverse relationship between farm size and yields from an analysis of Indian farm management data, there has been much debate on this topic and its relevance in the design of rural development strategies. A frequently quoted study on this relationship is that of Berry and Cline (1979). Their conclusions were that "the evidence presented. . .points to systematically higher land productivity on small farms than on large ones, and to total factor productivities that are at least comparable" (Berry and Cline, 1979, p. 4). Results supporting the inverse relationship have been used to justify redistributive land reform on economic grounds suggesting that a decrease in average farm size will increase efficiency in the sector. Binswanger et al. (1993) have, however, indicated that most of the empirical work on the farm size–productivity relationship has been flawed by methodological shortcomings, and has failed to deal adequately with the complexity of issues. From there then the request that ". . .more work is needed on the subject" (Binswanger et al., 1993, p. 49).

In South Africa, the evidence of the inverse relationship has been used to provide economic justification

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for the land reform programme. Van Zyl (1996) followed the guidelines provided by Binswanger et al. (1993) to improve the methodological aspects of such research. He shows an inverse but not statistically significant relationship between farm size and productivity on commercial grain farms in South Africa when measures of total factor productivity are used. He therefore argues that significant efficiency gains can be made if farm sizes in the commercial farming sector become smaller. Whether these results can be generalized, and whether they specifically apply to the horticultural sector and to wine grape production in particular, can be questioned. This sector is important, as it currently enjoys the highest growth rate in South African agriculture and generates a significant quantity of foreign exchange. The wine industry is in turn an important part of the horticultural sector with the value of exports almost five times higher now than in 1990. As a successful industry, wine production would seem an ideal candidate for land reform. The purpose of this paper is to establish whether the conventional argument of an inverse relationship between farm size and productivity can be used to support the case for land reform.

This paper will firstly determine whether wine grape production in the Western Cape is characterised by constant, increasing or decreasing returns to scale (DRS). This being established the existence of a possible inverse relationship between farm size and productivity will be examined. Particular attention is given to distinguishing between partial and total productivity measures. Several authors have argued that the use of partial measures are not correct, since all inputs are not taken into account (Binswanger et al., 1993; Lund and Hill, 1979; Van Zyl, 1996). In this paper, we argue that when total factor productivity measures are used, the inverse relationship does not hold under all conditions.

2. Methodological considerations in analysing the size–productivity relationship

Although the concept of efficiency is difficult to define (Pasour, 1981), we will consider an 'efficient farm' as a farm using less resources than other farms to generate a given output. The superior performance is manifested in higher efficiency ratios, and a lower cost per unit of production. This study uses two efficiency or productivity measures. The first, which is used in most farm size productivity studies, is land productivity. This is a partial measure and relates output to a single input, land, and so assigns overriding significance to the average physical product of a single factor as a measure of productivity. Land productivity, even though important due to land scarcity, does not account for the use of other inputs. Total factor productivity measures alleviate this problem and are measured as the ratio of aggregate output to an aggregate of all inputs. This estimate relates to the production and profit functions and is measured by the Tornqvist–Theil approximation (Evenson et al., 1987; Thirtle et al., 1993).

Prior to the estimation of these productivity indices, the returns to scale of individual farms is examined. The method used is based on data envelopment analysis using the general framework developed by Farrell (1957). The approach uses a linear programming procedure to minimise inputs per unit of output, to determine the frontier of best practice farms, and then to determine the efficiency of all production units relative to the frontier. This approach allows a decomposing of the efficiency results to determine whether the farm is experiencing increasing, constant or DRS. Formally defined, the measure of overall efficiency of farm i is:

$$F_i(y,x) = \min[\lambda : \lambda x \in L^+(\mathbf{Y})] \tag{1}$$

where y is the individual farm outputs and x is the individual farm inputs. The underlying technology is characterised by the production possibility set $L^+(\mathbf{Y})$. The minimised parameter, λ, determines the amount by which the observed input combination can be reduced to produce a given output. The efficiency level is defined as the solution to the programming problem (the expression above the line).

$$\begin{array}{rcl} F_i(y,x) & = & \min\lambda, \\ \text{subject to}\, z\mathbf{Y} & \geq & Y_i \\ z\mathbf{X} & \leq & \lambda x_i \\ z & \geq & 0 \\ \hline (\text{scale constraint : I})\,\Sigma z_i & = & 1 \\ (\text{scale constraint : II})\,\Sigma z_i & \leq & 1 \end{array} \tag{2}$$

where $\mathbf{Y}$ is the output matrix of all farms, $\mathbf{X}$ is the input matrix of all farms and z is the vector of farm-specific non-negative intensity parameters, which are used to construct convex combinations of observed inputs and outputs for the ith farm.

However, since the solution to the original programming problem, as stated in Eq. (2), is an aggregate measure including both technical and scale efficiency, these elements should now be considered separately, using Färe et al. (1985). This decomposition of the measure of total efficiency, $F_i(y,x)$, into pure technical efficiency, $T_i(y,x)$ and scale efficiency $S_i(y,x)$ can be shown as follows:

$$F_i(y,x) = T_i(y,x)^* S_i(y,x) \tag{3}$$

The left hand term was determined above and now $T_i(y,x)$ is calculated as a programming problem in which constant returns to scale (CRS) is not imposed, so that technical efficiency is measured independently of scale effects. This is stated in Eq. (2), with constraint (I) included. The scale effect is then simply calculated from Eq. (3) as $S_i(y,x)=F_i(y,x)/T_i(y,x)$. Finally, constraint (II) is imposed in place of constraint (I) to determine whether the non-constant returns are increasing or DRS. Fig. 1 represents this graphically using a production function rather than the isoquant approach. With output **Y** and one input **X**, the CRS frontier is denoted with the straight line total product curve, OP, which passes through the observations for the efficient firms B and C. The additional constraint of the z vector has the effect of enveloping the data more closely allowing for variable and non-increasing returns to scale (IRS). The model is solved for different constraints on z. A scale efficiency coefficient of

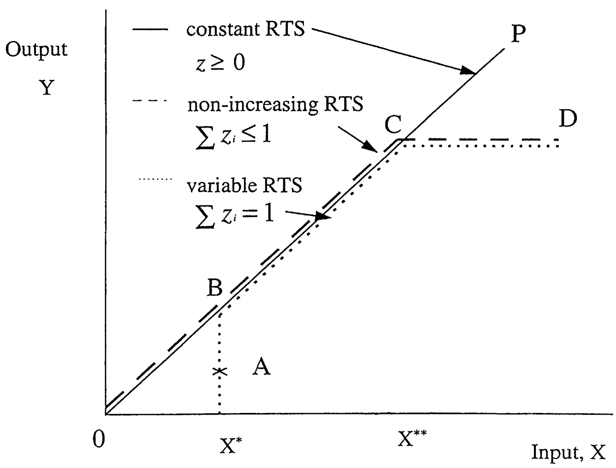

Fig. 1. Decomposition of scale efficiency.

less than one would indicate non-CRS. If the scale efficiency coefficient derived are the same for the non-increasing and variable returns constraint the farm exhibits decreasing returns. Similarly if these are not equal then the farm exhibits increasing returns.

3. Data

The study was performed using farm management data from 117, 96, 112 and 124 wine farms in four wine producing areas of the Western Cape, namely Stellenbosch, Robertson, Worcester and the Olifants River respectively. In 1995 these regions produced 53% of all wine grapes in the country, and represent all the major production systems found in the industry in South Africa. Information on input use, output realised and percentage age distribution of the vineyard were collected for the years 1992 to 1995. The farms included in the analyses have similar characteristics and operate in a similar institutional and marketing environment. All farmers are members of co-operative wine cellars implying very few, if any, scale economies in processing and marketing. All of the producers make use of permanent hired labourers whom reside on the farm. During peak times such as pruning and harvesting additional seasonal labourers are hired. Farmer's also share similar access to the credit market. The Co-operative Winegrower's Association (KWV) provides these farmers with extension services. The farms included in the sample are all commercial ventures with farm sizes ranging from 7 ha to 250 ha, with average capital invested at R43,000[1] per hectare, including the investment in vineyards (30% of total capital). An average yield of 26.8, 20.3, 9.0 and 18.0 tons per hectare were achieved in the Olifants River, Robertson, Stellenbosch and Worcester respectively with corresponding average farms sizes of 26.7, 37.2, 83.5 and 59.8 hectares. The farm sizes included in the sample should be considered in the context of the total net farm income on these farms. In all the regions the net farm income of the smallest farm is comparable to the salary of middle level management positions in rural non-farm enterprises such as co-operatives and banks. Between 80 and 100% of gross

[1]As of November 1996, the exchange rate was R4.70=US$1.

farm income is earned from the sale of grapes to cellars for wine making.

One output and seven input variables were used in the analysis. Wine grape production was used as the output. The inputs used were fertilizer, herbicides, pesticides, labour, machinery, vineyard improvements and land. Machinery was converted into a flow variable by including depreciation, interest and running costs. The interest rate element reflects the opportunity cost of holding capital. A 5% interest rate on the land value was used as a measure of the flow resource of land (Nieuwoudt, 1987). The value of outputs and inputs were used to account for quality differences. The opportunity cost approach was used to derive the value of family labour. No adjustments for land quality was made since the differences between vineyards in the growing areas are negligible. Management and information is also a significant input, this was not explicitly included in the model. Technical and marketing information is provided by KWV free of charge.

4. Results

4.1. Returns to scale of wine grape producers

The results in Table 1 suggest that approximately 50% of wine grape producers in the Western Cape experience CRS with approximately 10% and 40% having increasing and decreasing return to scale, respectively. The scale efficiency scores in Table 1 shows the distance of farms from the scale efficient frontier. Even though there appear to be a relatively large number of farms experiencing DRS, the magnitude of these scores is close to 100, where 100 implies CRS. These are consistent with the general view that the returns to scale in agriculture tend to be constant. The small percentage of farms experiencing IRS is a reflection of the farmer co-operative membership with wine cellars resulting in limited scale economies in processing and marketing. The results also shed some light on the relationship between returns to scale and farm size and productivity. The value of output and the farm size column in Table 1 suggest that farms experiencing IRS are on average smaller than those with CRS. There is no consistent relationship between farms with DRS and farm size. The total factor productivity estimates are consistent with the returns to scale result, with farms exhibiting CRS being more productive than those with increasing or decreasing returns.

4.2. Farm size–productivity relationship

Table 2 shows the *t*-statistics of a simple regression of productivity on farm size.

Table 1
Average output, farm size and TFP indices for farms exhibiting increasing, constant and decreasing returns to scale

Region	Year	Percentage of farms			Scale efficiency score			Value of output index			Farm size index			Total factor productivity		
		IRS	CRS	DRS	IRS	CRS	DRS	IRS	CRS	DRS	IRS	CRS	DRS	IRS	CRS	DRS
Olifants	1992	6	56	38	92	100	94	62	100	92	60	100	95	84	100	79
	1993	0	49	51	–	100	97	–	100	99	–	100	112	–	100	77
	1994	11	57	32	90	100	93	48	100	136	52	100	167	80	100	86
	1995	3	52	45	88	100	98	31	100	109	50	100	113	82	100	87
Robertson	1992	21	46	32	92	100	92	46	100	110	52	100	115	89	100	82
	1993	9	59	32	85	100	96	33	100	80	49	100	88	73	100	85
	1994	13	54	33	76	100	87	47	100	116	45	100	136	72	100	74
	1995	18	59	23	75	100	82	24	100	79	38	100	102	72	100	70
Stellenbosch	1992	13	42	45	87	100	91	49	100	104	65	100	124	79	100	83
	1993	14	36	50	79	100	83	36	100	95	47	100	117	75	100	73
	1994	19	31	50	85	100	89	29	100	91	44	100	128	73	100	77
	1995	9	44	47	89	100	96	36	100	108	55	100	137	83	100	74
Worcester	1992	8	38	54	91	100	89	40	100	88	41	100	108	91	100	76
	1993	7	40	53	98	100	91	61	100	101	72	100	135	71	100	76
	1994	6	33	61	67	100	93	28	100	102	45	100	146	63	100	75
	1995	4	56	40	89	100	96	19	100	75	25	100	113	56	100	70

Table 2
t-Statistics for regressions of the respective variables on farm size

Region	Year	Farm size				Number of labourers			
		Linear		Logarithms		Linear		Logarithms	
		Yield	TFP	Yield	TFP	Labour productivity	TFP	Labour productivity	TFP
Olifants	1992	−0.59	1.07	−0.68	0.36	**−2.25**[b]	0.88	**−2.46**[b]	0.68
	1993	**−1.93**[b]	−0.43	**−1.73**[b]	−0.53	**−1.55**[a]	−0.92	**−1.38**[a]	−1.12
	1994	**−2.06**[b]	0.02	**−1.44**[a]	0.54	−1.30	0.62	−0.67	1.11
	1995	**−2.35**[b]	−0.19	**−2.33**[b]	−0.27	−0.60	−0.88	−0.57	−1.04
Robertson	1992	−0.07	0.49	0.57	0.55	−1.10	−0.58	−0.65	−0.04
	1993	−0.15	0.59	−0.01	0.27	**−1.40**[a]	−0.01	**−1.65**[a]	−0.31
	1994	−0.31	0.51	−0.21	0.64	−0.59	−0.50	−0.50	−0.23
	1995	−0.30	1.25	−0.30	0.83	−1.14	−0.66	−1.22	−0.29
Stellenbosch	1992	1.33	1.15	**1.47**[a]	0.85	**−1.64**[a]	−0.02	**−1.86**[b]	0.39
	1993	0.88	1.07	0.94	**1.48**[a]	−0.77	0.06	−0.56	0.36
	1994	**1.44**[a]	−0.58	**1.72**[a]	−0.24	**−2.04**[b]	−0.77	**−2.05**[b]	−0.08
	1995	0.15	−1.21	0.63	−1.23	**−3.46**[b]	**−1.60**[b]	**−6.27**[b]	**−1.81**[b]
Worcester	1992	0.08	−0.54	0.03	−0.16	−1.23	0.45	−0.86	**−1.38**[b]
	1993	−0.05	−1.27	0.73	−1.18	**−2.67**[b]	**−1.36**[a]	**−3.32**[b]	−0.71
	1994	−0.59	−0.56	−0.79	−0.78	**−1.34**[b]	−0.79	**−1.73**[b]	−0.99
	1995	−0.89	−0.70	−1.19	−0.92	−1.07	**−1.72**[a]	−1.17	−1.21

[a]10% significance level.
[b]5% significance level.

$$y = \alpha + \beta A + u \qquad (4)$$

where y is yield or total factor productivity, A is farm size, and u is the disturbance term. The equation was estimated both as a linear and log-linear function. The values in Table 2 are the t-statistics for the β coefficients in the relevant equation. A second relationship between labour productivity and total factor productivity and the number of permanent labourers employed was examined. This was performed in an attempt to test the hypotheses of a decline in productivity due to the decline in supervision with an increasing number of labourers, this captures the transactions cost of labour management. In this case, labour productivity and total factor productivity were simply regressed on the number of permanent labourers.

A number of important results are revealed in Table 2. An inverse relationship between farm size and both land and total productivity is weak and not consistent. In some cases, although not significant, it is positive. This is the case, particularly in Stellenbosch where some smaller farms are bought predominantly for aesthetic value and farming is not the primary activity of the owner. Regional differences also exist in the strength of the farm-size–productivity relationship with the Olifants River experiencing the most significant relationship. This region has the smallest farms ranging from 7 to 76 ha with an average farm size of 28 ha. The inverse relationship between productivity and the number of permanent labourers employed on the farm was stronger than the relationship between productivity and farm size. In all cases, the strength of the inverse relationship diminishes when total factor productivity measures are used relative to the partial measures such as land productivity, these partial measures do not take account of the differences in other inputs used.

Thus, the productivity differential favouring small farms over larger farms does not increase significantly with differences in size in the majority of the wine producing regions. This suggests that evidence supporting land reform on Western Cape wine farms based on the inverse relationship between farm size and productivity remains limited. However, farms in the industry cover a wide range of farm sizes, and the evidence supports the argument that it is feasible for new entrants to enter the industry with farms as small as 7 ha. This appears to be particularly relevant in the Olifants River where there is some evidence of a significant and negative relationship. However, it also appears feasible in the other regions where smaller farms are still relatively close to the efficiency frontier. Some analysts may argue that the stronger negative relationship between labour productivity and the number of permanent labourers provides evidence for increasing mechanisation. However, the constraint is that the nature of wine grape farming does not allow for intensive mechanisation. This in turn could be an argument for downsizing the present farm structure, as opposed to confining the arguments to the inverse relationship between farm size and productivity.

5. Conclusion

This paper analyses the returns to scale of wine producers in the Western Cape of South Africa and then tests the almost 'stylised fact' of the inverse-relationship between farm size and productivity. Both a partial productivity and total productivity measure were used. The results suggest that caution be used when advocating rural development policies based on the inevitability of an 'inverse relationship' existing in all sectors of agriculture. There appears to be a fairly weak inverse relationship which differs in significance between wine production regions. However, given the wide range of farm sizes in the industry, it appears feasible for new entrants to start with operations as small as 7 ha. The results suggest that it is misleading to generalise about the existence of the inverse relationship between farm size and productivity across all farming systems and regions. Finally, it is clear that there is no single optimum farm size for wine grape production in South Africa but rather an optimal distribution of farm sizes.

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