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DECOMPOSITION OF OUTPUT GROWTH IN THE PHILIPPINE SUGARCANE SECTOR: A STOCHASTIC FRONTIER PRODUCTION FUNCTION ANALYSIS USING BALANCED PANEL DATA

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ABSTRACT

Output growth in the sugarcane sector was estimated and decomposed into different component sources to find out its major drivers. A stochastic frontier production function analysis using balanced panel dataset was done to facilitate the decomposition. Total factor productivity growth, rather than factor accumulation, was found to be the major driver. The principal source of total factor productivity growth was technical efficiency improvement, followed by technical change. Technical efficiency is significantly influenced by education and tenurial status of farm operators, farm size, topography, and location or milling district. The effect on productivity growth of the scale efficiency change was very minimal as sugarcane production just slightly exhibit increasing returns to scale. The changes in the input uses by farmers in the later part of the study period seemed to have reduced allocative efficiency.

Key words: factor accumulation, total factor productivity, technical change, technical efficiency, scale efficiency

INTRODUCTION

The neoclassical growth model defines output level and growth as a function of a country's resource endowment and productivity or total factor productivity (TFP). Since resource-driven growth is not sustainable as there are limits to resource mobilization and the incremental growth in factors of production is subject to the law of diminishing marginal returns, the emphasis is placed on productivity growth (Felipe, 1997). Nowadays, more than ever, productivity growth is very vital for a country's healthy and thriving economy because of increasingly stiff trade competitions in the globalized market that production should be cost-efficient to stay in the market.

This study assessed output growth in the Philippine sugarcane sector and decomposed the measured growth into two main component sources i.e., factor accumulation and TFP growth (TFPG). It further decomposed the latter source into its subcomponent sources e.g., technical change, technical efficiency change, and scale efficiency change, and analyzed technical efficiency to identify its determinants. These were done with the end in view of identifying the major drivers of growth and establishing their implications on policies and action programs for the sector.

The sugar industry plays an important role in the Philippine economy. While it had lost its status as the country's leading export earner and the industry could only meet the domestic demand and the declining US quota allocation, sugar remains among the country's major agricultural exports. In 2009, sugar export earnings at US$89.8 million provided quite a substantial share to total (BAS, 2011). The industry also continues to be a major employment provider especially in the rural areas, employing an estimated 556,000 people in the farm and 25,000 workers in the mills and refineries.

Moreover, about 3.7 million people are indirectly dependent on the industry and other sugar-related activities (Quizon et al., 2003). For the last five years (2006-2010), the area planted to sugarcane averaged 388.7 thousand hectares and the volume of production averaged around 2.2 million metric tons (mt) annually (PHILSURIN, 2011). The share of sugarcane in the agricultural GVA hovered around 2.6% (NSCB, 2011).

The increasing domestic demand for use in the food, beverage, confectionery, and fruit processing industries and for general public consumption has sustained and kept the industry afloat since the major slump in 1986 that resulted to widespread poverty and malnutrition in major sugar-producing areas. In the succeeding years, the industry has been dealing with lingering threat of stiff competition with imported sugar due to the ratification of the World Trade Organization's (WTO) agreement in 1995 and the transfer of sugar from exclusion list to sensitive list in 2001 for Common Effective Preferential Tariff (CEPT) for ASEAN Free Trade Area (AFTA). The complete removal of the sugar import tariff protection in compliance with the CEPT agreement has been extended only until 2015 per the country's request from the ASEAN members for waiver of CEPT/ATIGA (ASEAN Trade in Goods Agreement) through the invocation of the Protocol. While this gives the industry more time to prepare for the stiffer competition ahead, the industry will need to institute reforms that will substantially improve its productivity.

It is well known that there is no way by which the country's sugar and sugar-related products can become competitive unless production becomes cost-efficient. The government and the industry people recognize the need to improve productivity, both at the farms and mills, to enhance the competitiveness of domestically produced sugar and to enable the industry take advantage of the emerging opportunities.

Statistics reveals four important facts about the domestic sugarcane yields in the country: (1) they are relatively low compared to other major producing countries in Asia (e.g. China and India) and are highly fluctuating; (2) growths are generally slow and in some areas even declining over time; (3) there are wide differences across producing areas and among different farm sizes; and (4) there are wide gaps between the actual and the potential yields. All of these may be taken as indicative of the existence of room for improvement in the sugar industry performance at the farm level. Yields are, nonetheless, only a partial or an average measure of farm productivity and is sometimes misleading. This study focused on TFP, which is a more accurate and more meaningful measure of productivity.

METHODOLOGY

Data Sources and Collection Method

The data used in the analysis consisted of a balanced panel composed of 312 observations collected from 104 sugarcane farms from eight sugarcane-producing provinces in Luzon and Mindanao, or nine milling districts. The data were collected for three time periods, crop years (CY) 2002/03, 2003/04, and 2006/07. Farm survey data for CY 2002/03 and CY 2003/04 were obtained from the Sugar Regulatory Administration (SRA). Another round of survey was conducted for CY 2006/07 for the purpose of the study which was jointly funded by SEARCA, Department of Agriculture-Bureau of Agricultural Research (DA-BAR), and PhilRice. The farm surveys covered broader cross sections, but only 104 were considered in the present study. The respondents in the survey were randomly selected. The 104 sample respondents were consistently included in all the three rounds of survey. The distribution of the sample farms included in the panel data set is shown in Table 1.

Three categories of data and information were collected from the sample sugarcane farms. These included: (1) input-output data, (2) farm operator characteristics, and (3) farm characteristics and practices. While there were information on access to support services, e.g. extension and credit, and membership in farmer organizations that were also collected, these were not considered in this study as these were obtained only in the last round of survey. The input data included the physical quantity of land, human labor, draft animal power, machine power, seed pieces, chemical pesticides, chemical fertilizers, and organic fertilizers used in the farm production. All output data were in terms of both cane and raw sugar. Farm operator-specific information included age, educational attainment, and tenurial status, while the farm-specific pieces of information included farm size, topography, soil type, whether liming and ratooning were practiced, and the proportion of the whole farm with ratoon crop.

Table 1. Distribution of sample sugarcane farms across the nine milling districts

Milling District	Respondents
Carsumco	6
Tarlac	2
Pampanga	13
Balayan	5
Don Pedro	16
Pensumil	9
Bukidnon	41
Davao	8
Cotabato	4
Total	104

Stochastic Frontier Production Function
Estimation and Technical Efficiency Analysis

There are several alternative approaches to TFP measurement. They are broadly categorized as either frontier or non-frontier approaches, and, under each of these two broad categories, the approaches are subcategorized as either parametric or non-parametric. Under the parametric approaches are either stochastic or deterministic models [Grosskopf (1993) as cited in Kiani et al. (2008)].

The use of stochastic frontier model was deemed appropriate for modeling sugarcane production. Firstly, the model can account for the existence of random, exogenous variables which are beyond the control of farmers. Random variables such as weather, pests, and diseases, indeed have influence on sugarcane production which is, like any other agricultural production, biological in nature and highly dependent on the state of nature. Secondly, the model does not rule out technical inefficiency among farms which is quite an acceptable assumption, given weaknesses on information and extension system as well as limitations on managerial and technical skills among some farm operators/managers in the country.

The study adopted the model specification and the single-stage estimation procedure developed by Battese and Coelli (1995) using FRONTIER 4.1.. Having panel data, the stochastic frontier production function was specified as follows:

$$(1) \quad y_{it} = \beta_o \prod_{j=1}^{J} x_{jit}^{\beta_j} e^{\theta t} e^{\varepsilon_{it}}$$

where i =1,…N, j=1,…J, and t=1,…T. y_{it} denotes total quantity of output of farm i at time t. x_{jit} denotes the quantity of input j used by farm i at time t. β_o, θ, and β_js are parameters to be estimated. β_js specifically measure partial output elasticities with respect to input js. t stands for time trend. The linear time trend is inserted in the model to capture neutral technological change. ε_{it} is error term for farm i at time t. This error term consists of two components. The first component is the symmetric disturbance, v_{it}, which reflects white noise, including exogenous shocks which are beyond the control of farmers as previously mentioned. This is assumed to be independently and identically distributed [$N(0, \sigma_v^2)$]. The second component is the one-sided, non-negative component representing technical inefficiency, u_{it}. It is assumed to be independently distributed as truncation at zero of the normal distribution with mean μ and variance σ_u^2 [$N(\mu,\sigma_u^2)$]. The inefficiency component is specified as follows:

$$(2) \quad u_{it} = \delta_o \sum_{l=1}^{L} \delta_l z_{lit}$$

where z is vector of farm-specific variables that may cause technical inefficiency in farm i at time t and δ is a vector of unknown parameters to be estimated.

The descriptions of the specific variables included in the stochastic frontier production and inefficiency models are presented in Table 2. A total of nine types of variable inputs (x) were considered, viz: land, human labor, draft animal and machine powers, seedpieces, chemical pesticide, chemical fertilizer (broken down into active ingredients such as nitrogen, phosphate, and potash), and organic fertilizer. Machine power was converted into its equivalent draft animal power using the conversion factor (1 hour of animal work = 0.13587 hour of machine work) adopted by Fernandez and Nuthall (2009) and was lumped with draft animal power to have only one variable for the two factors of production. Machine power and draft animal power are alternatively used for land preparation and cultivation activities.

For the technical inefficiency component, a total of 22 explanatory variables (z) were considered. These included age, educational attainment, and tenurial status of farm operators; dummy variables for size classification of farms; land share of new plant; and dummy variables for farm mechanization, lime application, land topographies, soil types, and milling districts. The default variables for tenurial status, farm size classification, land topography, soil type and milling district dummies were full owner, small farm, flat topography, clay loam and Carsumco, respectively. Milling district dummies were included since the SRA's extension service has been integrated with the Milling District Development Council (MDDC) structure. MDDCs were created by PHILSURIN in sugar producing districts to identify productivity concerns and problems , disseminate R&D results to sugarcane growers, and implement sugar productivity programs. Each MDDC has an office, greenhouse to rear tissue-cultured plantlets, nurseries, hot water treatment facilities, and a weather station. Propagation and dispersal of new HYVs are done at MDDCs. Hence the efficiency and effectiveness of extension services can vary across milling districts depending on the performance of concerned MDDCs.

Measurement and Decomposition of Output Growth
and Total Factor Productivity Growth

Output growth ($\dot{y}$) is directly measured as the percentage change in total output between two periods, i.e.:

$$(3) \quad \dot{y} = \frac{y_2 - y_1}{y_1} * 100$$

The measured output growth is decomposed into two major component sources: (1) the component which is due to factor accumulation or increase in input use ($\dot{y}_x$) and (2) the component which is due to productivity improvement (TFPG or $T\dot{F}P$). The measurement of output growth due to factor accumulation makes use of the partial output elasticities with respect to variable inputs (β_js) and the respective measured changes in input uses, $\dot{x}_j$s, i.e.:

$$(4) \quad \dot{y}_{\dot{x}} = \sum_{j=1}^{9} \beta_j \dot{x}_j, \quad \text{where } \dot{x}_j = \frac{x_2 - x_1}{x_1} * 100.$$

The TFPG, on the other hand, is measured as the residual after growth of output due to factor accumulations is taken out, i.e.:

$$(5) \quad T\dot{F}P = \dot{y} - \dot{y}_{\dot{x}}$$

Table 2. Description of variables included in the stochastic frontier production and inefficiency models

Variable Name	Variable Symbol	Measurement Unit	Parameter Symbol
Stochastic Frontier Production Model			
Output	y	ton cane	
Constant			β_0
Land	$x_{1 \text{ or } L}$	hectare	β_1 or β_L
Human labor	$x_{2 \text{ or } HL}$	man day	β_2 or β_{HL}
Animal and machine power	$x_{3 \text{ or } AMP}$	animal day	β_3 or β_{AMP}
Seedpieces	$x_{4 \text{ or } S}$	lacsa	β_4 or β_S
Chemical pesticide	$x_{5 \text{ or } C}$	real peso term	β_5 or β_C
Nitrogen fertilizer	$x_{6 \text{ or } N}$	kilogram	β_6 or β_N
Phosphate fertilizer	$x_{7 \text{ or } P}$	kilogram	β_7 or β_P
Potash fertilizer	$x_{8 \text{ or } K}$	kilogram	β_8 or β_K
Organic fertilizer	$x_{9 \text{ or } O}$	ton	β_9 or β_O
Time trend	t	year	θ
Inefficiency Model			
Constant			δ_0
Age	z_1	year	δ_1 or δ_{AGE}
Education	z_2	year	δ_2 or δ_{EDU}
Part owner	z_3	=1 if part owner, = 0 if otherwise	δ_3 or δ_{POWN}
Lessee	z_4	=1 if lessee, = 0 if otherwise	δ_4 or δ_{LESS}
Dummy for medium-size farm	z_5	=1 if medium-size, = 0 if otherwise	δ_5 or δ_{MED}
Dummy for large farm	z_6	=1 if large, = 0 if otherwise	δ_6 or δ_{LRG}
New plant land share	z_7	percent share of new plant to total farm area	δ_7 or δ_{PL}
Dummy for mechanized farm	z_8	=1 if mechanized, = 0 if otherwise	δ_8 or δ_{MECH}
Dummy for application of lime	z_9	=1 if had applied lime, = 0 if otherwise	δ_9 or δ_{LM}

Variable Name	Variable Symbol	Measurement Unit	Parameter Symbol
Dummy for slightly rolling topography	z_{10}	=1 if slightly rolling, = 0 if otherwise	δ_{10} or δ_{SRT}
Dummy for rolling topography	z_{11}	=1 if rolling, = 0 if otherwise	δ_{11} or δ_{RT}
Dummy for sandy soil	z_{12}	=1 if sandy, = 0 if otherwise	δ_{12} or δ_{SS}
Dummy of sandy loam soil	z_{13}	=1 if sandy loam, = 0 if otherwise	δ_{13} or δ_{SLS}
Dummy for clay soil	z_{14}	=1 if clayey, = 0 if otherwise	δ_{14} or δ_{CS}
Dummy for Tarlac milling district	z_{15}	=1 if in Tarlac, = 0 if otherwise	δ_{15} or δ_{TAR}
Dummy for Pampanga milling district	z_{16}	=1 if in Pampanga, = 0 if otherwise	δ_{16} or δ_{PAM}
Dummy for Balayan milling district	z_{17}	=1 if in Balayan, = 0 if otherwise	δ_{17} or δ_{BAL}
Dummy for Don Pedro milling district	z_{18}	=1 if in Don Pedro, = 0 if otherwise	δ_{18} or δ_{DPE}
Dummy for Penafrancia milling district	z_{19}	=1 if in Penafrancia, = 0 if otherwise	δ_{19} or δ_{PEN}
Dummy for Bukidnon milling district	z_{20}	=1 if in Bukidnon, = 0 if otherwise	δ_{20} or δ_{BUK}
Dummy for Davao milling district	z_{21}	=1 if in Davao, = 0 if otherwise	δ_{21} or δ_{DAV}
Dummy for Cotabato milling district	z_{22}	=1 if in Cotabato, = 0 if otherwise	δ_{22} or δ_{COT}

TFPG may be decomposed into four components or sources, viz: technical change $(\dot{T})$, technical efficiency change $(\dot{TE})$, scale efficiency change $(\dot{SE})$, and allocative efficiency change $(\dot{AE})$ [Kumbhakar and Lovell (2000) as cited in Lambarraa et al. (2007)]:

$$(6)\quad \dot{TFP} = \dot{T} + \dot{TE} + \dot{SE} + \dot{AE}$$

Technical Change Component

Technical change shifts the production frontier and changes the maximum attainable output for given input level over time. Depending on the sign of the regression coefficient of time trend, θ, the effect of technical change may be positive (i.e., there is improvement in the sugarcane technology and hence an increase in sugarcane output over time given the quantities of inputs are constant) or negative (i.e., there is technological regress and hence a decrease in sugarcane output over time given the quantities of inputs are constant). Technical change effect was computed using the following formula:

$$(7)\quad \dot{T} = \frac{\partial \ln y}{\partial t} = \theta * 100$$

Technical Efficiency Change Component

This TFPG component measures growth in output due to the improvement with which the farms use available technology. A farm can increase its productivity, even when there is no technical change, by making a more efficient use of its inputs and by operating closer to the production frontier. The technical efficiency change can be interpreted, therefore, as the rate at which a farm moves towards or away from the production frontier (Coelli, *et al*., 2005). A positive value for this component means an increase in technical efficiency of sugarcane farmers between two periods while a negative value means a decrease in their technical efficiency.

$$(8) \quad \dot{TE} = -\frac{\partial u}{\partial t} = \frac{(\overline{TE}_2 - \overline{TE}_1)}{\overline{TE}_1} * 100$$

Scale Efficiency Change Component

This TFPG component arises from the improvement in the scale of operation of farm as it moves towards the technologically optimum scale of operation (Coelli *et al*., 2005). This was computed as follows:

$$(9) \quad \dot{SE} = (\varepsilon - 1)\sum_{j=1}^{J}\left(\frac{\varepsilon_j}{\varepsilon}\right)\dot{x}_j$$

where ε measures the homogeneity of the production function and is equivalent to the $\sum \varepsilon_j$ or $\sum \beta_j$. When ε is =, >, or < 1, the production function is characterized by constant returns to scale (CRS), increasing returns to scale (IRS), or decreasing returns to scale (DRS), respectively. $\dot{SE}$ is positive when the production function is IRS and input uses are increased, and negative when production function is DRS and input uses are increased.

Allocative Efficiency Change Component

Allocative efficiency measures the ability of the farm to use the right proportions of inputs to produce output, given the relative prices of inputs. It captures the effect of deviations of farm's relative expenditures on inputs from the respective inputs' normalized output elasticities.

$$(10) \quad \dot{AE} = \sum_{j=1}^{J}\left[\left(\frac{\varepsilon_j}{\varepsilon}\right) - s_j\right]\dot{x}_j$$

where $S_j = \frac{p_j x_j}{\sum_j p_j x_j}$ is a measure of expenditure share of input *j*. p_j denotes unit price of input *j*.

EMPIRICAL RESULTS

Sample Characteristics

Majority of the sample sugarcane farmers were in their 40s and 50s and had either reached or finished college education. About 50% were, in fact, degree holders. The dominant tenurial status was either full owner or part owner. Only about one-fifth was lessees. Full owners included those who had inherited or purchased land and those who had received land ownership via the government's agrarian reform program. Part owners were farmers who, aside from their own land, also had leased and tilled someone else's land. The average farm size under lease arrangement and part ownership was larger (53 hectares and 43 hectares, respectively) compared to the average farm size under full ownership (25 hectares).

With regards to the characteristics of the sample farms, majority of the farms (about 80%) were small to medium size. The local sugar industry's size classification of farms was adopted in the study, i.e., small farms are 10 hectares at most, medium farms are greater than 10 to 50 hectares, while large farms are greater than 50 hectares. The average farm size had increased from 35 hectares in CY 2002/03 to 38.6 hectares in CY 2006/07. Some farmers had expanded the area they tilled either by acquiring or by leasing more lands. The expansion in farm area might have been triggered by the strengthening of the sugar prices both in the local and world markets during the period. Majority of the farms had generally flat topography, and had either clay loam or sandy loam types of soil. Most had planted more than one (two to four) sugarcane varieties. Sample farmers in Mindanao seemed to be more receptive to newly introduced high yielding varieties than the sample planters in Luzon as evident in the greater number adopting 1990 series of sugarcane varieties.

Input and Output Growth Analysis

In CY 2002/03, the weighted average production of the sample farmers was 1,981 tons of sugarcane (Table 3). This average farm production was obtained using the following average input levels: 34 hectares of land, 3,951 man days of labor, an equivalent of 543 animal days of combined draft animal and machine powers, P2,400 worth of chemical pesticides (mainly for treatment of seedpieces and for rat control), 3.78 tons of nitrogen fertilizer, 1.61 tons of phosphate, 2.91 tons of potash, and 21 tons of organic fertilizer.

In the following crop year, CY 2003/04, the sample farms recorded about 3.3% (64 tons) average growth of cane production (Table 3 and Figure 1). This output growth was obtained with increases in the levels of input use such as machine power (60%), organic fertilizer (40%), and phosphate (23%). Land, labor, and nitrogen usage also increased though minimally. There were reductions in the use of draft animal power, potash, seedpieces, and chemical. The reduction in the use of draft animal power was significant at 5%. The growth in average production mainly came from ratoon, as the average share of new plant had actually gone down.

Likewise, CY 2006/07 posted positive growth of farm production at 12.3% over CY 2003/04's average. The growth was achieved despite hefty decreases in phosphate (-50%) and potash (-47%) application. The use of land, seedpieces, draft animal power, chemical, nitrogen fertilizer, and organic fertilizer had increased though not so much as to match the rate of decreases in aforementioned inputs. The significant drop in the use of fertilizers (particularly phosphate and potash) could be attributed to the marked increases in the costs of fertilizers. (Costs of different fertilizer grades in the areas covered by the study reportedly had increased between 57% and 153%). In contrast to what had been observed in CY 2002/03, growth during this period mainly came from new plant as farmers were expanding their area planted to sugarcane given the strengthening market prices over the last two years.

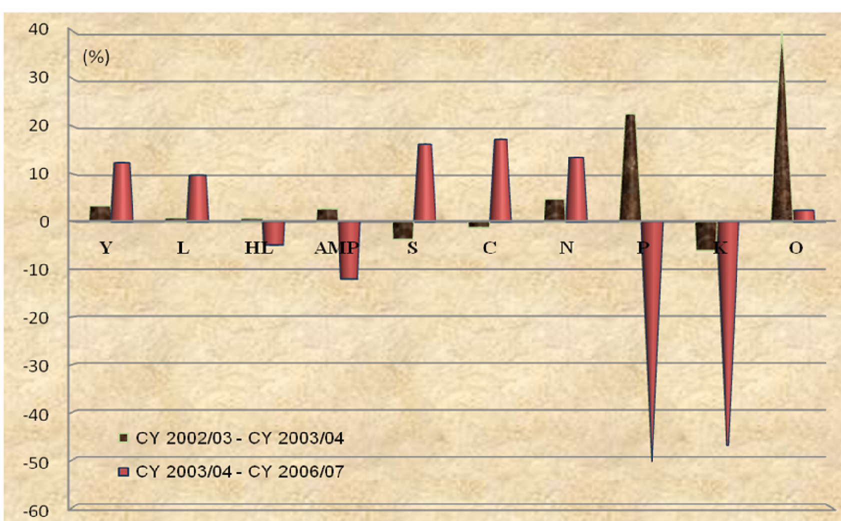

Fig. 1 Growth rate of sugarcane output and input use of sample farms.

Table 3. Average output and input levels of sample farms

Crop Year	n	Output	Input								
		Cane (ton)	**Land** (ha)	**Human Labor** (md)	**Animal Machine Power** (mad)	**Seed** (lacsa)	**Chemical** (P'000)	**Nitrogen** (kg)	**Phosphate** (kg)	**Potash** (kg)	**Organic Fertilizer** (ton)
Output-Input Level											
CY 2002/03	104	1,981	34	3,951	543	153	2	3,782	1,610	2,913	21
CY 2003/04	104	2,046	34	3,977	557	147	2	3,961	1,974	2,736	29
CY 2006/07	104	2,298	37	3,781	490	171	3	4,492	980	1,449	30
CY 2002/07	312	2,108	35	3,903	530	157	3	4,078	1,521	2,366	27
Growth											
CY 2002/03 - CY 2003/04		64	0	26	14	-6	0	179	364	-177	8
CY 2003/04 - CY 2006/07		252	3	-196	-67	24	0	530.8**	-995	-1286.8	1
Growth Rate (%)											
CY 2002/03 - CY 2003/04		3	1	1	3	-4	-1	5	23	-6	40
CY 2003/04 - CY 2006/07		12	10	-5	-12	16	17	13	-50	-47	2

** - Mean difference or growth is significant at 5% α.

Stochastic Frontier Production Analysis

Table 4 presents the results of the stochastic frontier production function estimation. σ^2 is statistically highly significant suggesting that random effect is quite important and therefore the stochastic frontier function estimated via ML estimation is a better model than the non-frontier (average) model obtained via OLS technique. γ is also highly significant and close to 1 (0.84) suggesting that 84% of the composite random effect or error term is due to the inefficiency component, *u*. This is confirmed by the LR test: the LR test statistic of 147.49 is much greater than the critical value $\chi^2_{0.99}(22) = 39.664$.

As gleaned from Table 4, the elasticity coefficients of seven out of nine variable inputs are positive, but two of these seven (chemical pesticide and phosphorus) are statistically not significant. Animal and machine power as well as seedpieces have negative elasticity coefficient but the latter is not statistically significant. The non-significant coefficients obtained for chemical pesticide and phosphorus may suggest low importance of these variable inputs in sugarcane production. On the other hand, the negative coefficient obtained for seedpieces suggests excessively high planting rates (reaching the third stage of production) by farmers. This is possible because seedpieces are usually not bought, but obtained from previous or standing crop. The same is true about the use of animal and machine power—some farms might have employed excessive amount of power as reported by Fernandez and Nuthall (2009) in Central Negros areas.

Table 4. Stochastic frontier production function estimate

Parameter	Parameter Estimate		Standard Error	Parameter Estimate		Standard Error
	OLS Estimate			*ML Estimate*		
β_o	1.9404	***	0.2387	1.9101	***	0.2172
β_L	0.5352	***	0.0536	0.5248	***	0.0459
β_{HL}	0.4938	***	0.0492	0.5578	***	0.0441
β_{AMP}	-0.0419	*	0.0279	-0.0672	***	0.0285
β_S	0.0000	ns	0.0003	-0.0004	ns	0.0003
β_C	0.0007	***	0.0002	0.0002	ns	0.0002
β_N	0.0004	ns	0.0005	0.0009	***	0.0003
β_P	-0.0012	***	0.0003	0.0003	ns	0.0003
β_K	0.0005	**	0.0003	0.0008	***	0.0003
β_O	0.0001	ns	0.0004	0.0005	*	0.0003
θ_t	0.0130	**	0.0058	0.0103	**	0.0051
σ^2	0.0259			0.0316	***	0.0033
γ				0.8408	***	0.0279
Log likelihood function	132.85			206.59		
LR test				147.49		

Sugarcane output is relatively more responsive to changes in land and labor quantities, considering the larger magnitudes (0.5248 and 0.5578, respectively) and high statistical significance of the elasticity coefficients obtained for them. Nonetheless, output is not very responsive to fertilizer applications as indicated by the very low coefficients obtained for them, i.e., 0.0009, 0.0003, 0.0008, and 0.0003 for nitrogen, phosphate, potash, and organic fertilizer, respectively. The relatively higher elasticity coefficient obtained for nitrogen compared to phosphate and potash are quite consistent to the observations made by Paningbatan, et al. (2004) when they studied the yield response of sugarcane to fertilizer applications. They noted that sugarcane farms in the Philippines are more nitrogen-deficient and respond more to nitrogen fertilization than to phosphorus and potassium applications. They noted further that many of their sugarcane test sites required very low, or no, phosphorus fertilizer. However, some farms were expected to require extremely high phosphorus fertilizer, not only because of low nutrient in the soil, but also because of very low fertilizer efficiency due to high fixation. They also noted that next to nitrogen, response to potassium is usually apparent than other nutrients.

Decomposition of Output Growth by Source

Output grew 3.3% between CY 2002/03 and CY 2003/04 and 12.3% between CY 2003/04 and CY 2006/07 (for a span of three crop years), thus making for an annual average growth of 3.9%. This was about the same as the output growth recorded by the entire sugarcane sector during the same period. Only 24% (or 0.9 percentage point) of this annual average growth can be attributed to factor accumulation (Table 5). The major driver of growth in the sugarcane sector for the entire period under study was TFPG, which accounted for an annual average of 76% (3 percentage points). In turn, the major sources of TFPG were technical efficiency improvement and technical progress which accounted for 49% and 26%, respectively. Gains from scale efficiency were very minimal at 0.02 percentage point per annum which was about 0.4% of annual average output growth. The very low contribution of scale efficiency improvement is due to the fact that sugarcane production exhibits low economies of scale. Note that the production function is homogeneous of degree 1.0179 only and hence characterized by nearly constant returns to scale.

Over time, the relative contribution to the output growth of technical efficiency change increased while that of the technical change waned.[2] The improvement in the contribution of technical efficiency may be traced to the following factors: (1) the integration of SRA extension into MDDC structure and the institutionalized approach to extension and training at mill districts which facilitate access of farmers to the latest technologies, (2) more efficient propagation and dispersal of new HYVs through the MDDCs, (3) SRA's Outreach Program for the sugar industry which gives basic training on sugar production to new sugar farmers particularly agrarian reform beneficiaries, and (4) increase in farm machineries in sugar areas and irrigations for nurseries, and strengthening of SRA's support and extension services with the use of ACEF (agricultural competitiveness enhancement funds).

The continuous technological change, on the other hand, may be attributed to the continuous efforts of SRA and PHILSURIN to develop, test, and release new HYVs that are resistant to common sugarcane diseases such as smut, downy mildew, leaf scorch, and mosaic, and insect pests like cane borer and white grub. SRA maintains two research stations. Aside from variety improvement, their areas of research or R&D thrusts also include improvement of cultural management practices (e.g. cultivation and harvesting), soil fertility improvement, fertilization, integrated pest management, development of sugarcane farming system, and utilization of indigenous materials as fertilizer source.

[2] In absolute terms, this remained constant.

Table 5. Decomposition of total output growth by sources (%).

Crop Year	Total Output Growth	Sources of Output Growth					
		Factor Accumulation	**TFPG**	$\dot{T}$	$\dot{TE}$	$\dot{SE}$	**Unexplained Residual**
Total							
CY 2002/03 - CY 2003/04	3.3	0.61	2.64	1.03	0.92	0.01	0.68
CY 2003/04 - CY 2006/07	12.3	3.13	9.20	3.08	6.77	0.05	-0.70
CY 2002/03 - CY 2006/07	3.9	0.93	2.96	1.03	1.92	0.02	0.00
Annual Average							
CY 2002/03 - CY 2003/04	3.3	0.61	2.64	1.03	0.92	0.01	0.68
CY 2003/04 - CY 2006/07	4.1	1.04	3.07	1.03	2.26	0.02	-0.23
CY 2002/03 - CY 2006/07	3.9	0.93	2.96	1.03	1.92	0.02	0.00
Share on Total Output Growth							
CY 2002/03 - CY 2003/04	100.0	18.8	81.2	31.6	28.3	0.3	21.0
CY 2003/04 - CY 2006/07	100.0	25.4	74.6	25.0	54.9	0.4	-5.7
CY 2002/03 - CY 2006/07	100.0	24.0	76.0	26.4	49.3	0.4	-0.1

As previously mentioned, allocative efficiency change was not estimated because of data limitation. There were unexplained residual growths amounting to 0.68 percentage point between CY 2002/03 and CY 2003/04 and -0.23 percentage point between CY 2003/04 and CY 2006/07. If these could be fully attributed to allocative efficiency change, then its contribution to total output growth in CY 2003/04 must be substantial and declined to negative value in CY 2006/07.

Technical Efficiency Analysis

Table 6 summarizes the distribution of technical efficiency scores of the 104 sample farms in each cropping period. The weighted average of the predicted technical efficiency scores in CY 2002/03 was low at 76% (but quite comparable to the measured average overall technical efficiency score of 73% by Fernandez and Nuthall (2009) for farms in Central Negros for 1988). There were nonetheless some movements and improvements in the technical efficiency scores of farms over time: average technical efficiency score was up by one-percentage point (to 77%) in CY 2003/04 and by five-percentage points (to 82%) over three year period between CY 2003/04 and CY 2006/07. The latest predicted average technical efficiency of 82% implies a latent potential to increase average sugarcane production in Luzon and Mindanao, given the state of technology in CY 2006/07, by as much as 18% by catching up.

The results of the technical inefficiency analysis show that farm efficiency is highly influenced by the educational attainment and tenurial status of farm operators, as well as by the size of the farm (Table 7). Technical inefficiency of farm decreases with education. The average technical efficiency scores of farm operators who reached elementary, high school, and college levels were estimated at 70%, 80%, and 81%, respectively (Table 7). This finding points to the importance of education in boosting the sugarcane farm productivity. In this case, at least high school level is considered good enough.

Table 6. Distribution of technical efficiency scores of sample farms

Technical Efficiency	CY 2002/03		CY 2003/04		CY 2006/07		CY 2002/03 - CY 2006/07	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Below 0.50	3	2.9	0	0.0	0	0.0	3	1.0
0.50 - 0.59	7	6.7	8	7.7	3	2.9	18	5.8
0.60 - 0.69	5	4.8	11	10.6	14	13.5	30	9.6
0.70 - 0.79	20	19.2	20	19.2	28	26.9	68	21.8
0.80 - 0.89	29	27.9	23	22.1	18	17.3	70	22.4
0.90 - 1.00	40	38.5	42	40.4	41	39.4	123	39.4
Weighted Average	0.76		0.77		0.82		0.79	

Technical inefficiency of farms under lease arrangement is statistically significantly lower compared to full and part ownerships (Table 7). The average technical efficiency score of the former was 92% while that of the latter groups was only 74% (Table 8). It is possible that because farm operators have to pay for the use of land under lease arrangement they are compelled to run their farm in an efficient manner. The low average technical efficiency score of farms under full ownership, on the other hand, may be attributed to the fact that operators of some of these farms have acquired land ownership via agrarian reform only recently and are still learning the ropes in sugarcane farm management. It is also possible that they lack the proper logistics that could help them run the farm efficiently.

Large farms are more inefficient than either small or medium ones (Table 7). It is reflected in the average technical efficiency score of large farms which was lower at 77% as against the 84% and 82% averages of small and medium farms, respectively (Table8). This trend can be explained by the results of analysis of variance of per hectare output and input levels which indicated that there were no statistically significant differences in the mean output levels among the three farm size classifications despite the fact that larger farms generally used more of each and every input except nitrogen fertilizer.

One finding that was expected, although not statistically significant, showed that farms with greater proportion of new plants than ratoon plants are more technically efficient. Similarly, farms that mechanize as well as farms that apply lime tend to be more technically efficient as revealed by their negative coefficients in the inefficiency regression analysis (Table 7).

The results of the regression analysis also confirmed that flat topography is the ideal land for sugarcane production. Specifically, farms with rolling topography were statistically significantly more inefficient than farms with slightly rolling and flat topography (Table 7). Average technical efficiency scores of farms with flat, slightly rolling, and rolling topography were 81%, 76%, and 74%, respectively (Table 8).

The Philippine Recommends for Sugarcane particularly specified clay loam soil as the preferred soil type in areas with less rainy months while light textured soils with good drainage are suitable in areas with longer wet season (The Sugarcane Technical Committee, 2001). The results of inefficiency regression analysis (Table 7) somehow confirmed this given positive coefficients obtained for farms with sandy and clay soils and negative coefficient for farms with sandy loam soil (indicating farms with sandy and clay soils are more technically inefficient and farms with sandy loam soil are less technically inefficient than farms with clay loam soil).

Table 7. Inefficiency model estimate

Parameter	Parameter Estimate		Standard Error
δ_O	0.5540	***	0.1492
δ_{AGE}	-0.0006	ns	0.0017
δ_{EDU}	-0.0133	***	0.0052
δ_{POWN}	-0.0502	ns	0.0403
δ_{LESS}	-0.1139	**	0.0551
δ_{MED}	0.0507	ns	0.0488
δ_{LRG}	0.1158	**	0.0583
δ_{PL}	-0.0012	ns	0.0011
δ_{MECH}	-0.0075	ns	0.0642
δ_{LM}	-0.0163	ns	0.0486
δ_{SRT}	0.0403	ns	0.0393
δ_{RT}	0.1417	***	0.0526
δ_{SS}	0.0490	ns	0.1328
δ_{SLS}	-0.0023	ns	0.0346
δ_{CS}	0.1025	ns	0.2074
δ_{TAR}	-0.1400	ns	0.1502
δ_{PAM}	-0.9583	***	0.2773
δ_{BAL}	-0.3286	***	0.1184
δ_{DPE}	-0.9572	***	0.2184
δ_{PEN}	-0.1243	*	0.0803
δ_{BUK}	-0.0747	ns	0.0777
δ_{DAV}	-0.1107	*	0.0841
δ_{COT}	-1.5343	***	0.4716

Among the nine milling districts, farms in Cotabato, Pampanga, Don Pedro, and Balayan were statistically less inefficient with average technical efficiency scores of 98%, 97%, 96% and 87%, respectively, while farms in Bukidnon, Carsumco, and Penafrancia were the most technically inefficient with average technical efficiency scores of 71%, 72%, and 75%, respectively (Table 7 and Table 8). These are quite interesting results because farms in Bukidnon milling district posted high average yield of 61.2 tc/ha for the entire study period. This yield was quite comparable to the average yield of 62.2 tc/ha posted by farms in Don Pedro milling district, yet the farms in the former milling district had low technical efficiency score. This irony may be partly explained by the differences in the rates of input usage by farms in the two milling districts. Farms in Bukidnon employed more labor than farms in Don Pedro to produce sugarcane. Moreover, farms in Bukidnon applied phosphate and potash while their counterparts in Don Pedro did not use these types of fertilizer; they instead apply more nitrogen which has greater production elasticity.

Table 8. Average efficiency scores of sample farms by different classifications, CY2002/03-CY2006/07

Classification	n	Mean	Classification	n	Mean
Age Bracket			*Liming Practice*		
< 30	3	0.75	Lime	34	0.68
30 - 39	40	0.75	Do not use lime	278	0.82
40 - 49	99	0.76			
50 - 59	88	0.78			
60 - 69	60	0.86	*Topography*		
70 & above	22	0.76	Flat	199	0.81
			Slightly rolling	93	0.76
			Rolling	20	0.74
Educational Attainment					
Elementary	54	0.70			
High school	57	0.80	*Soil Type*		
College	201	0.81	Sandy	11	0.90
			Sandy loam	119	0.84
			Clay loam	181	0.73
Tenurial Status			Clay	1	0.66
Lessee	73	0.92			
Part owner	122	0.74			
Full owner	117	0.74	*Milling District*		
			Carsumco	18	0.72
			Tarlac	6	0.83
Farm Size			Pampanga	39	0.97
Small	129	0.84	Balayan	15	0.87
Medium	119	0.82	Don Pedro	48	0.96
Large	64	0.77	Pensumil	27	0.75
			Bukidnon	123	0.71
			Davao	24	0.80
Mechanization			Cotabato	12	0.98
Mechanized	237	0.79			
Non-mechanized	75	0.78			

CONCLUSION

Over the five-year period covered by the study, the sample farms recorded a modest annual average production growth of 3.9%, which was about the same as the production growth recorded for the entire sugarcane sector. On average, 76% of the production growth was accounted for by total factor productivity growth and the remaining 24% was accounted for by factor accumulation. Having productivity growth rather than factor accumulation as the major driver of output growth in the sugarcane sector is quite an acceptable performance. However, there is still room for improving sugarcane productivity and output growth in the country.

Overall, technical efficiency improvement had been the major source of productivity growth, accounting for an average of 65% (or 49% of total output growth). The more recent average technical efficiency measure was 82%. This indicates that the sector can still increase sugarcane output by 18%, even without technological change and using the same levels of inputs, by improving the adoption of the existing technology at the farms or by catching up. This, therefore, calls for intensification of extension and support services provided by SRA and the MDDCs to expedite the catching up. The SRA should see to it that newly released HYVs actually reach farmers at the shortest time possible to minimize adoption lag and to maximize economic benefits from R&D. This could be facilitated through massive propagation and dispersal of planting materials in cooperation with the private sector.

Education and tenurial status of farm operators, farm size and topography, and milling district dummies were found to be significant determinants of technical efficiency. These findings should serve as guide on how technical efficiency of farms can be further improved. For instance, training services can be focused more on farm operators who have less education to improve their technical and farm management skills and thereby compensate for their lack of education. Likewise, extension services in the milling districts that were identified to be least technically efficient, e.g. Bukidnon, Carsumco, and Pensumil, can be further intensified to facilitate catching up of farmers in these milling districts.

The study showed that the second major driver of productivity growth was technical change. This contributed an average of 32% to the TFPG (or 26% to total output growth). Since this was only about half of the contribution of technical efficiency change and average technical efficiency of farms was already high at 82%, it is about time to shift attention to and bolster the sugarcane R&D to hasten the generation of better production technologies and thereby shift the production frontier.

The finding that sugarcane production may be characterized by constant returns to scale is contrary to what many think that sugarcane production is characterized by increasing returns to scale or economies of scale. This must be further investigated by expanding the sample size in the areas covered by the study and extending the study area to cover farms in Visayas especially in Negros which account for more than 50% of the country's sugarcane production. If it would be confirmed that sugarcane production is really characterized by constant returns to scale then scale efficiency change cannot be an instrument to attain comparative cost advantage and competitiveness. Moreover, there will be no harm in subdividing farms into smaller farms (e.g., with the implementation of agrarian reform) or in increasing the farm size as both small and large farms would have almost the same average cost of production per unit.

Similarly, a study regarding allocative efficiency of sugarcane production in the country must be conducted. The economically optimal combination of inputs given their relative prices must be established and compared with the actual combinations of inputs the farmers are using.

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