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Henry Haszler, Phillip Hone, Mary Graham and Chris Doucouliagos

Abstract

Improvements in the efficiency of agricultural production represent an important source of growth for the Fiji Islands economy. An analysis of the nature and extent of efficiency differences between root crop farmers suggests that there are modest, but economically significant gains that can be made from improving farm level efficiency. On average, around 25% of root crop production is lost due to technical inefficiency. Although our results did not show that larger producers were more efficient than smaller semi-subsistence producers we did find that focus on a smaller range of crops and concentration on farming in terms of work time both tended to improve the efficiency of farmers that produced dalo. The implications of these results for the agricultural R&D system are discussed. The key policy finding is that given the modest gains in production that are feasible from improving technical efficiency, a major growth in root crop production and consumption is likely to be more dependent on the introduction of new technology than the better dissemination of the existing technology.

1. Introduction

The economy of the Fiji Islands is currently suffering a sizeable downturn in the level of economic activity. Unemployment is rising and with negative GDP per capita growth of -7.1% in 2007 (see Table 1), and incomes are falling. The speed and extent of the economic recovery of the economy will depend in part on the ability of resource managers to make full and efficient use of the resources they have available to them. This applies as much to those producers involved in the rural sector as to those in manufacturing and service industries such as tourism. The efficient use of resources in the agricultural sector has the potential to expand agricultural production and increase exports. In doing so, the wellbeing of those involved, both directly and indirectly, in agriculture will improve through higher farm incomes and greater employment levels.

Table 1: Key Data on the Fiji Islands Economy, 2005-2007

	2005	2006	2007
Agricultural raw materials exports (% of merchandise exports)	6.1	5.5	6.5
Agricultural raw materials imports (% of merchandise imports)	0.4	0.3	0.3
Agriculture, value added (% of GDP)	14.5	13.2	15.1
Agriculture, value added (annual % growth)	0.9	-0.5	-5.7
GDP growth (annual %)	0.7	3.6	-6.6
GDP per capita growth (annual %)	0.1	3.1	-7.1
GDP (constant 2000 US$)	1,898,582,528	1,966,931,456	1,837,113,984

Source: World Bank, World Development Indicators Online, available at < http://ddp-ext.worldbank.org/ext/DDPQQ/member.do?method=getMembers&userid=1&queryId=6>, accessed June 9, 2010.

The Fijian Government has an important part to play in realising any potential improvements in farm level efficiency. The government has the responsibility to establish the infrastructure and environment necessary to support a viable and efficient farm sector. It can directly influence farm level efficiency through its research and development (R&D) efforts. Government R&D can expand the technologies available to farmers and, with the use of extension services, assist farmers to adopt those technologies that are both relevant and available.

Fiji has a well established and sizeable extension system with employees spread throughout the country. The extension system forms an important part of the rural development process and from both a national and an internal Ministry perspective, it is important that the considerable resources available to extension services are appropriately deployed. This deployment is currently primarily guided by the judgments of managers and policy makers as to where the prospects for returns on these limited resources are greatest. A high level of co-ordination both within the Department of Agriculture and with other government and non-government agencies concerned with rural development is required.

The objective of the analysis reported here is to provide input into the decision making process on the allocation of extension resources. We concentrate on root crops which are an important segment of the agricultural sector in terms of local food security and as a potential source of export income. Root crops include dalo, a strategically important crop to the Ministry, and a culturally significant food item.

This report provides evidence on the current level of efficiency of root crop producers as well as identifying the factors that are limiting the efficiency of these farmers. Estimates of the potential efficiency gains through the efforts of extension service are provided. We specifically analyse the differences between semi-subsistence and larger commercial producers, since both are important segments of the agricultural sector and may have very different extension needs. However, the analysis is essentially an exploratory, aggregative analysis of the issues surrounding agricultural production. The results are intended to be useful at a broad strategic level rather than a micro tactical level.

The structure of this paper is as follows: The meaning and measurement of efficiency is examined in Section 2. This is followed in Section 3 with an explanation of stochastic frontier analysis (SFA), the analytical method used in this report. Section 4 provides details on the data and the sampling method used to obtain the household survey estimates. A summary description of the survey results is presented. The division or the categorization of the sample into commercial and subsistence producers and other data issues is explained in Section 5. Results of the efficiency analysis are presented in Section 6, followed by the conclusion and policy implications in Section 7.

2. Measurement of Efficiency

A production function defines the maximum output (Y) obtainable from a given set of inputs (X). It describes the technical relationship between the inputs and outputs of a production process. The output may be a single good (dalo), or multiple goods, (dalo, root crops, bananas etc.) and inputs typically represent labour (L), capital (K), and other relevant materials such as fertilisers, seed material, etc (M). The output function can be written as:

$$Y = AF(L, K, M)$$

Where F( ) is a function that shows how the inputs, (L, K, M) are combined to produce the output (Y), with A representing the technology that is used to combine the various inputs to produce the outputs. As technology improves, the same quantity of inputs can produce more output.

The main properties of a production function are that at least one input is required to produce an output, that an additional unit of input will increase output, but if the additional unit is added to other fixed inputs, output increases by smaller and smaller amounts. As illustrated in Figure 1 below, the Law of Diminishing Returns applies to each variable input. That is, the increase in output becomes successively smaller as additional units of an input are added.

The best practice technology being used and how well an economic unit is performing, that is, the efficiency of a unit, can be measured by considering its position relative to the frontier production frontier. The everyday meaning of the term “efficiency” refers to a situation where no resources are wasted. It is widely used in the economic literature, particularly in agricultural economics and policy, and can be traced back to the work of Farrell (1957) where a simple measure of efficiency, accounting for a single output and multiple inputs, is defined. The efficiency of an economic unit is a “holistic measure”, in that it takes account of all resources used and all outputs produced in determining “how well” or “how effectively” the decision making unit combines inputs to produce output. Economic efficiency provides a measure for whole farm comparison independent of the level of inputs used, or output produced, and can be used as a benchmark to make comparisons across many producers. Economic efficiency is a product of allocative and technical efficiency.

Technical efficiency is a measure of the relationship between inputs and outputs. A farm is said to improve its technically efficiency if it can increase output without changing its input levels and/or can achieve the same output with fewer inputs. Technical efficiency is a measure of the success of a farmer in identifying and adopting the best technology for use on their farm.

Allocative efficiency focuses on the ability of an economic unit to select the best mix of inputs given input price relativities to minimize cost by substituting or reallocating inputs. An efficient level of output will be generated at minimum possible cost using the most appropriate technology with the least cost input mix.

In this analysis we focus on technical efficiency (or sometimes called productive efficiency).

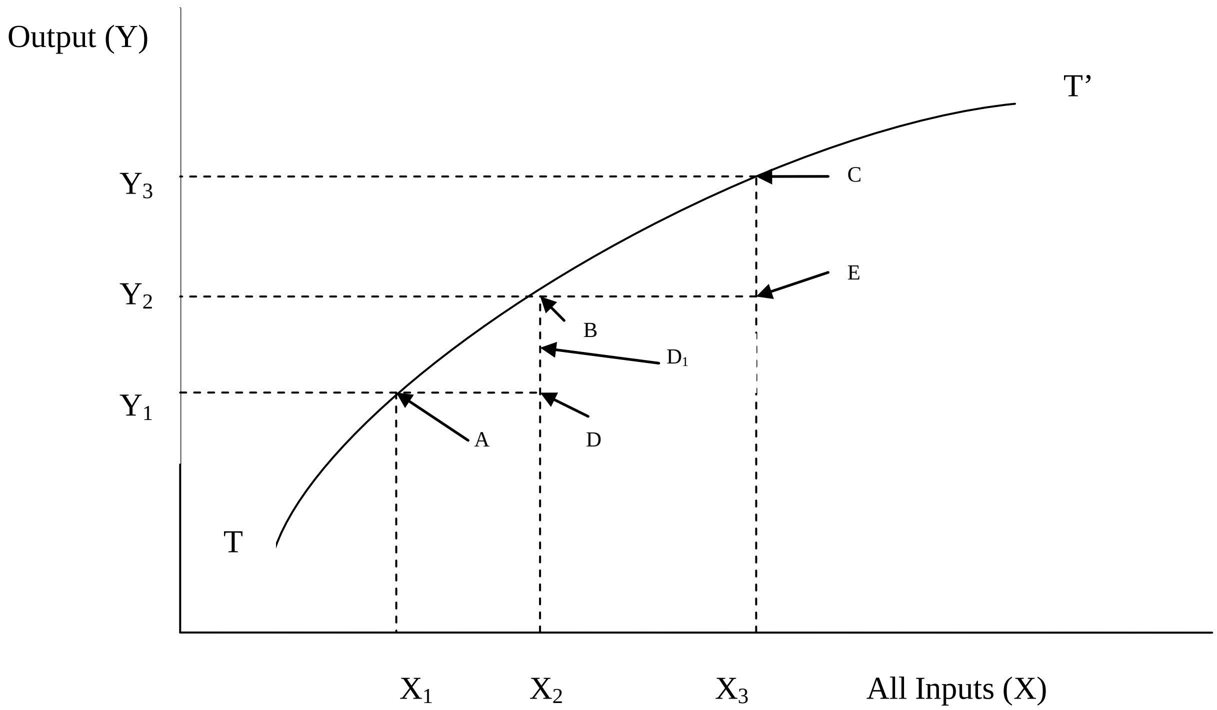
Partial measures of farm performance include productivity indicators such as output per acre or output per worker. These partial measures are unreliable indicators of performance and overall farm efficiency because they do not take into account the differences in input mixes that occur over time and between farms. For example, hiring more workers may expand output per acre while reducing output per worker. The real net impact of the change is only evident if a total measure such as technical efficiency is assessed that takes into account all inputs and all outputs.

Using an output orientated measure, the approach adopted to measuring efficiency in this analysis is portrayed in Figure 1 below. The horizontal axis (labeled X) measures the summation of all inputs used in production while the distance along the vertical axis (labeled Y) measures the total level of output. The curve TT´ represents the production frontier. It represents the highest level of output that can be produced, given the level of inputs and the available technology at a point in time in the industry. It is a best practice frontier showing the range of technically efficient options available to farmers. The points A to E marked in the figure represent the position of individual farms. For example Farm A, a small farm, uses X_1 inputs to produce Y_1 output while the larger Farm E uses X_3 inputs to produce Y_2 outputs.

The efficient farms in this example are farms A, B and C. They are all equally efficient because they lie on the best practice frontier. Farm A could be a small subsistence farmer using a technology characterized by few purchased inputs while Farm C might be a larger, commercial operation with a mechanised production system. All farms that are off the frontier are inefficient. Consider Farm D. It is inefficient because other farms (such as A and B) have demonstrated that it is possible to produce the same level of output (Y_1) with less inputs (see Farm A) and/or using the same inputs (X_2) it is possible to produce more output (Farm B produces Y_2).

Farm E produces more output than Farm A but is less technically efficient. To become efficient Farm E would have to reorganize its operations to expand output to Y_3 with the same inputs or reduce input use to X_2 while maintaining output at Y_2 (or some mix of these two strategies).

Figure 1: A Production Frontier



Technical efficiency identifies the best practice producers and measures performance of other producers in relation to the best practitioners. A technically efficient farmer will be adopting the 'best practice' production methods for a farm of their size and a given state of technology.

Technical inefficiency is the ratio of actual production achieved relative to the maximum possible given the inputs. It is measured as the distance the farm is away from the best practice frontier TT´, either as the percentage of inputs wasted (input orientation) or the percentage of output forgone (output orientation) by not using the most appropriate technology.

A technically efficient farmer will receive a performance score of 100% and the performance of other producers will be measured in relation to 'best practice'. Farmers who are not at best practice are given a score of less than 100%, and the extent to which they are operating at less than 100% indicates the extent to which performance could be improved if they were able to reach the standard of the best-practice farmers. For example, assume that Farm D in Figure 1 above has an inefficiency score of about 60%. This means that better farm level decision making could reduce input use by 40% or expand output production by 40%. The improvements in efficiency could come from a number of sources such as choosing a more appropriate input system like applying fertilizer at the appropriate time and levels, given the soil and climate conditions, or choosing disease resistant varieties to plant.

The farm level observations (A to E) are typically collected by surveys of farmers where detailed records of input use and output production are collected.

3. Analytical Method

To measure technical efficiency we need to understand the production systems of the most efficient farms. Farrell (1957) suggested that this information can be estimated from sample data. A parametric function, using econometric or statistical techniques, or a non-parametric function, using mathematical techniques, can be estimated. Stochastic Production Frontier Analysis (SFA) is a popular parametric technique and Data Envelopment Analysis (DEA) is a commonly used non-parametric estimation technique. Both compare outputs with inputs and rank the individual units in terms of their relationship to the best practice standard. If DEA techniques are used, the best practice (i.e. the highest output) is based on the most efficient farm, whereas if SFA is used, the best practice frontier is statistically estimated or inferred from the data collected and individual farms compared to the frontier (Abbott and Doucouliagos 2009). For a review of each method see Coelli, Rao, O'Donnell and Battese (1998). The literature contains numerous examples of both DEA and SFA being used to obtain performance measures of different agricultural sectors in both developed and developing economies.

The main strength of the SFA econometric approach is that it allows for errors in recorded data and other random factors beyond the control of a farmer such as weather, plant diseases and pests, and identifies the effect of these errors separately from inefficiency. However, SFA, being parametric, requires both an explicit functional form for the underlying technology and an explicit distributional assumption for the inefficiency term to be imposed. A full discussion of the different models can be found in the literature (see for example, Battese and Coelli 1988, and 1992).

No approach is strictly preferable. The choice of method essentially depends upon the objective of the research, the data to be utilised, and the intrinsic characteristics of the framework under analysis. If the aim of the research is to generalise from the sample to the larger population, then SFA, given its ability to undertake statistical testing, can be argued to be more appropriate. SFA provides technical information relating to each of the parameters and for this reason it is the method chosen to examine the performance of Fijian agriculture reported here.

A major limitation of the stochastic production frontier analysis is its ability to accommodate only one aggregated output, and hence where multiple outputs are considered, a stochastic distance function approach, rather than the production function approach, is used. Both approaches are considered in this paper.

3.1 Stochastic Frontier Analysis

Stochastic production frontiers were first developed by Aigner *et al*. (1977) and Meeusen and Van den Broeck (1977) and are now widely used and reported in the literature to measure farm performance (see for example, Battese and Coelli 1992, Coelli and Battese 1996, Kompas and Che 2006). The specification allows for a non-negative random variable, μ_i, associated with the technical inefficiency (TE) of the i-th farm, to be generated, as well the normal error term, v_i, to capture random variation in output due to factors beyond the control of farms, such as variation in weather patterns, measurement error or any unspecified input variable. The random error term can be positive or negative, and thus the frontiers vary about the deterministic part of the model, $\exp(x_i\beta)$.

In Figure 1 above, Farm D uses X_2 inputs to produce Y_1 output. If there are no inefficiency effects, the frontier output could be D_1. This is below the deterministic part of the frontier (point B), therefore the noise and inefficiency effects are negative. The distance between point D and point D_1 represents inefficiency, while the distant between D_1 and point B represents variation due to random events.

The specification can be formally expressed by:

$$Y_i = f(X_i, \beta)e^{v_i - u_i}$$

where *Y* denotes output, *X* the factor inputs, the subscript *i* identifies the farm, β represents the parameters to be estimated and *e* the error term reflecting both inefficiency, u_i and noise factors, v_i. The production frontier shows the relationship between inputs (for example, labour, fertiliser, seed) and outputs (crops), and the value of β indicates the relative importance of each input to the production process (Kompas and Che 2006).

A parametric production frontier needs to assume a functional form and two forms that are relatively easy to derive and commonly used in efficiency analysis are the Cobb-Douglas and the translog production functions.

A Cobb-Douglas stochastic frontier, using the terminology of Coelli *et al*. p.184 (1998) is defined by:

$$\ln(y_i) = x_i\beta + v_i - u_i \quad i=1,2\ldots.N \tag{1}$$

[1]

where

- $\ln(y_i)$ is the logarithm of the output of the i-th sample farm (i = 1, 2….n)
- x_i are the logarithms of the input quantities used by the i-th farm
- β is a column vector of unknown parameters to be estimated
- u_i is the technical inefficiency (TE) of the i-th farm and is this case study assumed to be an independent and identically distributed (i.i.d.) half normal random variable, and

[1] Where there are observations over time (i.e. panel data), a time trend, (t), is usually included in the model.

- v_i is the random error term, assumed to be an i.i.d. normal random variable with mean zero and constant variance, σv^2, independent of the u_i.

The technical efficiency of the i-th farm, in time period t, is given by the ratio of observed output to the maximum potential output, as defined by the frontier.

In addition to estimating the levels of technical efficiency among farmers, the factors influencing efficiency can also be examined. The literature contains studies using a two stage model where the predicted inefficiency effects are regressed upon a vector of farm specific factors, such as age or experience of the farmer (Coelli *et al.* 1998). However, this method means that the farm specific factors in the second stage regression are not identically distributed as the model assumes. Hence, Battese and Coelli (1995) recommend that the production frontier and the determinants of inefficiency be estimated in a single step model involving a stochastic production frontier as given above, as well as an equation that explains the technical inefficiency effect:

$$\mu_i = \delta_0 + z_i\delta \qquad (2)$$

where z_i refers to farm specific variables which are associated with technical inefficiency, and δ represents parameters to be estimated.

Details on the estimation of the stochastic frontier together with the inefficiency equation, using maximum likelihood techniques, as well as the measurement of individual efficiency scores can be found in Battese and Coelli (1995). Applications of this technique to areas of economics include Battese and Coelli (1995), Battese and Broca (1997), Paul *et al.* (2000) and Balcombe, Doucouliagos and Fraser (2007).

Equation 1 represents a single output frontier. In the present study our main focus is on an aggregation of all root crops, as root crops are of major economic importance to the Fiji Islands. Appendix B presents results for other crops, such as cassava, bananas and sugar. The analysis is then expanded into a multi-output production system with the use of a distance function, focussing on the production of both dalo and cassava. An output distance function describes the extent to which a farm can expand its output vector with a given set of inputs (O'Donnell and Coelli 2005). The distance measure, D_{oi}, is, with a given input level, the inverse of the factor by which the production of all output quantities could be increased and remain within the feasible production set. Hence it is equivalent to an output-orientated measure of technical efficiency (O'Donnell and Coelli, 2005).

A translog specification allows for the interaction between the various inputs and outputs. It is a functional and flexible form with the cross terms, that is, the interaction terms, providing valuable information on input and output substitution possibilities (Abbott and Doucouliagos 2009). However, to ensure symmetry and homogeneity in outputs, it is necessary to impose a number of constraints on the output distance function (see O'Donnell and Coelli 2005). This is achieved by arbitrarily choosing one of the outputs as the normalising variable[2].

A translog output distance function, with *M* outputs (*m=1…M*), *K* inputs (*k=1.. K*), *B* exogenous variables (*b=1…B*), time (*t*=1, … *T*) as a proxy for technical change, and *I* farms (*i=1, … I*), is represented by equation (5):

$$\ln D_{oit} = \alpha_0 + \sum_{m=1}^{M} \alpha_m \ln y_{mit} + \frac{1}{2} \sum_{m=1}^{M} \sum_{n=1}^{M} \alpha_{mn} \ln y_{mit} \ln y_{nit} + \sum_{k=1}^{K} \beta_k \ln x_{kit} + \frac{1}{2} \sum_{k=1}^{K} \sum_{l=1}^{K} \beta_{kl} \ln x_{ki} \ln x_{li} + \sum_{k=1}^{K} \sum_{m=1}^{M} \gamma_{km} \ln x_{kit} \ln y_{mit} + \sum_{m=1}^{M} \sum_{b=1}^{B} \gamma_{mb} \ln y_{mit} r_{bit} + \sum_{k=1}^{K} \sum_{b=1}^{B} \gamma_{kb} \ln x_{kit} r_{bit} + \delta t + \frac{1}{2} \delta t^2 \quad (3)$$

where *ln* denotes natural log, D_0 denotes the output-orientated distance (which is a function of v and u), *y* denotes an output, *x* denotes an input, *r* denotes exogenous explanatory variables, and the necessary constraints are imposed in order to ensure that homogeneity of degree one in outputs as well as symmetry. If we assume the distance a farm lies from the frontier may be due to statistical noise or inefficiency, we can add the error terms, v_i and μ_i to give the standard stochastic production fronteir model (for full details see O'Donnell and Coelli 2005).

In this case study, we estimated equations (1) and (2) jointly for all root crops combined and then estimated equations (3) and (2) jointly for dalo and cassava.

To estimate the production frontier, data on 4 inputs, namely land, labour, capital and purchased inputs, was used. Appendix A provides details on the measurement and aggregation of each of these variables. The efficiency results for the different production systems are presented in Section 6.

4. Data Sources

In this analysis the data was collected from a face to face farm survey of rural food producing households conducted by Ministry of Agriculture staff in 2007. The survey was based on a quasi-random sample. The survey list from Fiji's Household Income and Expenditure Survey (HIES) undertaken over 2002 and 2003 was used as the sampling frame. Narsey (2006) provides a description of the HIES and summarises some of its results.

To be included in the survey, households had to have sold any one of a number of farm products and/or to have indicated their involvement in subsistence food production in 2003[3]. The HIES

[2] When multiple outputs are produced, for example both dalo and cassava, the output of one product, for example, cassava, is divided by the dependent variable, dalo output, and the resulting data used as an input in the dalo production function.

[3] The urban component of the HIES was conducted over March 2002 to February 2003, while the rural survey covered the period May 2003 to April 2004. As Narsey (2006, p.1) explains, the urban and rural components of the HIES had to be split because of funding constraints related to the political events of 2000.

identifies a total of 20 agricultural and fisheries products including cassava, dalo, rice, bananas, pineapples, poultry, sugarcane and yaqona.

Table 2: Selected Details of Rural Sample (Number of households)

Category	Central Division (a)		Northern Division		Western Division		Total Fiji (a)		
	HIES	Sample	HIES	Sample	HIES	Sample	Total Population	HIES	Sample
					Ethnic Group				
Fijian	687	336	271	197	376	171	51,282	1,334	704
Indo-Fijian	53	21	210	103	583	84	30,631	846	208
Other	19	1	25	15	6	1	1,756	50	17
	759	358	506	315	965	256	83,669	2.230	929
					Source of Commodity Earnings (b)				
Cassava	187	120	10	10	84	59	10,582	281	199
Dalo	1	1	17	17	0	0	716	18	18
Rice	218	161	108	93	59	52	15,781	385	306
Sugarcane	0	0	63	31	306	52	13,128	369	83
Yaqona	218	134	131	109	51	45	16,196	400	288
Bananas	91	67	5	5	58	49	5,559	154	121
Pineapples	16	12	5	5	6	6	1,062	27	23

(a) Eastern Division included in Central Division. (b) Households reporting earnings from the products shown.
Source: Personal Communication, Toga Raikoti, Fiji Islands Bureau of Statistics, October 2006.

The sample was stratified by statistical division and households clustered in order to reduce travel costs. We were also mindful of including adequate numbers of Fijian and Indo-Fijian households because earlier research by Tubuna *et al.* (2007) had indicated differences in the farming systems applicable to the two groups. For financial reasons we did not include households from the more remote outer islands but households from relatively isolated areas on Viti Levu and Vanua Levu were surveyed. The survey also covered the island of Kadavu as it is an important location for commercial yaqona production.

Details of the original sample of 929 households are summarised in Table 2. The data suggest the sample is broadly consistent with the geographical and ethnic distribution of rural households and also with their agricultural commodity focus. Overall the HIES sample represents 2.7 per cent of rural households. The sampling fraction for Fijian households is slightly lower than the average while that for "Other" ethnic groups is somewhat larger. Our sample of 929 households represents a 1.1 percent sample of the population. Broadly speaking, our sample sizes are about

40 percent of the respective HIES samples. However, Indo Fijian households are underrepresented in our sample. The under-representation reflects the fact that relatively few Indo-Fijian households in the Western Division met our selection criteria, which included the production of crops other than sugar.

5. Identifying Subsistence Households

To examine the performance of the farm sector in Fiji, we need to identify and separate the different household types to develop the productive unit for analysis. Most of the households sampled are multi-product households in the sense that they produce more than one product, and a member of the household engages in some form of paid employment. The home use ratio and the farm income ratio as measures of subsistence activity are first examined. Then using data contained in the Tikina Profile Survey, households are classified into three categories: discrete subsistence, semi-commercial and commercial categories. The classifications are based on the value shares that home use makes up for the production of all crops, all farm products and the joint home use ratio.

Many rural households in Fiji, the other Pacific Islands and in the developing countries generally, can be described as subsistence households. Such households have relatively little connection with commercial markets and are generally low income households which meet appreciable shares of their needs – especially for food – through their own production activities. The food production of these households may be quite cost efficient in terms of achieving given levels of output at minimum cost. However, subsistence food production commonly relies on very few purchased inputs, such as fertilisers and farm chemicals, and so results in lower output per unit of land than the available production science and technology would allow. So, as a result of these distinctions, it is important to identify subsistence households when analysing farming efficiency in countries such as Fiji where subsistence production is an important component of the food system.

A household can be a subsistence producer either in terms of its output of individual farm and food products, or in terms of its overall activities, or both. For example, a household producing sugarcane or dalo on a fully commercial basis may also grow vegetables and fruit purely for home consumption in a "kitchen garden". So when analysing production efficiency for a single commodity it may be relevant to consider two measures or definitions of subsistence activity.

At the individual commodity level, *pure subsistence production* occurs where the household itself *consumes all* it produces. That is, home use equals 100 percent of the household's production. Alternatively, *pure commercial production* occurs where the household *sells all* it produces, holding nothing back for its own consumption. At the household level, a pure subsistence household would be defined as one which produces within the household absolutely everything it consumes, including food, shelter, medicines and even its tools. Alternatively, a pure commercial household would be one that sells all its available labour and intellectual services to the market and buys in all its consumption needs, even cleaning and other household services. Most – if not all – households in rural Fiji – and possibly everywhere else – fall between these definitional extremes. So "subsistence" households are best defined or identified by some type of relative measure.

A complicating factor is that most of the households in the sample are multi-product households in two senses. First, those households engaged in rural production generally produce more than one farm or food product. Second, many households have some of their members engaged part-time or full-time in off-farm work – as wage and salary earners employed by others or in running their own non-farm businesses. Some households also receive income in the form of pensions, remittances and other transfer payments. Table 3 below shows the income levels of the sampled households in the Northern, Central and Western Divisions, and the extent to which different crops are consumed at home.

Table 3: Income Sources and Home Use Ratios: Fiji Divisions

Item	Central Division		Northern Division		Western Division	
	Income $'000	Home Use Ratio	Income $'000	Home Use Ratio	Income $'000	Home Use Ratio
Crops/Crop Groups						
Root Crops	942	0.47	890	0.51	555	0.34
Cereals	0	0.01	288	0.08	54	0.03
Vegetables	300	0.15	67	0.36	214	0.26
Fruits	407	0.19	1,460	0.38	267	0.18
Sugarcane	0	0.00	567	0.00	832	0.00
Yaqona	1,189	0.22	1,972	0.31	324	0.06
Other Crops	67	na	15	na	39	na
Fresh Fish/Livestock	961	0.23	534	0.29	730	0.17
All Farm, Fish, Livestock	3,867	0.37	5,791	0.41	3,015	0.23
Non-Farm Income						
Business Income	318	na	708	na	143	na
Wages and Salaries	827	na	1,134	na	529	na
Welfare Payments	37	na	12	na	51	na
Remittances	75	na	48	na	48	na
Other Non-Farm	55	na	122	na	40	na
All Non-Farm Income	1,313	na	2,023	na	811	na
All Household Income	5,180	0.31	7,815	0.28	3,826	0.17

Note: Crop, fish and livestock incomes are estimated gross values of production at local market prices. The Home Use ratios for All Household Income are the joint adjusted ratios. All values in Fijian dollars.

The *relative* indicator of a household's subsistence status can be either a *continuous* variable or, based on that, a form of dummy variable reliant on *absolute cut-off points* that result in households being allocated uniquely to one group or another. For this analysis we test both forms of this variable. We also consider subsistence indicators for individual farm products, groups of farm products and a joint measure for the household overall. The overall joint measure relies on multiplicatively combining a measure of the relative importance of subsistence food production to the household with a measure of the relative importance of farm and food production in the household's overall income.

The reasons for using such a joint income/farm-activity measure are illustrated by the classification scheme in the following diagram for which for simplicity households are assumed to have discrete rather than continuous characteristics in terms of the two variables (see Figure 2).

Figure 2: Household Status

		Farm Income Ratio	
		Low (0.20)	High (0.80)
Home Use Ratio	Low (0.20)	"Sideline" Commercial Farming 0.20 x 0.20 = 0.04	Commercial Farming 0.20 x 0.80 = 0.16
	High (0.80)	"Sideline" Subsistence Household 0.80 x 0.20 = 0.16	Subsistence Household 0.80 x 0.80 = 0.64

Households might be classified on two criteria. On the first criterion households would be identified as having either a low (assume 20 percent) or a high (80 percent) share of their aggregate income coming from their farming and fishing activities. On the second criterion, households would be grouped according to whether their home use of food accounts for low (again assume 20 percent) or high (80 percent) share of their overall food production.

To enable aggregation over direct income and different commodities these shares need to be defined as value shares. The values used here are the actual household incomes from non-farm sources as reported in the survey and the estimated gross values of household farm and fishing production (GVP).

We define a household's *Farm Income Ratio* as the ratio of the estimated gross value of the households' food and fish production to the total value of the household's income – measured as direct income earned and received from all sources plus the estimated food/fish GVP. Our estimates of these gross values are based generally on prices at local markets (see Table 4). For households in the Central (and Eastern), Northern and Western divisions respectively we use average 2007 prices at the municipal markets in Suva, Labasa and Sigatoka as reported by the MoA or average 2007 prices for those Divisions collected by the Fiji Islands Bureau of Statistics (FIBoS) for compiling Fiji's CPI.

A typical household falling in the top left quadrant of the diagram might rely mainly on wages and salaries income or income from a non-farm business. However, these households may also produce commercial quantities of farm products in the sense that their farm output is well above their own needs. These households may be made up of, say, two parents engaged in commercial level farming and fishing activities plus adult children with well paying off-farm jobs. Households in the top right quadrant would represent commercial farming operations in the sense that farming provides their main source of livelihood *and* they sell the bulk of their produce.

Table 4: Average Prices in 2007 and Assumed Marketing Margins

Commodity	Households Producing	Marketing Margin (a)	Division/Municipal Market		
			Central/Suva	Northern/Labasa	Western/Sigatoka
	No.	Ratio	$/kg	$/kg	$/kg
Selected Crops					
Bananas	345	1.250	1.36	1.36	1.26
Beans	34	1.250	3.63	2.12	1.95
Cabbage	72	1.250	2.83	1.70	2.90
Cassava	670	1.250	0.84	0.63	0.57
Chilies	28	1.250	4.36	3.32	2.61
Coconuts (b)	130	1.250	1.67	1.26	3.25
Cucumbers	16	1.250	1.19	1.14	1.39
Dalo	629	1.250	1.02	1.00	1.22
Eggplant	49	1.250	1.18	0.74	1.14
Ginger	18	1.250	2.08	1.63	2.29
Pawpaws	107	1.250	1.26	1.22	1.21
Peanuts	3	1.375	5.16	5.15	3.73
Pineapples	118	1.250	1.67	1.49	1.74
Pumpkins	10	1.250	0.96	0.87	0.76
Rice (c)	66	1.000	0.36	0..36	0.36
Sugarcane	138	1.000	0.06	0.06	0.06
Tomatoes	21	1.250	4.44	2.11	2.98
Vudi (d)	88	1.250	1.36	1.36	1.26
Watermelon	33	1.250	2.05	1.19	1.50
Yams (e)	77	1.250	1.04	1.17	1.64
Yaqona (f)	339	1.375	26.93	29.58	20.85
Fresh Fish (g)	266	1.250	7.59	5.66	6.99
Livestock					
Cattle (h)	323	1.000	266.37	266.37	266.37
Eggs (i)	25	1.250	3.56	4.02	3.75
Goats (h)	144	1.000	38.42	38.42	38.42
Milk (i)	27	1.250	1.50	1.63	1.51
Pigs (h)	230	1.000	101.61	101.61	101.61
Poultry (i)	252	1.250	8.93	6.34	6.89

Note: Unless indicated otherwise, prices quoted are average prices in the indicated municipal markets. (a) A ratio of 1.25 indicates that the farm level price is assumed to be 25% less than the quoted market price. (b) Weight of 0.5 kg per coconut assumed. (c) Thai rice 5% brokens fob in USD, converted to FJD and paddy equivalent using 71% yield. (d) Same price as bananas assumed. (e) Price for uvi. (f) Weighted price of lewena (0.8) and waka (0.2). (g) Average of prices for kanace, kawakawa, sabutu, saqa and walu as collected by Fiji Islands Bureau of Statistics (FIBoS) for the CPI. (h) Average livestock buying prices reported by survey respondents. (i) Average FIBoS prices for CPI.

Sources: Personal Communication, Tevita Natasiwai, Economics and Statistics Division, Ministry of Agriculture and Primary Industries, Suva, May 2009; Personal Communication, Mitieli Cama and Peniasi Nasilivata, CPI Division, Fiji Islands Bureau of Statistics, Suva, August 2008.

Households classified into the lower left quadrant might again rely mainly on wages and salaries income or income from a non-farm business. But the farming efforts of these households are more likely to be characterised by kitchen gardening activities rather than more commercial levels of food production – hence the descriptive title for this group. As with their other "Sideline" counterparts, the "Sideline" Subsistence Households might comprise adult children in wage employment plus a retired parent couple who – in this case – may work full time as subsistence producers to maintain what for the household overall is essentially a kitchen garden. Finally, households in the lower right quadrant can be described unequivocally as subsistence households. They rely largely on their farming efforts for their livelihoods *and* consume most of what they produce.

In general, the higher is the composite ratio, the more likely that the household is a subsistence household. Households falling in the two top quadrants are more likely to be engaged in farming on a commercial scale relative to their own needs. And households in the two lower quadrants are more likely to be subsistence households, certainly as far as their food production and consumption are concerned. The potential overlap between the values of the ratios in the Low/High and the High/Low quadrants indicate the joint ratio may not distinguish very well between these two groups. The significance of this limitation is probably an empirical issue determined by the particulars of each data set.

For arithmetical convenience and to ensure that all households are brought into the joint variable, the Farm Income and Home Use ratios are each assigned a minimum value of 0.001 wherever either would otherwise equal zero. This makes the minimum value of the variable equal to 10^{-6}, or zero for all practical purposes. Theoretically speaking, there is no upper limit to the variable because Home Use of the various foods is defined to included own production as well as food purchased by the household. So a large household which buys in most of its food can generate a very high Home Use ratio. The maximum values in the data set are 76.7 for all crops taken as a group, 4.8 for all fish and livestock items and 9.7 for all farm products as a group. Nevertheless, the maximum value of the household Joint Home Use ratio in the data set turns out to be 1.25.

The correspondence between the raw and adjusted (i.e. 0.001) Joint Home Use ratios and the distribution of the adjusted joint ratio is shown in the following figure. Note that to help focus the comparison on the bulk of the data set, the axes in Figure 3 have been constrained to maximum values of 1.0 with the result that some outliers are not shown.

As noted above, we also calculated raw – that is unadjusted and non-joint – Home Use ratios for, first, individual crops, second, for all crops as a group, third, for all livestock products as a group and finally for all farm products as a group. The distributions of the All Crop, All Farm and Joint Home Use ratios are shown in Figure 4. There is clearly a high correlation between the three data sets.

Despite their close correspondence, the three data sets do measure different things. Consequently even the apparently small differences may have considerable analytical significance. Therefore it is important to recognise that any one household can fall into a different ratio class (eg less than 0.1) for each of the three different measures.

Figure 3: Raw and Adjusted Joint Home Use Ratios

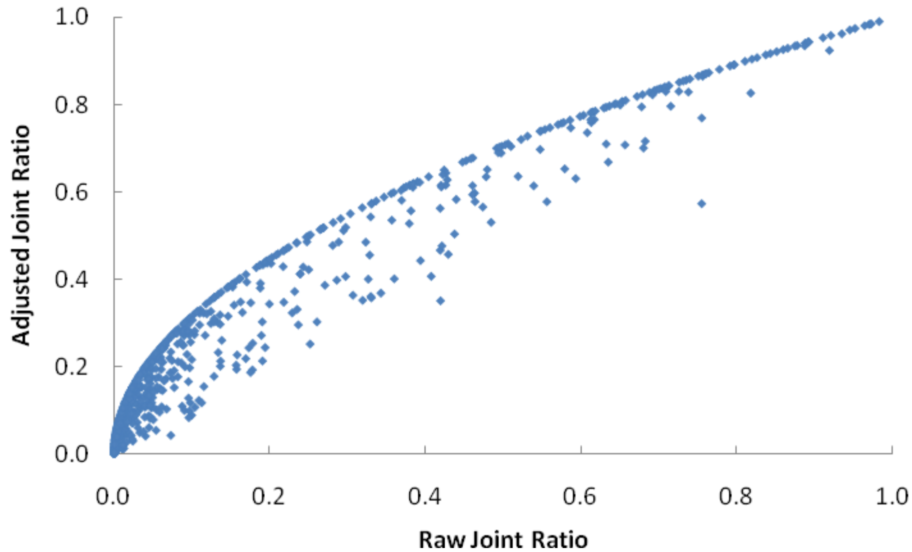
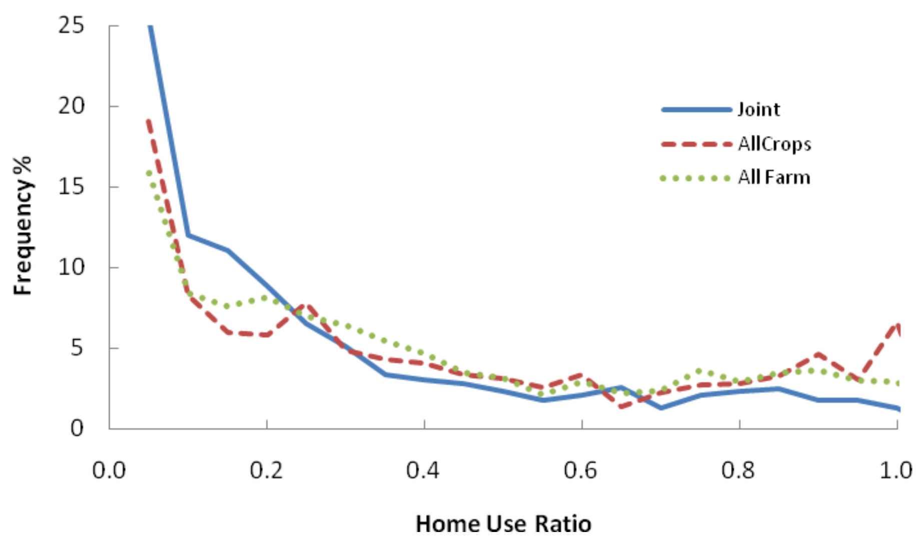


Figure 4: Distributions of Home Use Ratios



We also developed alternative discrete measures of household subsistence status for which we group households into discrete subsistence (Code 1), semi-commercial (Code 2) and commercial (Code 3) categories. These measures are derived from information for rural households obtained as part of the ongoing Tikina Profile Survey (TPS) conducted by the Ministry of Agriculture and Primary Industries (MAPI). The aim of the TPS is to provide a benchmark data set for each household to help inform extension advice to the farming community. Amongst other things, households are classified according to whether their farming activities are of a subsistence, semi-commercial or commercial scale. The classifications are made on an apparently qualitative basis by Ministry extension officers who carry out the progressive survey. The results of their classifications for four Tikina – for which the data were available – are shown in Table 5 below.

Table 5: Distribution of Rural Households by Business Type: Selected Tikina

Farm Type	Units	Naqalimare	Seaqaqa	Vitogo	Waicoba	Total Four Tikina
Subsistence	No.	23	130	149	145	447
Semi-Commercial	No.	3	98	8	43	152
Commercial	No.	175	85	342	21	623
	No.	201	313	499	209	1,222
Others	No.	0	0	24	2	26
All Households	No.	201	313	523	211	1,248
Subsistence	%	11.4	41.5	28.5	68.7	35.8
Semi-Commercial	%	1.5	31.3	1.5	20.4	12.2
Commercial	%	87.1	27.2	65.4	10.0	49.9
	%	100.0	100.0	95.4	99.1	97.9
Others	%	0.0	0.0	4.6	0.9	2.1
All Households	%	100.0	100.0	100.0	100.0	100.0

Note: Seaqaqa Tikina is in Macuata Province in the Northern Division. The other tikina are all in the Western Division, in Nadroga/Navosa, Ba and Nadroga/Navosa provinces respectively. The data cover the period 2005 (Seaqaqa) to 2008 depending on when the tikina was surveyed. The classifications of households to business types were made by MAPI staff on the basis of qualitative criteria.
Source: Personal Communication, Tevita Natasiwai, Economics and Statistics Division, Ministry of Agriculture and Primary Industries, Suva, July 2008.

While we do not have the extension officer classifications for our survey households, we can and do use their judgements to inform our classifications. For our classifications we use the value shares that home use makes up of household production for the groups All Crops and All Farm Products as well as for the overall household Adjusted Joint Home Use ratio. We identify cut-off points in the range of our continuous value based ratios that generate approximately the same percentages of households falling into each of the three categories as reported in the TPS data based on the extension officer's scoring. The results of our classifications are summarised in Table 6.

Despite the differences in cut-off ratios, there is a great deal of overlap in the classifications applied to individual households under the various home use ratios. The cross-tabulation below (Table 7) gives details of the numbers of households grouped identically (green cells) and differently (pink cells) under the different home use ratios. For example, the number 749 in the green cell indicates that 749 of the total of 860 households (grey cells) were identified to the same farm type status under the All Crops ratio as they were using the All Farm ratio. And 621 households were identically classified using the All Farm and the Joint Home Use ratios.

Table 6: Discrete Home Use Based Farm Type Classifications of Survey Households

Farm and Household Type	Target	All Crops		All Farm		Adjusted Joint Ratio	
	%	Cut-Off Ratio	Households %	Cut-Off Ratio	Households %	Cut-Off Ratio	Households %
Subsistence (a)	35	0.4750	35.1	0.4250	35.0	0.2625	34.5
Semi-Commercial	15	(b)	16.9	(b)	16.1	(b)	14.3
Commercial (c)	50	0.2625	48.0	0.2625	48.8	0.1625	51.2
	100		100.0		100.0		100.0

Note: Totals may not agree due to rounding. (a) The cut-offs are minimum home use ratios for subsistence households. (b) The home use ratios lie between those for the two other groups. (c) The cut-off shows the maximum home use ratio for commercial households.

Table 7: Cross-Tabulations

	All Crops	All Farm	Joint
All Crops	860	749	605
All Farm	111	860	621
Joint	255	239	860

In the cases where the classifications for a given household differed (the pink cells), the more comprehensive the measure of household income used, the more likely that differently classified households would be rated as relatively *more commercial* under the more comprehensive income measure. So nearly 60 percent of the 239 households classified differently under the All Farm and Joint ratios were classed as semi-commercial or commercial instead of subsistence or semi-commercial. However, only 44 percent of the 111 households differently classified using the All Crops and All Farm ratios were classified as more commercial under the All Farm ratio.

As with the continuous home use variables, the conclusion here is again that the three discrete classifications do measure different things. It follows again, therefore, that even the apparently small differences may have considerable analytical significance. Furthermore, the analysis of the discrete classifications confirms the earlier point that any one household can fall into a different farm type class (eg subsistence or commercial) for each of the three different home use measures.

6: Efficiency of Root Crop Producers

Based on the theoretical framework presented in Section 3, a generalised likelihood-ratio test was used to test for the functional form most appropriate for the sample data. In this case study, the Cobb-Douglas functional relationship was found to be the form that best summarized the data and using the computer program, Frontier 4.1, the level of technical efficiency of different crop producers is estimated. In addition, farm specific features that contribute towards the level of inefficiency are examined. The results of the analysis and the conclusions drawn reflect the sample data which, to ensure small farms were included, was drawn from the 2002/3 Fijian Household Income and Expenditure Survey, as discussed in Section 4. Since the sample is not strictly random, the results may or may not represent all of the agricultural producers in the Fijian Islands economy.

The specification of the variables used in the estimation process is outlined in Appendix A. Table 8 reports our basic results. Column 1 reports the results of estimating an aggregate production frontier (equations 1 and 2), with output measured as All Root Crops. This involves 395 farmers who used four inputs, land, labour, equipment and purchased inputs. Column 2 reports the results of estimating the output distance function (equations 3 and 2), for the 307 farmers who produced both dalo and cassava.

The top panel of Table 8 reports the parameter estimates of the production frontier/output distance function. All variables are expressed in natural log form and, hence, the coefficients can be interpreted directly as elasticities. A positive coefficient means that the output elasticity is positive. Land is the most important input for root crop production: A 10% increase in land increases total root crop production by 8.7% and increases dalo production by 8.2%. Land as an input incorporates the fertility of the soil, a reflection of both the soil type and rainfall pattern.

Equipment (a measure of capital stock) has a positive coefficient, though the output elasticity is small: A 10% increase in equipment increases all root crop production by 3.5% and dalo by 2.4%. Purchased inputs are also important for crop production, with a larger output elasticity than capital: A 10% increase in purchased inputs will, on average, increase dalo production by 4.2%, holding cassava production constant.

In contrast to these positive output responses, the coefficient on labour (family and hired) is negative for all root crop and positive for dalo production, but in both cases it is not statistically significant: An expansion in labour input will have no practical impact on crop production. This might reflect levels of inefficiency associated with larger family sizes and higher levels of available labour. Column 2 shows that there is an inverse relationship between dalo and cassava: An expansion in the cassava production comes at a cost of dalo production. This defines the production possibilities between these two root crops.

Table 8: Efficiency of Root Crop Producers

Variables	All Root Crops (1)	Dalo Producers (2)
Production Frontier/Output Distance Function		
Constant	8.995 (50.5)	8.113 (46.2)
Cassava	-	-0.518 (-22.7)
Land	0.869 (32.6)	0.816 (28.7)
Labour	-0.025 (-0.83)	0.023 (0.82)
Equipment	0.035 (2.19)	0.024 (1.82)
Purchased Inputs	0.076 (3.37)	0.042 (1.85)
Determinants of Inefficiency		
Constant	-0.815 (-0.75)	-6.985 (-1.96)
North (with Central as the base)	-1.207 (-2.47)	0.905 (0.96)
West (with Central as the base)	1.682 (2.47)	3.898 (1.99)
Head of Household is Female	-0.419 (-0.45)	0.123 (0.13)
Mataqali	-1.935 (-3.57)	-4.480 (-2.70)
Proportion of Time Spent on Farm	-1.790 (-2.76)	-4.245 (-2.56)
Years of Schooling	-0.022 (-0.47)	-0.002 (-0.05)
Adult Ratio	-0.376 (-0.47)	-0.366 (-0.42)
Number of Root Crops Grown	-0.403 (-2.14)	1.840 (2.47)
Number of Other Crops Produced (a)	0.816 (3.24)	0.696 (2.42)
Semi-commercial	-3.147 (-2.02)	1.564 (3.02)
Commercial	0.410 (1.00)	-0.764 (-0.23)
Gamma	0.87 (25.7)	0.94 (37.3)
Number of Farms	395	307
Average Technical Efficiency	0.76	0.77

Notes: Column 1 reports estimates of an aggregate production frontier (equations 1 and 2). Column 2 reports estimates of an output distance function (equations 3 and 2). Figures in parentheses are t statistics. (a) Sugarcane, vegetables, cereals, spices, etc. Gamma is the ratio of the variance parameters.

The estimated coefficients in the inefficiency model are of interest in this study. The bottom panel of Table 8 reports the estimates of the determinants of technical inefficiency in root crop production. A negative coefficient means that a variable is associated with greater efficiency. The location of a farm appears to be important for efficiency. Compared to farms in the Central region, farms located in the North are more efficient in all root crop production, but are equally efficient in terms of dalo farming. However, farms located in the West are less efficient than those in the Central region for both dalo and all root crops. Region no doubt captures a lot of factors such as climate and general agricultural conditions. It also reflects differences in off farm work opportunities, access to markets and the availability of cane production as an alternative to root crops.

The gender of the household head, years of schooling and the adult ratio, all have no effect on technical efficiency. In contrast, farms that were part of a Mataqali are more efficient. This could reflect advantages that come from the flexible access to land and labour these farmers have over those farmers dependant on leasehold land.

The proportion of available work time spent on farm is also an important influence on the efficiency achieved in the production of dalo and all root crops. Farm families that spend more time working off the farm tended to be noticeably less efficient than those more fully focused on the farm. That is, farmers not working substantial hours away from the farm tended to be more efficient than those working on their farms part time. This is consistent with the notion that those that are most reliant on the farm tend to put more effort into getting it right. Similarly, it means that those that have substantial outside work commitments don’t find it as worthwhile to fine tune their farming activities.

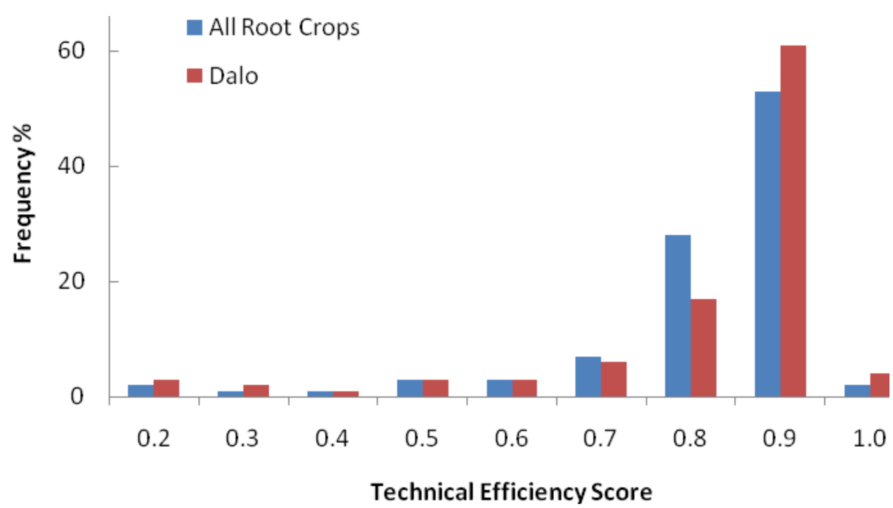
Crop diversity is important for efficiency. The number of root crops grown increases efficiency for root crops in general, but decreases efficiency in dalo production. The production of other types of crops (e.g. sugarcane, cereals and spices) is associated with lower efficiency levels in root crop production. That is, there are clear gains, in terms of efficiency, to specialization in farming.

The distribution of the technical efficiency scores is presented in Table 9 and illustrated in Figure 5. There are some extremely inefficiency farms in the sample. The average level of efficiency is 0.76 for all root crops and 0.77 for dalo. While these are relatively high, they do suggest that there is significant scope for expanding the production of root crops in Fiji. Nearly 45% of farms have an efficiency score of less than 0.80.

Table 9: Distribution of Efficiency Scores

TE range	All Crops		Dalo	
	Number of farms	% of farms	Number of farms	% of farms
0 < 0.2	7	2%	8	3%
0.2 < 0.3	4	1%	5	2%
0.3 < 0.4	4	1%	4	1%
0.4 < 0.5	11	3%	8	3%
0.5 < 0.6	11	3%	8	3%
0.6 < 0.7	29	7%	17	6%
0.7 < 0.8	110	28%	52	17%
0.8 < 0.9	212	54%	193	63%
0.9 < 1	7	2%	12	4%
Total	395	100	307	100

Figure 5: Technical Efficiency in Root Crop Production



We extended this analysis in three ways. First, we extended it to other crops. Second, we consider directly the effect of home use ratio on technical efficiency. Third, for each crop examined, other than sugar, two analyses were undertaken – one for farms that purchased inputs in the market place, and a second analysis, representing pure subsistence farming, of farms which used only three inputs, namely land, labour and some form of equipment (i.e. capital). Purchased inputs, rather than labour or capital, are important for increasing sugar production. Hence only commercial sugar production was analysed.[4] Separating the farms into the two groups provides a measure of the different technologies used by farmers and highlights the difference, if any, between commercial and pure subsistence farming. The number of producers included in the analysis ranges from one hundred and forty eight commercial banana farmers to just fewer than five hundred commercial farmers when all crops are aggregated. Any farmer who had a zero value for any one of the inputs used in the analysis was deleted from the sample. These results are presented in Appendix B. The distribution of the efficiency scores associated with these results are presented in Appendix C.

Table 8 shows that among producers of both dalo and cassava, there is no difference in efficiency between subsistence and commercial growers, though semi-commercial farmers are less efficient. However, Appendix B shows that pure subsistence farmers are less efficient in growing dalo: Those farmers that purchase inputs tend to achieve higher levels of efficiency in dalo. Cassava production is the most efficient single production process with average technical efficiency of 89% for pure subsistence farming and 80% for commercial farmers. Cassava is generally regarded as an easy to look after subsistence crop. However, the pure subsistence production of some crops, notably bananas, is only 52% efficiency. The performance of commercial banana and sugar producers is only slightly better, achieving 69% technical efficiency.

The relatively high average technical efficiency, particularly for cassava and all root crop subsistence farmers, is consistent with the conclusion that many of the farmers are using the most appropriate available technology. When coupled with the small differences in average technical efficiency between the commercial and pure subsistence farmers this suggests that there has been the extension effort targeted at commercial producers has been effective and/or there has been little technical progress in recent years for commercial farms. That is, slow technological progress allows farmers to catch up and improve their performance relative to the best practice frontier.

6.1: Comparability of Results

There are no published studies of technical efficiency of root crop production in Fiji or other Pacific Island countries with which to compare these results. Comparative data on yields is available but this is only indirectly and partially related to technical or productive efficiency.

[4] The sample data contained only 17 observations for sugar production that involved no purchased inputs. Another 8 observations were missing data on at least one other input. The number of observations are too few to undertake any statistical analysis.

Data on the technical efficiency of farmers in the sugar industry in Fiji are broadly consistent with these results. Reddy and Yanagida (1999) found 'a significant level of inefficiency exists at the farm level of Fiji's sugar industry', a claim supported more recently by Narayan (2004) who claimed 'the oldest industry is shriveling and is poised on the precipice of collapse'.

Reddy (2007), examined how selected countries have performed with respect to improving the efficiency of their agricultural sectors. Results revealed that in the four selected countries, namely Fiji, Tonga, Samoa and Papua New Guinea, the efficiency levels of the agricultural sector overall have not changed over four decades. Average efficiency levels were found to be 0.91, 0.89, 0.88 and 0.97 respectively. Reddy (2007) claims Fiji's agricultural growth has been stagnant since the mid 1980s, with the decline in crop production due largely to the decline in sugarcane production associated with the uncertainty surrounding the renewal of land leases. Growth in productivity and efficiency is important for achieving sustained growth and an improvement in economic welfare and Reddy's (2007) analysis found increases in Fiji's agricultural output is possible from both technical efficiency gains and technological change.

Given the importance of the agricultural sector to economic development in all countries and the potential for efficiency improvements as a means of the improving the sector's performance, there are a substantial number of studies focusing on the agricultural sector in both developed and developing economies. Different methodologies and strategies have been used to measure the technical efficiency of agriculture and while there is much debate about the merits of specific methodologies, the choice essentially depends on the objectives of the research and the data available.

Bravo-Ureta and Pinheiro (1993) reviewed 30 studies of technical efficiency in the agricultural industries of developing countries and reported an overall average level of 0.72. For SFA models applied to larger scale samples like the one used here they found technical efficiency scores typically ranged from 0.55 to around 0.80. Thiam *et al.* (2001) extended this work by applying meta-analysis[5] to conduct a more rigorous review of agricultural performance in developing countries. Technical efficiency estimates were regressed against inter-study differences. They found that studies using the more restricted Cobb-Douglas functional form, as done in this research, yielded lower average TE indices than those relying on the translog specification.[6] Cross sectional data, again as used in this report, was also found to produce lower TE estimates compared to studies using panel data, a conclusion also supported by Bravo-Ureta *et al.* (2007) in their meta-regression analysis of farm level technical efficiency studies of both developing and developed economies. The level of farm TE from all the developing country studies reviewed by Thiam *et al.* (2001) ranged from 0.17 to 1.0, with an average of 0.68. The studies focused predominantly on rice production in Asia, with India and the Philippines receiving the most attention.

Such findings are supported by Kwon and Lee (2004) who used both DEA and SFA to examine the technical efficiency of Korean rice farmers over a five year period, 1993-97. Using SFA, and

[5] Meta-analysis, as explained by Thiam *et al.* (2001), takes empirical estimates of some indicator, for example the estimate of technical efficiency, and using the differences across the studies as explanatory variables in the regression model, attempts to explains the variation in the estimates.

[6] As already noted in the text, we conducted formal tests and found that for our data, the Cobb-Douglas specification was the most appropriate.

hence allowing for the stochastic component to impact on efficiency, the average level of technical efficiency for all the regions was 0.72. This compares to an average technical efficiency of 0.75 when DEA, which attributes all deviations to inefficiency, is used. However, the results of both DEA and SFA analysis are comparable with those of Thiam *et al.* (2001) and Bravo-Ureta and Pinheiro (1993).

Dhungana *et al.* (2004) examined the technical efficiency of 76 Nepalese rice farms and using DEA, found the average level of technical efficiency to be 0.76. Factors influencing the level of inefficiency were also examined. The farmer's level of risk, farmer gender, age, education, as well as the endowment of family labour, were all found to be important influences.

Binam *et al.* (2005) report technical efficiency levels of 0.78, 0.8 and 0.77 among groundnut moncrop, maize moncrop and maize/groundnut intercrop systems respectively in slash and burn agriculture zone of Cameroon. The level of schooling received by the farmers and their membership to farmer's club or association were important factors influencing the performance of the farmers.

The results of Bravo-Ureta and Pinherio (1993) and Thiam *et al.* (2001) and others reported in the literature and discussed above suggest that the results obtained in this analysis are plausible. Substantial technical efficiency exists and some farmers are operating inside the best practice frontier by a large margin. However, further gains in efficiency can be made. The policy implications of this finding are addressed in the next section.

7. Conclusions and Policy implications

Farming is an important source of income in Fiji and can make a substantial contribution to the recovery of the national economy. The results from this project show that there is real scope for improving the technical efficiency of most farmers involved in the crop production. The current technical inefficiency in the production is costing the sector some 23% of annual total production of dalo, and 24% of total root crops.

The major factors determining the extent of technical efficiency in root crop production were location, specialisation and focus, and place in a Mataqali.

Producers from the Western Division tended to have lower efficiency scores than those from the other regions while farmers from the Northern Division had the highest average efficiency scores for root crops as a whole. Those farms that operated within the Mataqali system tended to have significantly higher efficiency scores than those outside the system.

Focus and specialisation in root crop farming was associated with higher efficiency scores. In particular, amongst those farms that produced dalo, lower numbers of root crops grown and lower numbers of other crops tended to be associated with higher efficiency score. Similarly, increasing the proportion of work-time spent on the farm seemed to result in higher production efficiency.

In contrast we found that for farmers that purchase inputs and grow root crops, on average, there was no substantial difference in efficiency between small semi-subsistence producers and larger, more commercial farms. This result does not mean that there is no difference in profitability between these farms. Technical efficiency and profitability are not the same thing. Technical efficiency is a size neutral measure of adoption of best practice technology. Our results show that there have been similar uptakes of the different best practice technologies in each group. However, the technologies are different in each group. In terms of Figure 1, farms C and A are both efficient. Small farms like A represent our semi-subsistence sample while the larger farms are represented by farm C. They are of very different size and most likely imply very different technologies, but they have both adopted the best technology for a farm of their respective sizes. Farm C might use tractors, herbicides and chemical fertilizers while Farm A, the small semi-subsistence producer, might use man power, hoes and shifting production plots.

One would expect that small subsistence producers would have similar efficiency levels. Their most appropriate technology is simple and largely unchanging. Producers have used similar technology for generations so common approaches to production are expected.

The finding that larger commercial growers had comparable technical efficiency scores to this group implies that the adoption of appropriate technology for this group has been high even though it involves relatively complex systems involving, purchased inputs such as fertilizer, machinery like tractors, and more challenging disease problems due to more intensive production practices. Therefore, our results are at least consistent with the conclusion that the extension effort in the commercial sector has been effective. At the very least we can conclude that there is no evidence of an extension failure.

Having said that, our results also show that the scope for expanding the production of root crops through the wider adoption of existing technologies is relatively limited – a 10% increase in production is probably possible given that 100% efficiency scores are not attainable for all producers. However, with Fiji's rapidly growing population and the governments desire to expand the consumption of traditional root crops, this increase looks inadequate. If a substantial increase in root crop consumption is to be achieved the increase in the necessary production with have to come from sources other than improved technical efficiency. The only three other sources available are completely new technology not tried yet, increases in the area used in root crop production and finally, imports from other countries.

The first two sources can be influenced by Government initiatives but they represent significant public policy challenges. New technology, or technological progress, in Fiji is largely dependant on government funded R&D efforts. This is an important area and one in which the Ministry of Agriculture has a patchy record. The expansion in cropping areas is limited by the availability of suitable land, especially in the case of Dalo. It may also be limited by the existing land tenure systems in Fiji.

This study has not addressed the presence of allocative inefficiency – losses in profits due to farmers producing the wrong outputs or using the wrong input mix. While this is a little harder to measure, the extent of this problem can be equally important. Some studies in developing countries have shown allocative inefficiency can be even greater than technical inefficiency.

While encouraging larger scale commercial production is an obvious step towards increasing profits and reducing poverty, it could have some unintended spillover implications. The potential for these highlights the importance of seeing agricultural and development as part of a wider policy agenda involving a wider policy community than those directly working in agriculture.

This study has presented information of a broad strategic value for the agricultural policy community. The fine tuning of regional extension tactics requires more detailed and focused information on the causes and barriers to improvements in technical efficiency and farm level productivity in general. The analytical approach outlined in this paper could be of some value in this regard but it would require purpose specific surveys of producers.

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Appendix A: Data Specification and Measurement

Variable	Specification	Unit of Measurement
Outputs		
All Root Crops	Sum of all root crops produced on the farm. Includes dalo, cassava, kumala	kg
Dalo	Sum of dalo and dalo-ni-tana	kg
Cassava	Quantity of cassava produced	kg
Inputs		
Land	Land area devoted to the output	ha
Labour	Family and hired labour	Man weeks
Equipment	Value of all equipment used in the production of the output crop	$
Purchased Inputs	Sum of all purchased inputs used in production. Includes fertilizers, herbicides and fuel.	$
Determinants		
North	0/1 Dummy taking a value of 1 if the farm is located in the Northern Region	0/1
West	0/1 Dummy taking a value of 1 if the farm is located in the Western Division	0/1
Head of household is Female	0/1 Dummy taking a value of 1 if the farm household is headed by a female	0/1
Mataqali	0/1 Dummy taking a value of 1 if the farm activity occurs on mataqali land	0/1
Proportion of time spent on farm	Farm hours/total hours	ratio
Years of schooling	Number of years of schooling for the head of the household, ie "Person 01".	number
Adult ratio	Number of adults/ number in household	ratio
Number of root crops grown	The number of root crops grown on the farm	number
Number of other crops produced	The number of non root crops grown. Includes Sugarcane, leafy vegetables, cereals, spices, etc.	number
Semi-commercial	0/1 Dummy taking a value of 1 if the farm is classified as Semi-commercial	0/1
Commercial	0/1 Dummy taking a value of 1 if the farm is classified as Commercial	0/1

Appendix B: Efficiency of Various Crop Producers, Summary of Results

Variables (log form)	Dalo Pure Subsist	Dalo Comm	All Root Pure Subsist	All Root Comm	Cassava Pure Subsist	Cassava Comm	Bananas Pure Subsist	Bananas Comm	Sugar Comm
Production frontier									
Constant	9.32 (63.25)	8.49 (49.98)	9.42 (72.89)	8.79 (67.88)	8.98 (27.80)	8.19 (51.90)	6.84 (27.02)	7.24 (22.45)	10.50 (37.48)
Land	0.76 (20.37)	0.76 (24.23)	0.88 (29.49)	0.81 (36.59)	0.85 (28.27)	0.74 (28.10)	0.46 (11.06)	0.55 (7.99)	0.67 (8.43)
Labour	0.12 (4.06)	0.007 (0.19)	0.04 (1.3)	0.04 (1.27)	0.09 (3.35)	0.19 (8.68)	0.38 (9.91)	0.28 (5.82)	0.06 (0.96)
Equipment	0.01 (0.05)	0.12 (9.43)	0.01 (0.7)	0.09 (6.04)	0.01 (0.29)	0.03 (2.17)	0.05 (1.80)	0.07 (1.69)	0.05 (1.92)
Purchased Inputs	-	0.04 (1.58)	-	0.02 (1.10)	-	0.09 (4.16)	-	0.04 (0.80)	0.08 (2.17)
Determinants of inefficiency									
North	-0.50 (-1.26)	-5.12 (-3.21)	-0.07 (-0.21)	-3.70 (-6.84)	0.12 (0.71)	-0.48 (-2.47)	0.31 (1.02)	2.41 (3.32)	-3.73 (-2.37)
West	-0.27 (-0.94)	1.88 (2.31)	0.13 (0.69)	2.27 (3.66)	-0.06 (-0.34)	-0.93 (-4.33)	-1.15 (-1.42)	0.50 (0.62)	-12.17 (-5.80)
Female H/H	-0.08 (-0.21)	0.80 (0.81)	-0.65 (-1.16)	-0.34 (-0.23)	-0.09 (-0.59)	-0.07 (-2.62)	-0.23 (-0.57)	0.18 (0.18)	-2.68 (-2.64)
Mataqali	-0.62 (-1.53)	-2.49 (-3.01)	0.33 (0.99)	-3.43 (-10.08)	0.07 (0.61)	0.01 (0.17)	0.14 (0.54)	-0.17 (-0.35)	7.12 (6.13)
Proportion of Time on Farm	0.99 (2.14)	-8.32 (-2.67)	1.22 (2.8)	-6.55 (-8.47)	0.58 (3.04)	0.57 (6.56)	1.38 (2.89)	0.88 (1.21)	-4.73 (-5.87)
Years of Schooling	-0.17 (-0.40)	0.08 (1.99)	-0.05 (-1.71)	0.09 (1.49)	-0.01 (-0.38)	0.01 (0.56)	-0.01 (-0.23)	-0.01 (-0.04)	0.19 (1.95)
Adult ratio	0.26 (0.45)	0.84 (1.35)	0.63 (1.52)	1.08 (1.31)	0.11 (0.62)	0.04 (0.84)	-0.35 (-0.75)	1.13 (1.56)	4.07 (4.99)
No. Root Crops	0.04 (0.06)	-0.40 (-1.45)	-0.87 (-1.89)	-0.79 (-2.58)	-0.14 (-0.63)	0.01 (0.45)	-0.14 (-0.91)	-0.72 (-2.79)	0.08 (0.15)
No. Other Crops	-0.23 (-0.38)	0.59 (3.05)	-0.07 (-0.66)	0.01 (0.03)	0.01 (0.19)	-0.06 (-5.19)	0.05 (0.77)	-0.25 (-2.64)	-0.62 (-3.79)
All Crop Home Use Ratio	-2.09 (-3.41)	-2.52 (-2.56)	-0.03 (-0.31)	0.99 (1.10)	-0.47 (-1.65)	-0.13 (-0.87)	0.99 (0.62)	-0.11 (-0.99)	10.89 (5.85)
Joint Home Use Ratio	1.01 (3.24)	1.60 (4.42)	0.042 (0.21)	1.32 (7.42)	-0.04 (-0.18)	-0.07 (-1.79)	-0.18 (-0.56)	-1.59 (-1.49)	2.85 (2.45)
Sigma Squared	0.62 (3.79)	3.10 (3.37)	0.37 (3.96)	2.42 (5.56)	0.21 (7.43)	0.29 (13.45)	0.65 (4.65)	0.79 (4.66)	4.37 (8.78)
Gamma	0.72 (8.98)	0.95 (54.31)	0.40 (1.94)	0.92 (47.38)	0.02 (0.053)	0.04 (2.22)	0.45 (2.19)	0.419 (2.77)	0.97 (85.84)
Number of farms	297	312	308	395	342	305	217	148	113
T.E.	0.64	0.71	0.83	0.77	0.89	0.80	0.52	0.69	0.69

Notes: t-statistics reported in brackets. T.E. denotes technical efficiency. Pure Subsist denotes pure subsistence farms (no hired inputs). Comm denotes
commercial farms. Gamma is the ratio of the variance parameters.

Appendix C: Distribution of Efficiency Scores, Various Crops

T. E. Range	All root Crops Subsist		All root Crops Comm		Dalo Subsist		Dalo Comm		Cassava Subsist		Cassava Comm		Bananas Subsist		Bananas Comm		Sugar Comm	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
0<20	0	0	7	1.8	6	2.0	16	5.1	0	0	0	0	5	2.3	5	3.4	5	4.4
20<30	1	.3	3	0.7	20	6.7	4	1.3	0	0	0	0	22	10.1	5	3.4	0	0
30<40	2	.7	4	1.0	27	9.1	7	2.2	0	0	0	0	35	16.1	8	5.4	3	2.7
40<50	7	2.3	7	1.8	29	9.8	7	2.2	0	0	0	0	44	20.3	6	4.1	7	6.2
50<60	14	4.6	8	2.0	26	8.8	12	3.9	1	0.3	69	22.6	31	14.3	12	8.1	4	3.5
60<70	20	6.5	26	6.6	40	13.5	47	15.1	22	6.4	64	21.0	42	19.4	20	13.5	25	22.1
70<80	40	13.0	126	31.9	60	20.2	121	38.8	49	14.3	16	5.2	23	10.6	31	20.9	37	32.7
80<90	116	37.6	208	52.7	86	28.9	95	30.5	81	23.7	11	3.6	15	6.9	58	39.2	31	27.4
90<100	108	35.1	6	1.5	3	1.0	3	0.9	189	55.3	139	45.6	0	0	3	2.0	1	0.9
100	0	0	0	0	0	0	0	0	0	0	6	2.0	0	0	0	0	0	0
Total	308	100	395	100	297	100	312	100	342	100	305	100	217	100	148	100	113	100