Optimal Structure of an Agribusiness Firm Considering the Economics of Major, Linked Components

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In recent years, "downsizing" and "fiscal responsibility" have become prevalent terms in corporate America and government circles. Many businesses have sought to reduce employees or reconfigure business operations in response to various economic factors. There are often difficulties in efficiently downsizing integrated firms since the effect of reconfigured enterprises must be considered in terms of all operations as a whole.

The Texas Department of Criminal Justice (TDCJ) provides an excellent opportunity to investigate effects of downsizing pressure on a highly-diversified, integrated agribusiness complex. TDCJ provides dietary and other requirements for over 120,000 inmates through its Agriculture Department (TDCJAG). TDCJAG includes: 38,300 acres of vegetable and field crops; 67,700 acres of pasture; two feed mills; swine, beef, and poultry livestock operations; an egg-processing facility; two meat-packing plants; two cotton gins; an alfalfa dehydrator; four grain elevators; and a vegetable cannery. The goal of the Agriculture Department is threefold: 1) to provide agricultural commodities to meet inmates' dietary and other needs thereby reducing the cost of buying outside products, 2) to provide employment for inmates, and 3) realize maximum returns to State resources through efficient management.

Recently, critics of TDCJ have raised the downsizing question for a number of TDCJAG's practices and suggests that resources devoted to agriculture could be used more efficiently elsewhere. The impetus for this interest appears to be traceable to *Behind the Walls*, a 1992 report associated with an external performance review of the TDCJ System administered by the Comptroller's Office (Sharp, 1994). A component of that report addressed TDCJ Agriculture

and recommended several substantial alterations to prevailing management policies (Sharp 1994, pp. 305-10).

In this paper, the cost effectiveness of TDCJAG is examined by looking at tradeoffs between the fixed cost of resources employed and the net value of the products created by TDCJAG operations. Four approaches are taken to this question. First, we examine the total discontinuance of TDCJAG operations. Second, we consider partial enterprise discontinuance for the beef enterprise without considering discontinuing other enterprises. Third, elimination of the beef enterprise along with elimination of other enterprises is considered. The final approach is a consideration of how the opportunity cost of the inmate labor resource affects the optimal TDCJAG enterprise combination.

Methodology

In order to analyze the efficiency of the resource allocation in the TDCJ, a model must be able to: 1) capture the inter-linkages of the various enterprises to optimize activity levels of each enterprise, and 2) consider the fixed costs of the resources allocated in comparison with the savings in operating costs. In order to capture the inter-linkages of the various enterprises, a mathematical programming model is used. To capture the fixed costs of the various enterprises including the opportunity cost on the resources devoted to agriculture, two methods are used. In the first approach, a linear programming model is used to account for the operating costs and revenues. Then, capital budgeting is used to incorporate the fixed costs. Subsequently, a second approach is used, incorporating the fixed costs into the model via integer variables. This allows the model to optimize the enterprise configuration

The PRISAG LP Model

In an effort to improve management of its agricultural operations, TDCJAG funded development of a linear programming systems model of the total agriculture and food/fiber supply system, hereafter referred to as PRISAG, in a joint project with the Texas Agricultural Experiment Station (TAES). From project inception, the basic assumption was that TDCJAG would be a continuing operation. That is, the intent of the model's development was to assist TDCJAG management in identifying optimal enterprise combinations, particularly in regard to the supplying of menu meat and vegetable entre items to the food services Department. As such only variable costs and revenues were originally included in the model, with fixed costs associated with capital assets and other fixed resources ignored. A brief description of the model follows.

PRISAG chooses optimal activity levels for a number of enterprises which maximize the sum of net returns in the Agriculture Department, plus the cost of food, fiber, and broomcorn purchased to meet TDCJ inmate dietary and other requirements. The enterprise activity levels are chosen so as to maximize the net returns subject to: 1) dietary and other requirements of inmates, 2) balance constraints on commodities, livestock, vegetables, canned goods, meat, etc., which force the use of an item to not exceed supply; 3) capacity constraints limiting the operation size, 4) inmate labor availability, and 5) land availability.

Efficiency of TDCJAG as a Whole

To identify the net returns associated with TDCJ agriculture operations, the PRISAG model is allowed to optimize. The model is then solved again with upper bounds of zero placed upon all agriculture production and processing activities. This solution gives the variable costs of operating without agriculture. Then, fixed costs and other costs are added to these solutions to find the total cost of operating with and without agriculture. If the adjusted cost with agricultural

operations is less than the cost without agricultural operations, then there is a value associated with having the agricultural operations.

Results. When the PRISAG model is allowed to optimize, there is a $33.2 million net cost of operating. This cost includes $28.5 million in operating costs and $18.6 million in food purchases offset by $13.9 million in sales of agriculture commodities. When an opportunity cost of 5 percent on the capital investment is added along with other fixed costs, the total net cost is $58.3 million. This cost includes $2.3 million that is the fixed cost of providing services to other departments such as grounds maintenance and pest control. A break out of these costs is provided in table 1.

When the model is solved without TDCJAG, all of the dietary and other requirements are purchased from external sources, garbage, no longer fed to swine, is disposed, and garden plots next to the kitchens are continued. The total operating cost is $71 million. Fixed costs of activities currently performed by the agriculture department for other departments is $3.5 million. The total cost of operating without agriculture is $74.6 million.

When the total cost of operating with agriculture (i.e., $58.3 million) is compared to the total cost of operating without TDCJAG (i.e., $74.6 million), it is found that discontinuing TDCJAG would force the State to increase the yearly budget to TDCJ by $16.3 million.

Efficiency of Resource Use by the Beef Enterprise

The beef enterprise does not produce any products used by other enterprises or utilized by the Food Services Department. The beef enterprises exist as a commercial cattle operation to produce weaned calves to be sold externally. As such, it is a stand-alone operation. The beef enterprise uses many resources. It has been targeted by other State agencies as a possible misuse of State resources. The consequences of eliminating the beef enterprise are evaluated through

acknowledgment of both the saved variable and fixed costs in comparison to the magnitude of foregone sales revenues along with recognizing the greater production of other enterprises possible as a result of the "freeing up" of several resources now associated with the beef cattle operation. That is, a comprehensive partial budgeting analysis was conducted.

Results. Elimination of the cattle operation reveals that the net gain to TDCJ, including fixed costs savings, is over $1 million. Foregoing cattle production results in a $4.1 million loss in sales revenue, but saves $507,000 in the cattle raising costs and $667,000 in pasture production. Cattle elimination also saves $316,000 of expenditures on ration ingredients, $1,096,000 in ration production, and $23,000 in purchase of hay. Field crops devote fewer acres to the production of ration ingredients, resulting in the growing of more acres of crops to sell. In doing so, the field crop operation incurs $36,000 more in variable costs of crop production, but also increases the sales of commodities by $376,000. The beef enterprise generates net receipts of $1 million above all specified operating costs.

The fixed costs associated with the beef enterprise must also be considered to determine the net value of the beef enterprise. The $2 million in fixed costs of the beef enterprise includes: 5 percent opportunity cost of land and the breeding livestock, management salaries, and veterinary costs. As a result, the annual net value of the beef enterprise is estimated to be $-1 million.

Efficiency of the Resources Devoted to Agriculture Considering Individual Enterprises

The PRISAG model does not endogenously account for the fixed costs, and can not readily determine if eliminating one enterprise would cause another to be eliminated. Here, the fixed costs and the opportunity cost of the resources devoted to the various enterprises within TDCJAG are incorporated into the PRISAG model through the use of integer variables to create a modified model PRISAG-MIP. PRISAG-MIP is then be used to optimize the enterprise mix of

TDCJAG. Below is given a description of the model changes, followed by the assumptions made and the results.

Modifications to PRISAG

To analyze the discontinuance of some or all agricultural enterprises within TDCJAG, binary, integer decision variables (e.g., "Have-Enterprise") were added to the PRISAG model. One of these "Have-Enterprise" variables is the entire TDCJAG operation. In order for this variable to be 0, all of the other "Have-Enterprise" variables must also be zero. For the "Have-Enterprise" variables, a solution value of one infers keeping the operation and zero means eliminate or do not include the operation. The parameter in the objective function on the "Have-Enterprise" variables is the respective fixed costs excluding land for each enterprise. If an operation appears in the solution, the value of one for the respective "Have-Enterprise" variable allows inclusion of the entire amount of the fixed costs, excluding land, in the objective function. If the binary variable is zero and the operation is discontinued, none of the fixed costs are added into the objective function value. The fixed cost of land is viewed as a rental rate and land is allowed to be rented out in any increment.

Each "Have-Enterprise" variable appears in an enterprise balance constraint with a coefficient of a large negative number representing the supply of enterprise capacity. The production variables for that enterprise are included in the enterprise balance constraint as a use of enterprise capacity. In all, there are 13 "Have-Enterprise" variables and 13 enterprise balance constraints associated with the 13 various enterprises.

Results. The solution to the unrestricted MIP model chooses to eliminate the beef enterprise for the reasons discussed in the last section; however, further ramifications are found. Namely, both beef production and one of the two feedmills should be shut down. The variable

cost savings from operating the Coffield feedmill when the cattle are removed are less than the fixed costs of the feedmill. In this case, discontinuing the beef cattle enterprise causes a decrease in the demand for feed sufficient to warrant discontinuing a feedmill. Using the alternative approach of capital budgeting in conjunction with the linear model (and forcing shutdown of both the beef enterprise and a feedmill) produces the same results as the modified PRISAG-MIP model. Such an approach does not readily determine which enterprises should be shutdown, however, forcing analysts to embark on a multitude of analyses to assess the economics of various combinations of the many possible enterprises.

Accounting For the Labor Opportunity Costs

TDCJAG makes heavy use of inmate labor without incurring any direct cost for it. However, there may be a cost due to added security, or opportunity costs for labor that could be used in non-agricultural operations. On the other hand, there also may be a return to the work opportunity in terms of lessened security and/or therapy. It is difficult to measure an exact cost (benefit) of using inmate labor. This study represents an attempt to find the optimal enterprise structure of TDCJAG under a range of inmate labor costs.

Assumptions About the Use of Inmate Labor and Adjustments to PRISAG-MIP.

There are two types of inmate labor: trustee labor and line labor. Trustees are inmates that can work with less supervision and security. If the inmates can be used elsewhere, there is probably a higher opportunity cost of using trustee labor than for using line labor. If the costs are negative (i.e., there is a positive value associated with inmates working in Agriculture), the value of trustee labor should also be greater than that of line labor because of the types of jobs being performed. For these reasons, it is arbitrarily assumed that the cost of using trustee labor is twice that of using line labor.

Results are generated using four different labor costs: -$5 per hour of trustee labor, no cost for inmate labor, and $5 and $10 per hour for using trustee labor. The above wage rates were chosen for the following reasons. The highest cost ($10 per hour) is approximately equivalent to the cost of a Texas farm worker. Inmates may not be as productive as farm workers, so a cost consistent with the minimum wage of $5 per hour of trustee labor is also used. The current practice of not charging anything for the use of inmate labor is considered. An extreme case where a benefit is accruing for the use of inmate labor is also considered when the use of trustee labor accrues $5 per hour benefit.

Results. There are several ways results can be displayed. Let us look at enterprises used, the labor used, and the net revenue. When there is no labor cost, the beef enterprise and the Coffield feed mill are shut down. The same enterprises were shut down when labor had a negative cost. As the cost of using inmate labor increases, first the cannery and swine operations are shut down. Then as the cost of trustee labor rises to $10 per hour, the alfalfa dehydrator and the Michael packing plant are also shut down.

As seen in table 3, the trustee labor use is inversely related to the wage rate; similar results are evident for the line labor. In particular the labor use increases when there is a benefit to using labor and decreases as the cost of using inmate labor increases. The slack hours of inmate labor are rather high. The reason for this is that the same inmates are employed in every period, while the agriculture operations do not have an even demand for labor requiring more labor during some periods and less in others. As labor becomes more costly, the labor employed is used more efficiently decreasing the surplus labor. This is seen in table 3. The hours available decrease by a smaller percentage than the slack labor hours.

Table 4 shows a summary of the different operating levels of the various enterprises under the different costs of using inmate labor. As would be expected, we see that when the value of using trustee labor rises from zero to $5 per hour, most enterprises increase production. The swine and poultry enterprises were already operating at capacity so they do not increase. Since there was no increase in the livestock operations, there was no need to increase the feed mill production. As the cost of labor went up from zero to $5 per hour for trustees, most enterprises decreased the level of production. Poultry stayed at the same level as it continued to supply all the eggs needed by the diet. The swine operation and the cannery were shut down. Garbage disposed went up to reflect the disposal of garbage previously fed to the swine. The production of feed decreased by 63 percent reflecting the decrease in feed needed for the swine. Field crop production went down by 12 percent and edible crop production went down by 56 percent. As the cost of labor increased to $10 per hour for trustee labor, most enterprises had even higher decreases in production. The big changes were the shutdown in the Michael packing plant, and a decrease in field and edible crop production. Since the livestock operations did not change, the feed production and garbage disposal showed very little change.

Conclusions

The question raised by the Texas state budget office of whether resources devoted to TDCJAG could be used elsewhere is one with a complex answer. As a whole, the results here indicate the resources devoted to TDCJAG are providing a positive return. However, the results show some TDCJAG enterprises, particularly beef cattle and feedmills, are not using resources in a profitable manner.

Using a linear model with capital budgeting or using a mixed integer model both suggested the beef enterprise should be discontinued. The mixed integer model that endogenously

considered the impact of the fixed cost and inter-related enterprises also found that a feedmill could be discontinued when the beef enterprise is discontinued. The choice of whether to use a linear model and capital budgeting or a mixed integer model is one for the decision makers to make. They are the ones in a position to note whether the increased solving time and complexity of a mixed integer model is worth the ability to look at the whole question in one model.

The optimal structure did not change when a positive value was associated with using inmate labor. The beef enterprise and a feedmill were still unprofitable. As a positive cost was added to the use of inmate labor, more enterprises were discontinued. First the cannery and swine operations were discontinued. Then, as the cost of using labor increased, the alfalfa dehydrator and the pork packing plant were eliminated. This shows that the cost (benefit) of using inmate labor has a significant impact on the optimal structure of TDCJAG.

The approaches used in this paper worked well for the problem of finding the optimal structure of an operation. Using both a linear programming model combined with capital budgeting and using a mixed integer programming model could work when determining the value of the operation as a whole. Such models allow a complex structure to be imposed and the inter-linkages of the enterprises to be considered. When determining the value or possible elimination of a particular enterprise, the approach using a linear programming model and capital budgeting did not find the optimal results as readily. While it found that an unprofitable enterprise ought to be eliminated, it did not find that in doing so another enterprise should also be eliminated. This implies that the use of the more complex, mixed integer model works better when looking at whether to continue or close down inter-related enterprises.

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Table 1. TDCJ costs with Agriculture Division operating at optimal levels

Model Costs		
Sale of Agriculture Commodities (a)	$ -13,929,220	
Cost of Operations	28,535,010	
Cost of Food Purchased	18,615,055	$ 33,220,845
Non -Model Costs		
Opportunity Costs of Capital Investments @ 5%		
Land (b)	6,260,756	
Packing Plants	1,000,000	
Ramsey Cannery	500,000	
Farm Machinery & Equipment (c)	307,426	
Breeding Livestock (d)	447,652	8,515,834
Maintenance/Replacement/Depreciation Costs		
Packing Plants	1,000,000	
Ramsey Cannery	500,000	
Ellis and Ramsey Cotton Gins	60,000	
Ramsey Alfalfa Dehydrator	15,000	
Darrington Egg Processing Facility	5,000	
Eastham and Coffield Feed Mills	20,000	
Farm Machinery & Equipment (e)	985,342	2,585,342
Management Salaries and Fringes (f)		11,702,962
Non-agriculture services provided by Ag, but not in LP model		
Security	301,854	
Mechanical	516,842	
Facilities (g)	1,481,682	2,300,378
Costs with TDCJAG		58,325,361

(a) This revenue is deceasing the net cost.
(b) $125,215,120 value of the land multiplied by 5 percent opportunity cost.
(c) The average machinery investment is $130 per acre of field crops, $225 per acre of vegetables, and $ 57 per acre of hay crops.
(d) Cows are valued at $800 per head and sows are valued at $125 per head.
(e) The machinery replacement cost is figured at $20.60 per acre of field crops, $55.30 per acre of vegetable crops, and $9.40 per acre of hay crops.
(f) This included $8,933,559 in salaries and 31 percent benefits.
(g) Including $369,205 for pest control, $751,873 for general maintenance and $360,604 for garden plots.

Table 2. Summary of relevant information for the model s optimal solution compared to the solution without a cattle operation

				Difference	
		Base	No Cattle	$	%
OBJ FCN	$	$ -33,220,845	$ -34,237,807	$ -1,016,962	3

Crop Land Used	Acres	38,555	38,182	-373	
Pasture Used	Acres	50,483		-50,483	-100
Vegetable Land Used	Acres	6,738	6,865	127	2
Cows	Head	12,774		-12,774	-100
Hens	Head	193,575	193,575		
Sows	Head	3,170	3,170		
Hogs Slaughtered	Head	1,691	1,691		
Pork Processed	Pounds	4,774,629	4,774,629		
Beef Processed	Pounds	10,000,000	10,000,000		
Meat Bought	Pounds	1,000,807	1,000,807		
Vegetables Canned	Cases	501,280	501,280		
Feed Mixed	Tons	42,663	33,261	-9,402	-22
Garbage Disposed	Tons	41,823	41,823		

Table 3. Trustee labor use and percentage change for different labor costs

	Trustee Labor Cost Per Hour					
	$0	-$5		$5		$10	
			change		change		change
Inmates	1,712	1,800	5%	987	-42%	805	-53%
Hours Used	1,134,122	1,227,943	8%	743,449	-34%	520,795	-54%
Hours Available	1,592,839	1,676,978	5%	934,395	-41%	662,513	-58%
Slack Hours	458,717	449,035	-2%	190,946	-58%	141,718	-69%

Table 4. Summary of enterprise operating levels

		Trustee Labor Cost Per Hour						
	Units	$0	-$5		$5		$10	
				change		change		change
Field Crop	acre	35,079	35,711	2%	30,910	-12%	19,140	-45%
Edible Crop	acre	6,824	7,404	8%	2,988	-56%	2,696	-60%
Pasture	acre	0	0		0		0	
Cows	head	0	0		0		0	
Hens	head	193,575	193,575		193,575		193,575	
Sows	head	3,170	3,170		0	-100%	0	-100%
Pork Made	pounds	4,774,629	5,798,218	21%	4,625,535	-3%	0	-100%
Beef Made	pounds	10,000,000	9,792,462	-2%	10,000,000		10,000,000	
Canned	cases	513,062	526,684	3%	0	-100%	0	-100%
Feed Made	tons	64,022,394	64,035,622		23,447,891	-63%	22,887,321	-64%
Garb Disposed	tons	43,488	43,491		61,003	40%	60,928	40%