Technical Efficiency in Louisiana Sugar Cane Processing

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Abstract: *Participants in the Louisiana sugar cane industry have provided little information related to the efficiency of sugar processing operations. Using panel data from the population of Louisiana sugar processors, alternative model specifications are estimated using stochastic frontier methods to measure the technical efficiency of individual sugar factories. Results suggest the Louisiana sugar processing industry is characterized by a constant returns to scale Cobb-Douglas processing function with high technical efficiency.*

Key Words and Phrases: *Technical efficiency, Stochastic frontier, Resource allocation, Sugar cane processing.*

The sugar cane industry has contributed significantly to the Louisiana economy through income and employment over its approximate 200-year existence. The American Sugar Cane League, headquartered in Thibodaux, Louisiana, has estimated the value of the 1992 crop at $370 million with employment at about 20,000 jobs. The total economic contribution to Louisiana's economy is estimated to be over $1 billion, using a multiplier of 2.75 (Buzzanell). Louisiana's sugar cane processing industry has experienced considerable structural adjustment. Just in the past three decades, the number of sugar cane factories decreased while the total daily grinding capacity increased. Future challenges and prospects for the industry suggest that processors must strive for more productive and efficient use of resources, particularly in light of the uncertainty surrounding U.S. sugar policy and its relationship to the changing cost structure of the industry.

Although adjustment to changing economic and physical scenarios has been progressive, little is known about the technical efficiency (TE) of the surviving factories using economic models of TE measurement. Louisiana sugar factories use a "liquidation factor" (LF) as a measure of TE. This measure relates the amount of sugar actually recovered (in pounds per ton of cane) as a percentage of the theoretically recoverable sugar (also referred to as predicted sugar recoverability). However, this index is of limited value as a measure of performance. First, its interpretation is somewhat subjective because it is not constrained between zero and one and thus has an open upper bound. Second, it only accounts for one of the inputs used in the production of raw sugar, ignoring the other inputs in the production function. Thus, the LF lacks a formal economic justification.

The construction of a TE index consistent with the factory production function is needed because it may provide useful information related to differences in technical performance associated with factory size, predictions of technical efficiencies of individual factories based on the production process, and an indication of dollar losses due to technical inefficiencies. Capital investments in the sugar cane processing industry, particularly those associated with factory improvements, tend to be sizeable, with the rate of return on capital directly linked to firm technical efficiency. Thus, knowledge on technical efficiency alone can significantly contribute to a better understanding of factory performance and perhaps to enhancing the chances for long-term factory survival. In the Louisiana sugar industry, the profit incentive to reduce technical inefficiency at the processing level spreads to both sugar cane producers and landlords due to the traditional contractual arrangement between producers and processors.

This paper provides measures of technical efficiency of individual Louisiana sugar cane processors using a stochastic frontier production function. The first section briefly highlights the structural changes that have occurred in the Louisiana sugar cane processing industry. The second section presents a review of literature concerning efficiency measurement. The procedures, including model specification and data, are included in the next section, followed by the main results of the study and a quantification of technical efficiency. The paper concludes with a summary of the main implications of the work and adds some observations on future research.

Structural Changes in Louisiana Sugar Processing

The Louisiana sugar industry dates back to 1795 when sugar was one of the main agricultural commodities produced in the state. Sugar continues to be an integral part of the Louisiana economy and a significant contributor to domestically produced supplies. Sugar cane production and primary processing are currently concentrated in the state's southern parishes. Producers and raw sugar factories share the proceeds obtained from the sale of raw sugar and blackstrap molasses, with factories normally retaining 40 percent of raw sugar as "payment in kind" for services, transferring the remainder to growers as payment for cane. A typical "molasses bonus" generally gives factories the first 6 cents per gallon, with the rest distributed evenly between the grower and the factory.

Historically, the larger sugar plantations owned their own factories, but the number of factories began to decline as processing centralized in response to the steam engine, larger evaporators, and other processing technologies available to entrepreneurs. Transportation improvements moved cane by rail and paddle boats to central factory locations (Buzzanell). The process of adjustment continues. Just over the past three decades, the number of raw sugar factories decreased from forty-six in the early 1960s to twenty in 1992. However, average cane grinding capacity has increased from 2,402 tons a day in 1962 to 7,516 tons a day in 1992. Factories that closed were generally smaller (Buzzanell) and located in areas in which there had been a shift in production from sugar cane to other crops. Although it appears that factory size may be related to technical efficiency, and therefore to profitability, measures of factory TE not available.[1]

Literature on Technical Efficiency

Frontier efficiency analyses are often used to evaluate issues related to the structure of agriculture, the survival of the farm family, structural and financial aspects of agribusiness firms, and aspects of agricultural policy. The aim of previous studies has ranged from estimating technical efficiency to estimating economic (technical and allocative), scale and scope efficiencies. Technical efficiency relates to the question of whether a firm uses the best available technology in its production process whereas allocative efficiency reflects whether a technically efficient firm produces at the lowest possible cost. It is often the case that data are not available to estimate an economic efficiency index and, therefore, the focus of some studies is, of necessity, on the technical aspects of production.

Beginning with the pioneering work of Farrell, serious consideration has been given to the problem of estimating frontier production functions. A number of mathematical programming and econometric techniques have been developed that expand the options to researchers in formulating technical efficiency studies. Survey papers on frontier functions have been presented by Forsund, Lovell and Schmidt; Bauer; Battese; and Ellinger and Neff. The last two papers highlighted applications in agricultural economics.

The econometric approach to the estimation of frontier production function models has gained considerable popularity in the economics literature. This is due, in part, first to the ability of the model to separate out the deviations from the frontier into random and inefficiency components (Aigner, Lovell and Schmidt; Jondrow et al.; Kumbhakar; Battese and Coelli, 1992), and second to the advantage of conducting statistical inference about the response function and the inefficiency components. The most recent developments have expanded previous research by adopting models that capture hypothesized properties of technical inefficiency.[2]

The recent developments in Battese and Coelli (1991, 1992) have been applied to the study of Louisiana sugar cane farm TE (Kanjilal). Farm-specific technical inefficiencies were estimated from panel data of forty-five sugar cane farms under alternative model specifications and distributional assumptions. Results indicated that technical efficiency increased over time and that allocative inefficiency was much higher than technical inefficiency.[3] Previous studies at the processing level, however, have been concerned with cost structure and size economies (Campbell; Krenz, Shapouri and Angelo; Christy, Chapman and Heagler) to the exclusion of efficiency issues which also affect resource allocation. The findings in these studies suggest that the Louisiana sugar cane processing industry exhibits increasing returns to scale and that further concentration is expected.

Procedures for Measuring Technical Efficiency

Technical efficiency refers to the capacity of producing the maximum level of output for a given quantity of inputs and technology. If a firm is observed at a production plan (y^0, x^0), such a plan is technically efficient if $y^0 = F(x^0)$ and technically inefficient if $y^0 < F(x^0)$, where $F(x^0)$ is the maximum (frontier) output associated with the level of inputs, given by x^0. Therefore, technical efficiency can be measured by the ratio of actual to frontier values of output.

The following assumptions are adopted for the frontier specification: 1) the same production technology is followed by each firm in the industry, and 2) all inputs are homogeneous.

The empirical model considered for this study is given by

$$\ln Y_{it} = \beta_0 + \sum_{j=1}^{4} \beta_j \ln X_{ijt} + v_{it} - u_{it}, \quad i = 1, \ldots, 19; \; t = 1, \ldots, 7,$$

where Y = raw sugar produced (in tons), X_1 = sugar cane processed (in tons), X_2 = labor associated with factory operations (in hours), X_3 = gas (in M.C.F. - 1,000 cubic feet), and X_4 = wash water (in million gallons).

The v_{it} is a pure random variable while u_{it} is a one-sided random error ($u_{it} \geq 0$). By construction, $u_{it} > 0$ implies that inefficiency exists and $u_{it} = 0$ implies no inefficiency. Further, it is assumed that $u_{it} = u_i\, e^{-\eta\,(t - T)}$, and $v_{it} \sim N(0, \sigma_v)$, where η is an unknown parameter and u_i are positive truncations of the $N(\mu, \sigma^2)$ distribution.

There are three parameters in these models which relate to technical inefficiencies. The first is η which measures whether inefficiency in sugar processing has changed over time; $\eta > 0$, $\eta < 0$, and $\eta = 0$ imply that inefficiencies are decreasing, increasing, and remaining constant, respectively. Because inefficiency is assumed to be stochastic, its distribution is represented by a random variable with mode μ. The parameter $\gamma = \sigma_u/\sigma_v$ is associated with the degree of inefficiency; a zero value for γ implies the absence of inefficiency.

The preceding equation is commonly referred to as a stochastic frontier model. An attractive feature of this specification is that the model permits various restrictions on parameters η, μ, and γ (Table 1). Imposing the restriction $\eta = \mu = \gamma = 0$ implies absence of inefficiency. Similarly, the restriction $\eta = 0$ implies that inefficiency effects are time-invariant. The coefficients of the model and parameters describing the random and inefficiency errors are estimated by maximum likelihood methods, and restrictions are tested with classical likelihood ratio tests. Applications of these various models can be found in Battese and Coelli (1991, 1992), Schmidt and Sickles, Pitt and Lee; and Cornwell, Schmidt and Sickles, among others.

The Data

Data for this study consists of primary and secondary panel data which were obtained from nineteen independent sugar processing factories in Louisiana for the 1986 to 1992 grinding seasons. These data include raw sugar outputs along with corresponding input levels of sugar cane, labor, gas and cane wash water. Raw sugar production, Y, and inputs X_1 - X_4, are measured in annual totals as reported in confidence by the individual factories. One factory temporarily suspended operations for one year during the study. It was assumed that this factory achieved identical efficiency levels as in the previous year. This procedure resulted in a

Table 1.
Alternative Model Specifications and Restrictions

Model	Restrictions	Description
OLS	$\mu = 0, \eta = 0, \gamma = 0$	No Inefficiency
I	$\mu = 0, \eta = 0$	Inefficiency is time-invariant and distributed with a mode of zero
II	$\eta = 0$	Inefficiency is time-invariant and distributed as truncated normal
III	$\mu = 0$	Inefficiency is time-variant and distributed with a mode of zero
IV	No restrictions	Inefficiency is time-variant and distributed as truncated normal

Note: Models I-IV are estimated by maximum likelihood method; μ = distribution parameter, η = time-variance parameter and γ = inefficiency parameter.

complete set of panel data for the nineteen raw sugar factories in the industry.

Results

The estimation results are presented in Table 2. The first column shows the OLS regression results, followed by results for models I-IV as defined in Table 1. Sugar cane, the main input in the production of raw sugar, obtains the highest output elasticity at either 0.93 or 0.94. The sum of the estimated coefficients of the frontier model is close to one, and a t-test on the hypothesis of constant returns to scale is not rejected (estimated t-value is 1.24 with 128 degrees of freedom).[4] Labor and wash water have very low elasticities and are significant variables only in model IV. In all models, the gas variable exhibits a negative relationship and is insignificant.

The stochastic frontier models (I-IV) also report parameter estimates for η, which measures the time varying properties of the non-negative firm effects (u_{it}), μ which is the mode of the distribution for firm effects, and γ which measures inefficiency (a value between 0 and 1). The general specification of the frontier model IV is equivalent to the traditional response function if the parameters γ, η, and μ are simultaneously equal to zero; this is a test of the null hypothesis H_0: $\gamma = \eta = \mu = 0$ which can be

Table 2.
Parameter Estimates of Stochastic Frontier Production Functions for Louisiana Sugar Factories

	Models				
Variable	OLS	I	II	III	IV
Constant	-2.527 (-5.99)	-2.506 (-5.69)	-2.506 (-5.67)	-2.525 (-5.65)	-2.604 (-4.52)
Sugar Cane	0.947 (22.27)	0.935 (21.05)	0.934 (21.59)	0.941 (22.53)	0.935 (39.29)
Labor	0.058 (1.54)	0.061 (1.52)	0.062 (1.56)	0.059 (1.53)	0.062 (2.08)
Gas	-0.002 (-1.13)	-0.002 (-1.03)	-0.002 (-1.07)	-0.002 (-1.12)	-0.002 (-1.11)
Wash Water	0.040 (1.11)	0.047 (1.22)	0.048 (1.27)	0.042 (1.09)	0.060 (2.24)
Ln L	154.62	154.85	154.86	155.09	156.62
Adj. R^2	0.95				
γ		0.098 (0.62)	0.060 (0.38)	0.291 (2.05)	0.203 (0.70)
μ			0.022 (0.28)		0.049 (0.35)
η				-0.273 (-4.40)	-0.245 (-0.74)
σ^2	0.006	0.006	0.006	0.008	0.007

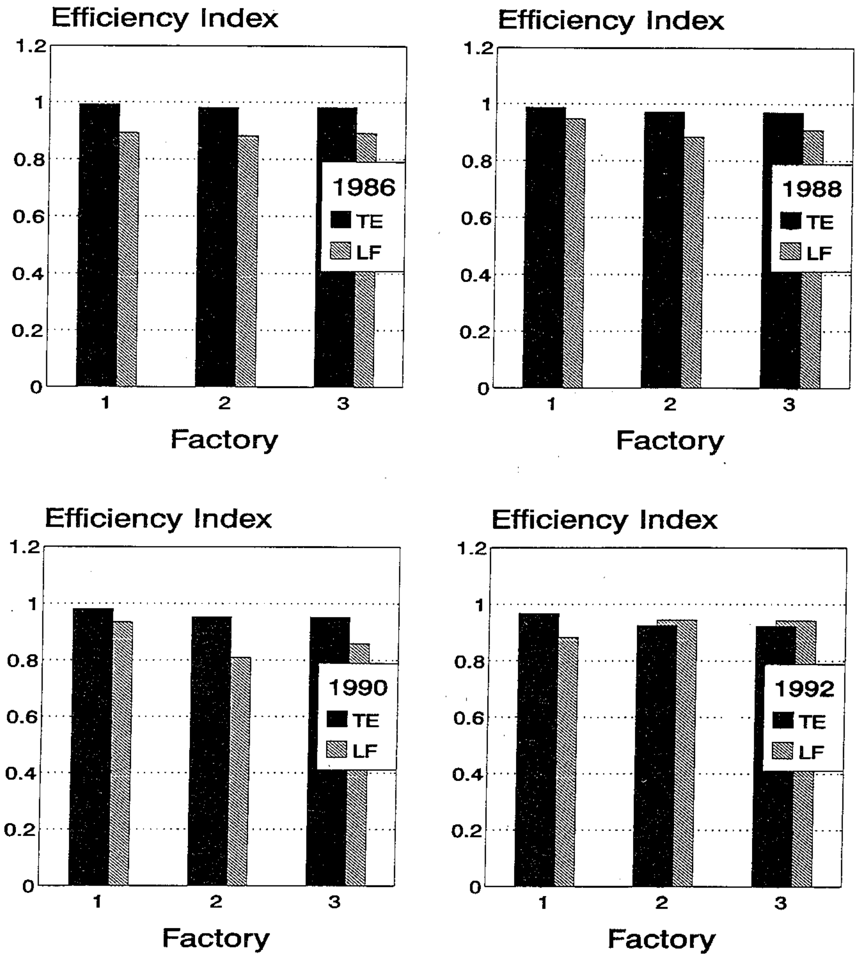
Note: T-ratios appear in parenthesis; γ is an inefficiency parameter, η is a time-variance parameter and μ is a distribution parameter.

tested by estimating a ratio of the likelihood functions for models IV (the unrestricted model) and OLS (the restricted model). This likelihood ratio test is distributed as Chi-squared with 3 degrees of freedom. For the balanced panel data used in this study, the hypothesis is not rejected (the estimated likelihood ratio equals 4.0), suggesting that the traditional average response function may be appropriate for these data. In comparing the results III and IV, however, when the inefficiency distribution parameter μ is set to zero, the inefficiency parameter γ and the time-varying parameter η become significant (model III), but this significance disappears when μ is estimated in model IV. To avoid specification bias,[5] we adopt model IV to predict technical efficiency. The hypothesis that no relevant explanatory variables have been omitted from the regression equation was tested using the RESET test (White et al., pp. 169-177). We implemented three versions of the test which resulted in estimated Chi-squared values of 0.60, 0.63, and 0.81 which imply that omitted variables are not a problem with these data, where the null hypothesis is that the model is properly specified. Tests for heteroscedasticity (Godfrey) and autocorrelation also support well-behaved residuals.

The liquidation factor described in the introduction is commonly used by cooperative factories (comprising about half the factories in the state) to measure performance. For the 1986 to 1992 period, the minimum and maximum liquidation factors were about 0.82 and 1.025, respectively. An alternative measure of TE for individual sugar factories and for the industry was estimated using the procedure of Battese and Coelli (1991).[6] During 1986, sugar factories experienced a relatively high level of efficiency when compared to the efficiency frontier. The lowest TE index for 1986 was 0.981 while the highest was 0.993. The TE index for the worst factory in 1992 was 0.918 while that for the most efficient factories was 0.97. Bar charts comparing average factory performance using TE and LF indexes during the 1986 to 1992 period appear in Figures 1 and 2. Figure 1 compares three factories representing small (factory 1), intermediate (factory 2) and large (factory 3) processors for 1986, 1988, 1990 and 1992. Figure 2 represents average factory performance during the period 1986 to 1992. It is observed from these figures that the liquidation factor tends to underestimate factory technical performance in processing raw sugar relative to the frontier index. Also, a relative ranking of factory technical performance based on the LF would not coincide with that of the TE index. These figures also highlight that there is no difference in technical performance between small and large factories. In fact, some of the most efficient factories appear to be small (Figure 1). Lastly, it is apparent that TE is rather stable across factories based on either the LF or TE indexes.

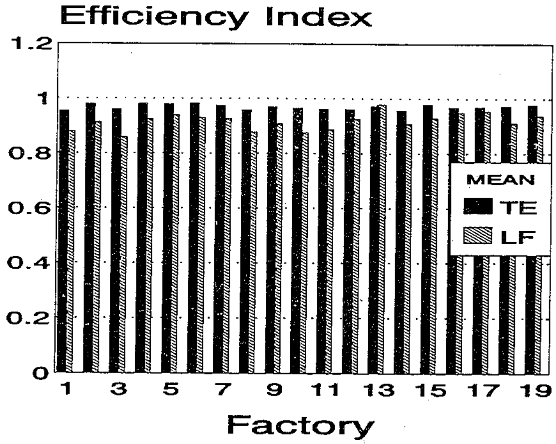
The inefficiency index (1-TE) can be interpreted as the largest percentage cost savings that can be achieved by moving the factory toward the frontier-isoquant through a radial scaling of all inputs. Or, alternatively, the presence of technical inefficiency reduces output given the level of inputs, thereby reducing profit. During the 1986-92 period, approximately 381,010 tons of sugar cane were processed in Louisiana which, when multiplied by the mean technical inefficiency index, results in significant

Figure 1.
Technical Efficiency Indexes, Frontier Index (TE), and Liquidation Factor (LF), Louisiana Sugar Processing Industry, Selected Factories and Years



loss in output to the industry. Figure 3 presents the estimated loss in revenue per ton of cane to landlords, factories and producers given the proceed-sharing agreement prevailing in the industry. The estimated factory loss per ton of cane represents 40 percent of the total loss. The remaining 60 percent of the estimated loss is divided between producer and landlord on an 80/20 basis to comply with the tenure agreement prevailing in the industry. Perhaps the most striking observation is the magnitude of

Figure 2.
Average Technical Efficiency Indexes, Frontier Index (TE), and Liquidation Factor (LF), Louisiana Sugar Processing Industry, 1986-1992



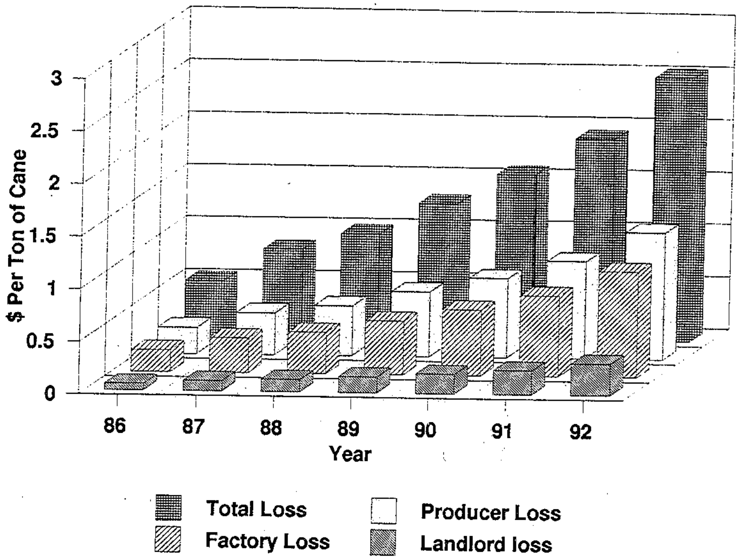
losses sugar cane producers might be incurring due to factory technical inefficiencies, which range from about $0.25 to $1.21 per ton.

Summary and Implications

This study quantifies the technical efficiency of individual Louisiana sugar factories and measures the economic losses from technical inefficiency. The alternative econometric models tested in this study all lead to the same basic conclusion, supporting the existence of high technical efficiency within the Louisiana raw sugar processing industry relative to the stochastic frontier.

Much of the interest in this study is related to the implications of inefficiency not only for factories, but also for producers and landlords. A major repercussion of the share agreement is that only 40 percent of all losses due to technical inefficiency in processing actually accrue to the raw sugar factories. The remaining 60 percent of losses are absorbed by growers and landlords on a basis commensurate with the land tenure agreement (normally 80/20 percent of after-milling proceeds for grower and

Figure 3.
Estimated Loss in Revenue to Landlords, Factories and Producers due to Technical Inefficiency in Sugar Processing, 1986-1992



landlord, respectively). For all involved parties, technical inefficiency in processing results in a shortfall of potential revenues.

The estimated high levels of technical efficiency during the 1986 to 1992 period suggest that the industry has achieved a stage of equilibrium by adjusting toward fewer and larger factories. The finding of constant returns to scale implies that zero economies of scale characterize the processing industry during the study period. This result appears consistent with the recent halt in the decline of factory numbers that had caused considerable concern during the 1967 to 1985 period when factory numbers declined by more than 50 percent. Productivity increases, therefore, would require introduction of new innovations or a higher level of technology.

The notion of technical efficiency in this study encompassed total factor employment. Consequently, the technical efficiency estimates treat the contribution of each factor of productive efficiency equally, thereby masking any difference in efficiency attributable to particular inputs. It is found that the liquidation factor commonly used by some factories to measure technical performance in general underestimates factory performance. This suggests that any loss in profits resulting from factory operations may be smaller than currently estimated.

Given the current trend in environmental concerns and regulations, it appears that the impact of such regulations may come about as a decrease in both technical and allocative efficiency of factories given that sugar processing in Louisiana can be characterized by a constant returns-to-scale technology and high technical efficiency relative to a production frontier. Perhaps the findings here may serve as an incentive for the sugar processing industry to share with researchers individual factory data that would permit estimation of allocative efficiency.

Notes

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1. Recent developments in the estimation of frontier production functions (see Battese and Coelli, 1991 and 1992, for a survey) facilitate a much more detailed analysis of TE and firm-specific effects. Ideally, a quantification of economic efficiency would be preferable. Unfortunately, the data needed to provide such measures are not available.

2. Refer to Battese for a detailed discussion of this issue and for additional citations.

3. Kanjilal measured allocative efficiency (AE) indirectly, that is, without using formal economic models of AE measurement because of data limitations. We do not adopt his suggested approach because it is only an approximation to AE based on aggregated data.

4. The finding of constant returns to scale, and the misspecification tests presented later, leave little logical basis to question the validity of the Cobb-Douglas specification for these data. But it is noteworthy to emphasize that the assumptions of such specification (particularly constant factor substitution and complementarity of inputs) could be

restrictive in other applications. The FRONTIER 4.0 computer program can be used to estimate more general specifications such as the translog function.

5. It is well known in the econometrics literature (Judge et al., pp. 857-860) that if we have a reason to believe a variable should be included in an economic model, its exclusion from the model due to statistical insignificance would result in biased estimates for the remaining parameters. Thus, we use model IV so we can arrive at an unbiased economic valuation of what the results imply to the industry in terms of foregone revenue.

6. Tabulated results are available from the authors upon request.

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