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AN INTRA-FIRM STUDY OF X-EFFICIENCY OF TAIWAN'S SUGAR INDUSTRY

CHI SCHIVE

I. INTRODUCTION

EFFICIENCY measures use standards which are applied at various levels of aggregation: macro, industry, and firm. Economists have traditionally been concerned with allocative or market efficiency, and this is efficiency at the macro level of aggregation. Industry-wide efficiency measures, using linear programming and linear regression, have sought to determine deviations of individual firms from the industry frontier. This is accomplished by estimating the efficiency of a particular firm relative to the "best" firm in the industry. Clearly, this type of efficiency is a "relative" one.[1] It is also measuring non-allocative efficiency, what Leibenstein calls X-efficiency [8] [9] [11]. Such estimates have been made for industries in the United States, Sweden, Brazil, Norway, France, Ghana, Tanzania, India, Thailand, and Mexico [6].

To expand on these findings, this study applies linear programming and linear regression techniques to a multiplant monopolist—the Taiwan Sugar Company.

The remainder of this paper is organized in the following way. Section II presents information on the Taiwan Sugar Company, the method for measuring X-efficiency among the company's various plants, and the measurement of both inputs and outputs. Section III will present the model of X-efficiency for the Taiwan sugar industry. Section IV presents the empirical results while Section V discusses implications of these findings and conclusions.

II. THE TAIWAN SUGAR COMPANY, MEASUREMENT AND DATA ISSUES

A. *The Company*

The Taiwan Sugar Company (Tai-Sugar) is a fully owned government enterprise with monopoly power in Taiwan's sugar industry. The company has twenty-three sugar mills of different capacities scattered around the island, with the exception of the northern part of Taiwan. In its "golden age" during the 1950s, Tai-Sugar was the largest corporation on the island and contributed to slightly more than half of the island's total exports. However, the situation has changed significantly during the last decade.

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1 These studies are reviewed in [6].

Since 1976, deteriorating international sugar prices and the rising cost of production has significantly and adversely affected the company's sugar production. In 1977, Tai-Sugar produced a total of 1.08 million tons of sugar and exported 594,000 tons of sugar. By 1984, both figures had decreased to 619,000 tons and 122,000 tons, respectively. With the exception of 1976 and 1977, the production of sugar has generated a loss. Under these unfavorable circumstances, the company has initiated several steps to diversify its product lines, starting from pig raising to manufacturing animal feeds, vegetable oil, pulp, etc. In 1984, non-sugar production had already exceeded that of sugar. Nevertheless, the sugar production sector of the company has, to a large extent, remained intact in terms of the number of mills, total employees, product-mix, technology and equipment. Plant level data for sugar manufacturing from 1976 to 1983 provides the basis for this study of technical or X-efficiency.[2]

Several characteristics associated with the company's sugar production make the study unique and provide a suitable situation to test X-efficiency theory. First, all mills were established before World War II and only minimum modifications and expansions were made in a few mills during the period under study. Therefore, a standardized technology was applied. Furthermore, because there was a job rotation system among plant managers, any specific information on production would be known by everyone. Therefore, the assumption of full information can be correctly applied. In regard to the quality of labor, all employees were under the same payroll system, and job rotation existed at all management levels. Thus, no significant difference in this regard will be expected.

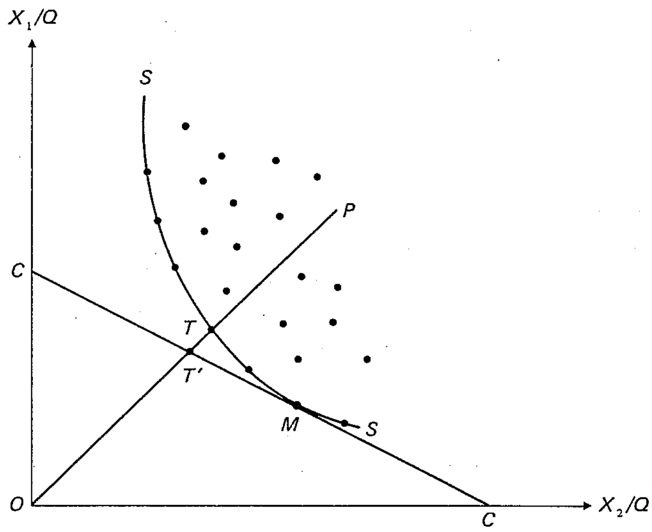
Finally, with respect to output, though mills did not produce exactly the same kind of sugar, they could be divided into three groups according to their specializations: raw sugar mills, refined sugar mills, and mills producing both. Within each group of mills, although there existed grade differences, mainly in terms of sugar content, the differences were not significant. The product differentiation either within or among mills does not pose a problem in analysis because weights can be applied to convert different products into a standard product. Given the (relative) homogeneity of the mills one would not expect any significant difference in production efficiency among mills.

B. *Measuring Plant Level Efficiency*

We adopt Farrell's technique to measure technical or X-(in)efficiency of each mill. In a single case of two inputs, X_1 and X_2, and one output, Q, the production function of a mill can be represented by a point in a two-dimensional diagram, where the axes represent two unit factor inputs, X_1/Q and X_2/Q, respectively. This is shown in Figure 1. Given all the production points, we can construct a production frontier, SS, consisting of the minimum input combination such that no observation lies between the envelope and the origin. SS thus represents the

[2] The primary plant level data covering all inputs, costs, and the various outputs of each mill were available when the author conducted a study evaluating the performance of the Taiwan Sugar Company for the Chung-Hwa Institution for Economic Research in 1984. This study was supported by the Ministry of Economic Affairs.

Fig. 1.



most efficient production points, i.e., all points on SS are equal in technical efficiency but differ in price efficiency, where point M is the minimum cost given the cost line CC. For any point P not on SS, we can draw a line between P and the origin, which intercepts SS at point T. The X-efficiency or technical efficiency index of P is measured by $\overline{OT}/\overline{OP}$, which means that in order to produce one unit of Q, the most efficient production point T uses only the $\overline{OT}$ portion of inputs, comparing with the point P ($\overline{OP}$), since identical factor proportion held between these two points.[3] As implied, the issue of inappropriate techniques at market prices is ignored here in measuring the technical efficiency. In computation, a linear programming model can be constructed to calculate the efficiency index of any production point.[4]

The novelty of Farrell's efficiency measure lies in its simplicity. For example, the technique proposed makes no assumptions as to the form of production function, and hence no estimation on parameter(s) is necessary.[5] Furthermore,

3 See [2] [13]. Here we do not attempt to distinguish X-efficiency from technical efficiency. For a subtle distinction between these two concepts, see [10].

4 Given a production set A of two inputs X_1, X_2 and output Y, any production point $P_i \in A$ can be represented by (x_{i1}, x_{i2}), where $x_{i1}=X_{i1}/Y_1$, $x_{i2}=X_{i2}/Y_2$, $i=1, 2, 3, \ldots, n$. The most efficient production points P_k, P_l are those satisfying the following conditions:

$$\lambda_1 x_{k1}+\lambda_2 x_{l2}=x_{i1},$$
$$\lambda_1 x_{k2}+\lambda_2 x_{l2}=x_{i2},$$

where $\lambda_1+\lambda_2 \geq 1$. The efficiency index for P_i is defined as $1/(\lambda_1+\lambda_2)$. This two-factor model can be easily extended into n-factor model.

5 Farrell's method is, thus, called the "deterministic nonparameter frontier" approach in comparison with other approaches which assume certain forms of production function

the technique makes no assumption as to the degree of returns to scale. Nevertheless, with the efficiency indices calculated and various measures of scale available, the degree of returns to scale can be tested, instead of being assumed at the beginning.[6] In fact, the simplicity of the technique allows the maximum degree of applicability.

The great convenience of Farrell's measure is not without limitation. A frequently observed limitation is that where the efficiency indices measured are too sensitive to the frontier, which, to a large extent, depends on which inputs are selected in calculating the frontier.[7] In an extreme case, if a chosen input maintains a fixed proportionate relationship with output, then the measure will break down by reducing all efficiency indices into unity with numerical value one.[8] This problem, which is similar to the multicollinearity problem in regression analysis, is not insurmountable. Theoretically speaking, if a certain input varies proportionately with output in a production system, then the productive efficiency of the system will be independent of the use of that specific input and hence that input should be excluded from the measurement. Empirically, the selection of inputs may be determined by both the research purpose and the empirical results.

C. *Inputs and Outputs*

We include three factors: direct labor, indirect labor, and fixed capital, in calculating the efficiency index of each mill. The most important material, sugarcane, is not included in the measurement because sugar yield rates (sugarcane/sugar) vary within a narrow margin (between 8.5 and 9.0), and the inclusion of sugarcane in the measurement will unify the efficiency indices to a great extent. Fuel and electricity are also omitted in the measurement because sugar processing uses bagasse as a main source of energy and thus fuel and electricity are insignificant in total energy consumed.

Direct labor at each mill is measured by manhours of direct labor used in the mill during its yearly operational seasons. Indirect labor is calculated from the number of salaried personnel in each mill. The value of the fixed assets of each mill, covering buildings, equipment, transportation equipment, and miscellaneous equipment, is net of depreciation and adjusted by a capital goods price index.

Regarding output, most of the mills are either completely specialized in producing one type of sugar (raw or refined), or have a very high degree of specialization, sometimes up to 90 per cent, of one type. There are only three mills which produce a nearly equal amount of raw and refined sugar. For purposes of measuring each mill's output, raw sugar production is converted into refined sugar

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or relationships between input and output. For cost function approaches, assumptions on producer's behavior and market structure should be made. All other approaches are classified under four categories: the deterministic parameter frontier, deterministic statistical frontier, stochastic frontier, and cost function approaches. See [5].

6 See [3].

7 To cite a few, see [4, pp. 294–95] [7, p. 95] [14, pp. 778–79].

8 In Figure 1, the production frontier under this special situation will be a straight, vertical or horizontal, line comprised to all points and hence all efficiency indices will be unity with numerical value one.

equivalents applying domestic sugar prices as weights.[9] (The relative prices of these two types of sugar is constant during the period observed.) Each mill also produces and sells bagassee and molasses to other companies or to the pulp plant within the company. Again, domestic prices of these products are used as weights.

III. EFFICIENCY IN TAIWAN SUGAR PRODUCTION

Sources of efficiency differences may be sought from: (1) long-run institutional or natural environment dimensions, such as economies of scale, location of mills, technological differences linked to different product specialization, quality of land, and technical progress; (2) utilization rates, a short-run factor; and (3) specific characteristics of plant managers—their educational background, etc.

Scale economies. The sugar industry is a conventional food processing industry. In the sugar mill, almost all the equipment in sight, from crushing rollers and filters to evaporators and crystalization pans, are bulky and heavy. According to the two-thirds rule in engineering, the cost of equipment does not increase proportionally with the capacity of the equipment, but rather at around 60 per cent of the increase in capacity. This rule, in fact, is most applicable to continuous production processes using heavy capital investment, and capacity dominated by equipment volume.[10] Judging from the characteristics of sugar manufacturing, economies of scale should be evident in sugar mills.

Regional factors. The existing sugar mills, as mentioned before, are scattered around the island except for the northern region. Given the geographic condition of the island—high mountains, many in excess of ten thousand feet, divide the island East and West—climatic differences between the East and West regions are evident. In addition, soil conditions and the pace of industrialization differ with the different regions, and affect the allocation of land between farming and industry as well as the allocation of farm land between sugar and other crops. These factors have a great influence on sugar farming, including field management and the size of the crop.

Technical progress. This study covers eight consecutive years from 1976 to 1983. Technical changes, represented by a time variable, refer to an autonomous improvement in efficiency which is exogenously determined, i.e., not determined in the system. The introduction of the time variable serves another purpose, which may be equally important from a statistical point of view. That is, if certain explanatory variables as well as the dependent variable reveal a trend movement, then the coefficients estimated will be biased. However, this can be corrected by introducing this kind of variable.

Product specialization. Refined sugar is a decolorized sugar with higher sugar

[9] There exists another weighting system in the sugar industry which is based on the amount of steam consumption in processing different types of sugar. This system, although it has high engineering accuracy, is not proper because the energy used in processing sugar is self-generated from bagasse, and the weights fail to reflect other differences between producing raw and refined sugar.

[10] For details and empirical evidence, see [12].

content than raw sugar. Refined sugar takes longer to process, needs to be more carefully controlled and uses a different set of equipment than raw sugar. Hence product mix may affect the mill's relative performance.

A dummy variable is used to distinguish raw sugar mills from refined sugar mills. For the three mixed sugar mills, a 50 per cent cutoff point is chosen for classification. The product status of all mills has been unchanged during the observation period except in the case of one mill where the main product was transformed from raw sugar into refined sugar.

Proporitons of company-owned land. In 1984, the company owned around 60 per cent of all cane fields in Taiwan. The total number of acres of land has been quite stable, though the composition of the land has been changing gradually. Two factors, working in opposite directions, attribute to such a phenomenon. First, rapid industrialization has led to a reallocation of land toward industrial uses. However, the company has been putting great effort into cultivating new land in the hills, the river beds, and the sea. Second, the proportion of company-owned land varies among mills. In some mills, the proportion of company-owned land can be as high as 90 per cent, while in others below 10 per cent.

This variable may affect the mill's operative efficiency in many ways. First, the newly cultivated land is marginal land where the quality of sugarcane produced may be different. Second, the location of the new land—on the hills, in the river beds, and the sea—generally reduces the ease of production. Difficulties in transportation and field management may occur. Third, the harvesting management involved in company-owned and private land, such as the timing of the cutting, the trash content, the method of cutting (with top green or burning before cutting), and the waiting time between cutting and crushing the cane, may not be executed in an optimum way. Thus, sugar yield rate and plant operation efficiency may be influenced.

The first two factors suggest a negative relationship between the proportion of company-owned land and efficiency while the effect from the third one is uncertain. Two opposite results may arise from the different attitudes of plant managers. If a plant manager assumes a large responsibility in pursuing efficiency, then more company-owned land implies better field management and hence a higher efficiency rate is expected. However, under the existing system which offers no great reward for efficiency, the opposite attitude and result are likely. In all, we may expect that a higher proportion of company-owned land per mill tends to lower its operative efficiency.

Utilization rates. Utilization rates have been observed as a crucial determinant of labor productivity, and in calculating the efficiency index following Farrell's measurement system. In this system, two of the three factor inputs selected, fixed capital and indirect labor, are fixed in the short run and the unit inputs of these two factors vary in reverse proportion to utilization rates. Consequently, a higher utilization rate of a mill means less unit inputs for both fixed capital and indirect labor and hence a higher efficiency is recorded.

The utilization rate of mills is measured by the crushing capacity actually utilized on an annual basis. Because sugar mills are usually operated twenty-four hours a day, or at near 100 per cent daily capacity during the production seasons, the daily crushing capacity data cannot be used here. Instead, with the annual data of the total amount of cane crushed available, we can take the maximum operational days (208 days) per year and multiply it by the daily crushing capacity of each mill to estimate the annual crushing capacity and the utilization rate of that mill.[11]

Educational background of plant managers. Almost all plant managers of the company have received basic training either in agronomy or in engineering, mechanical, or chemical. Only one manager received a degree in business management. For those agronomist managers, field work experience and farm management are required training and are emphasized. Because field management is such an important factor in determining the mills' operative efficiency, and the educational background of plant managers may influence their relative emphases and expertise in field management, this factor may have a role to play in explaining the efficiency difference.

The quality of sugarcane. Although sugarcane is not included in the efficiency measurement, the quality of sugarcane is introduced to explain the possible efficiency differentials. The rationale behind this hypothesis is straight forward: higher quality sugarcane means less unit factor requirements for all input variables in the plant. Furthermore, in formulating other hypotheses, such as the location of mills, the proportion of company-owned land and the educational background of plant managers, the quality of sugarcane serves as an important link between efficiency and these factors. Therefore, there is a need to introduce this factor independently.

The sugar yield rate is taken as a proxy for the quality of sugarcane. It may be noted that in measuring the sugar yield rate of each mill, raw sugar is converted into refined sugar equivalent using the sugar content rates of different products, instead of sugar prices. This is done because the former reflects the quality of sugarcane while the latter more accurately represents cost differences.

IV. EMPIRICAL RESULTS

The frequency distribution of average mill efficiency for the entire eight-year period, and estimated by the linear programming method discussed in Section II, is presented in Table I. Although the average figures reduce the variation of efficiency indices and the discrepancy among them, the most efficient mill used slightly less than half the input per unit of output compared to the least efficient mill.

Table I also reveals that the frequency distribution of mill efficiency clusters around two extreme. For the entire set of twenty-three mills, the eight-year average was that the top one-third mills all operated at above 70 per cent efficiency, while the bottom one-third were below 50 per cent. Furthermore,

[11] To select a constant maximum operational day for all mills, which reduces utilization rates to a relative measure, poses no problem because the efficiency measure adopted is also based on the relative concept.

TABLE I

FREQUENCY DISTRIBUTION OF AVERAGE EFFICIENCY INDICES

	90–80%	79–70%	69–60%	59–50%	49–40%
Number of mills	1	7	4	4	7

Source: Taiwan Sugar Co.

the annual efficiency data of each mill indicated that most mills did not undergo significant changes in their relative performance over the eight-year period. Table I indicates that sugar mills operated at very different levels of efficiency.

The efficiency estimates deviced with linear programming will now serve as the dependent variable in order to estimate the effects of certain variables on efficiency. The variables are those discussed in Section III. The estimating equation takes the form:

$$E_i = \alpha_1 CO_i + \alpha_2 EDU_i + \alpha_3 PRODMIX_i + \alpha_4 REGION_i + \alpha_5 QUALSUGAR_i + \alpha_6 UTIL_i + \alpha_7 SCALE_i + \alpha_8 TECHCH_i, \qquad (1)$$

where E_i is the ith mill's average efficiency index for the entire period, *CO* is the percentage of land owned by the company, *EDU* is the educational background of the plant manager, *PRODMIX* is the product mix of the mill, *REGION* is the region in which the mill is located, *QUALSUGAR* is the quality of the sugarcane, *UTIL* is the utilization rate of the mill, *SCALE* is the mill's output capacity, *TECHCH* accounts for exogenous technological change occurring over the period.

In turn, *CO* is measured as the percentage of total acres owned by the company. *EDU* is a binary variable with a value of 1 if the plant managers are trained in agronomy and business, and zero elsewhere. *PRODMIX* is a binary variable with a value of 1 if the mill specializes in raw sugar or produces more raw than refined sugar, and zero elsewhere. *REGION* is a binary variable with a value of 1 if the mill is located in central Taiwan, and zero elsewhere. *QUALSUGAR* is measured by the ratio of sugarcane consumed per unit of sugar produced. *UTIL* is measured by the average annual crushing capacity utilized. *SCALE* is measured by the daily crushing capacity. This "input" measure of capacity, compared to the regular "output" measure, can be troublesome if there exists a wide range of options on product-mix. Fortunately, the product-mix of existing sugar mills is not so characterized, and this reduces the inconsistency between the input and output measures of capacity.

A total of 184 observations on twenty-three mills was used in estimating equation (1). Results are shown in Table II. These results show that greater individual incentives (less company-owned land) and more educated managers increase mill efficiency. This result for "quality" of managers is similar to that reported by Anderson and Frantz [1] in their study of textile firms in Mexico, and by Page [13] in his study of logging, sawmilling, and furniture manufacturing in Ghana. Other variables are now discussed.

TABLE II

DETERMINANTS OF MILL EFFICIENCY

Variable	Coefficient	*t*-value
CO	−18.180	−4.79[a]
EDU	5.532	3.63[a]
PRODMIX	13.000	8.45[a]
REGION	3.725	2.43[b]
QUALSUGAR	−5.367	−5.76[a]
UTIL	0.615	10.08[a]
SCALE	5.760	6.37[a]
TECHCH	1.218	3.65[a]
$\bar{R}^2=0.6933$		

Source: Taiwan Sugar Co.
[a] Significant at 99% level.
[b] Significant at 95% level.

In terms of long-term institutional and environmental factors, first, larger mills (*SCALE*) are closer to the production frontier than are smaller ones. This is not surprising given the nature of sugar manufacturing and the fact that the largest mill in the company had a daily crushing capacity of four thousand tons compared to the smallest one of only fourteen hundred tons. Secondly, although many external as well as internal factors have been discouraging sugar production, technical progress (*TECHCH*) did take place among mills during the eight-year period observed. Thirdly, raw sugar mills (*PRODMIX*) usually performed better than refined sugar mills. These results imply that technology differed between these two types of mills, which is not reflected by the weights chosen in converting raw sugar into refined sugar equivalent.

In regard to short-term factors, the utilization rate of a mill was overwhelmingly important in determining a mill's efficiency. Assuming that a mill is running at a 40 per cent utilization rate compared to another mill running at 80 per cent, the coefficient estimated of 0.615 implies that there will be a 25 percentage point difference in efficiency between these two firms, other things being equal.

In terms of the quality of sugarcane, the more sugarcane consumed per unit of sugar produced in a mill, the more other inputs required, and the lower the efficiency performance of the mill.

Noting the above findings, we are ready to examine the regional dummies. A total of nine mills located in central Taiwan were found to have performed better than the rest of the mills on average. The dummy variable representing East Coast mills did not stand up in the significance test and hence is dropped from Table II. However, we did find that Eastern mills performed better than the average. Nonetheless, the Eastern mills also had higher utilization rates, produced raw sugar, and were managed by agronomist managers most of the time. Because these Eastern mill-specific factors all contributed positively in explaining their better performance, the explanatory power of the regional dummy for Eastern mills was weakened.[12]

V. IMPLICATIONS AND CONCLUSIONS

Apart from the theoretical interest in whether there exists an intra-firm X-efficiency and in testing the relevant bypotheses, the empirical results reached provide vital information for the company on how to improve its overall performance.

First, given the fact that scale economies and utilization rates of a mill have a great bearing on a mill's efficiency, and that sugar mills in Taiwan are rather small by international standards,[13] the company should consider seriously the merger of existing mills. Second, because around one-third of the efficiency variations are left unexplained, and the gap between the relatively efficient and inefficient mills is very large, there must be ample room for efficiency improvement. Pressures on those less efficient mills to assimilate with the better performers, obviously lacking in the existing system, should be introduced. Third, regarding short-term policies, the company's management training program should be reinforced in light of the relatively poor performance of mills managed by engineers. More information on production and management should be collected, analyzed and made available for managers at all levels. The analysis of the pattern of efficiency changes for each mill would be useful in this regard.

On the basis of the empirical findings reached, a similar issue concerning efficiency can be raised in relation to the company's organizational status: Would the least efficient mills have survived over the past few years if the sugar industry in Taiwan was not controlled by public enterprise? Or, does public enterprise provide more effective shelters which hide inefficiency than does private enterprise, and hence postpone adjustments when they are necessary?

To provide a complete answer to both those questions is beyond the confines of this study. Nevertheless, Taiwan's past experience has shown that several agricultural products—pineapple, mushrooms, asparagus, bananas, eels, for example—have made quick and successful adjustments in response to changes in market conditions. Sugar manufacturing in Taiwan, on the other hand, has, to a large extent, remained intact in spite of the fact that both the internal and external conditions have been running against sugar production in Taiwan. More seriously, bad performance mills have been a persistent phenomenon. All these facts make one think that an industry under a government-owned monopoly tends to postpone adjustments when adjustments are necessary.

[12] This causality problem in a single equation regression approach can be solved by formulating a simultaneous equation model. Similar situations also hold for other variables, such as the quality of sugarcane, utilization rates, and product specialization. Further studies along this line would be useful.

[12] For example, the sugar industry in Thailand has an average mill capacity of around 5,700 tons while the same figure in Taiwan is around 2,700 tons. The largest mill in Thailand has a daily crushing capacity of 16,000 tons, the similar figure in Taiwan being only 4,000 tons.

This study applies Farrell's technique to measure the plant efficiency of a government-owned monopoly in Taiwan's sugar industry. The results show that sugar mills performed within a wide range of efficiency levels. Several hypotheses, which are linked to the long-term, short-term, and plant manager-specific factors, can explain the efficiency differentials among mills satisfactorily, and have much to offer the company with regard to future policymaking. The persistently wide gap between the efficient and inefficient mills during an eight-year period leads one to question the readiness of public enterprise to make changes and face new challenges.

Although Farrell's measure is applied with great convenience and the empirical results satisfactory in this study, it would be extended on two fronts: (1) On the methodological side, a comparative study of different efficiency measures based on the same set of data would be fruitful. (2) With regard to the empirical findings, an international comparison of sugar industries applying the same measure would yield significant results.

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