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Brazil's Beef Production and Its Efficiency: A Comparative Study of Scale Economies

by

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In recent years, Brazil –one of the world's main suppliers of agricultural products- has been raising beef productivity and exports. In Brazil, large farm land availability, ample feedstuffs supplies, a large domestic consumer market, and liberalization of trade barriers have allowed large firms to achieve economies of size that have made the country a major, growing source of meat production. Major differences exist between the modern and the traditional segments of the beef-cattle sub-sector. To assess competitive strength of Brazil's livestock operations, we estimate non-parametrically the efficiency and scale elasticity of 450 cattle operations. Our hypothesis is that large-size specialized farms exhibit cost economies and higher efficiency levels than other beef production operations.

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Brazil's Beef Production and Its Efficiency:
A Comparative Study of Scale Economies

Brazil ranks as the second largest world beef producer with the world's biggest commercial herd (170 million head). Brazil has abundant grazing land for calf and grass-fed beef production in the *Cerrados* region. Embodied technology advancements, lower labor costs, and a large domestic market have encouraged the development of large beef processing operations. However, Brazil's livestock sector has gone through a process of selective modernization. Major differences exist between the modern and the traditional segments of the beef-cattle sub-sector.

The purpose of this paper is to assess the competitive strength of Brazil's meat production and gain insights into the country's divergent livestock production activities, cost efficiencies, feed use, and competitiveness. In particular, the paper examines beef production's overall efficiency in Brazil and measures its competitiveness using a non-parametric technique. This paper looks closely at Brazils' regional diversity in livestock raising activities and examines the intensity of the various types of operation in order to evaluate their competitiveness and identify the sources of differences.

Between 1970 and 1991, Brazil's beef-cattle herd grew at a 3.1 percent average yearly rate, from 78.5 million to 152.1 million head. From 1963 to 2003 beef-cattle slaughter increased from 9.6 million to 34.0 million head; and the total carcass weight increased from 1.4 million to 7.4 million tons. However, these numbers hide large differences between regions. The beef-cattle industry in areas near the country's more developed core has experienced considerable modernization along with expansion of a dynamic agribusiness sector, which supplies the industry with modern inputs and

slaughters and processes animals for domestic and world markets. As a result, Brazil's beef exports increased from total value of US$298.6 million (in 1992 dollars) at a total value of US$618.1 million. A still substantial traditional beef-cattle industry can be found in the frontier areas and the more backward parts of Brazil; its productivity remains very low, and it is plagued by serious livestock diseases and management problems. Brazil still has low per capita consumption of beef products, averaging 11.1 kg/year in 2001.

Brazil's Beef Production System

Beef production accounts for about 20 percent of Brazilian agribusiness gross income. Brazil's production system is based on grass with less than 3 percent in feedlots. There are primarily three types of beef operations in Brazil: grass-fed small enterprises, grass-fed medium specialized operations, and grain-fed/grass-fed large commercialized beef operations. The *small beef enterprises* raise less than 500 head per household per year. The so-called *medium specialized beef* operations on average produce over 1000 head annually. The last category is called commercialized *beef production enterprises* with over 4000 head per year.

Production costs in Brazil are estimated to be 60 percent lower than in Australia and 50 percent lower than in the United States. The average slaughter age is at 4 years and the slaughter rate is just 21 percent, compared to 2 years and 37 percent in the United States (see Dyck and Nelson, 2003).

In the last fifteen years, beef and veal production in Brazil experienced a dramatic increase in total quantity produced and the number of animals raised (figure 1). Yield per animal from 1980's to 2000's increased by almost 20%. The beef industry in Brazil is

characterized by dispersion and lack of integration. This is unlike the Brazilian poultry industry, which has been developed around the concept of strategic groups for commodities (chicken) and specialties (processed products), and is characterized by high productivity and high technology use.

The land ares in the *Cerrados* totals 127 million hectares, with 49 million hectares of cultivated pasture and 12 million hectares of annual crops. Available land in the *Cerrados* is estimated at 60 million hectares, which translates into a potential production of 240 million tons of grains.

Brazil's Cattle Production--a Closer Look

We use a unique database, the Livestock Costs and Practices Survey conducted annually since 1993 by FNP Consultoria & AgroInformativos, a consulting company specializing in agribusiness. The survey includes detailed information on cost of production, feed use, and other important economic characteristics of beef production. Carried out in the most important beef producing areas in Brazil, the survey provides a picture of beef production efficiency, costs, and feed use by size and types of production during the 2000-2002 period. The survey provides detailed cost of production information for 25 beef producing locations in Brazil, corresponding to the 5 major agricultural regions in Brazil, grouped by State.

In the next sections we present the distributional characteristics and the production profile of cattle operations in Brazil by region, type, and size.

Cattle production by region

Although cattle production occurs in all regions, it is generally concentrated in the northern, northeastern, southern, southeastern, and central regions of Brazil. Both figure 2 and table 2, which presents the balance sheet of cattle operations by region, reveal that operations in the northeastern and southeastern regions are more profitable. Detailed balance sheets of revenue and cost by state reveal the heterogeneity in cattle operations in Brazil.

Cattle production by type and size

Revenue and cost vary greatly by type of operation (table 4). Profitability increases as operations become less intensive in raising cattle. Overall, type I (cow/calf) and type II operations (background/feedlot) are most profitable followed by type III operations (calfing (birth) to slaughter).

Table 5 presents the balance sheet revenues and costs by type and size of operation. The table indicates that profitability increases with size. Independent of the type of operation, large cattle operations or operations with 5,000 AU (animal unit) and more are much more profitable than small cattle operations (with 500 AU).

Globalization of Brazil's Meat Products

With rising incomes and population, changing diets, and liberalization of trade barriers, global meat trade has reached a value of over $40 billion, and has grown at about 6 percent annually since 1990 (Dyck and Nelson, 2003). Meat trade flows among countries are determined largely by differences in countries' resource bases, preferences for meat types and cuts, barriers to trade, and the domestic industry structure. Producing countries with low-priced inputs and favorable natural resource bases for beef exports,

like Brazil, have competitive advantages in meat production. Land for forage and grain production is crucial for livestock success and Brazil's exports of meat products have increased drastically in the last decade (figure 3).

Beef exports from Brazil are the third largest in the world, behind the United States and Australia, with one-third in processed meats (mainly corned beef) and two-thirds in frozen/chilled meats value (see Table 1). Despite growth in domestic beef demand -Brazil is the world's second largest consumer market with over 7 million tons- exports have increased at a much faster pace, making this country a net exporter of livestock and livestock products. Given the potential for feedstuffs production (corn, soybeans, etc.), Brazil is also able to keep the costs of feed rations low for grain-fed beef. Despite lack of financing capital, lower labor costs and a large domestic market have encouraged the development of large beef-processing operations in Brazil.

Research Methodology

To evaluate the competitive strengths of Brazilian beef production, we use the data envelopment analysis (DEA) non-parametric method to measure the economic efficiency and scale economies while accounting for resource costs (fixed costs, operational costs, feed costs, feed efficiency). The analysis identifies cost economies and efficiency levels for each type of operation.

The Model and Estimating Method

Our study attempts to assess the economic performance, measured by overall efficiency, of the country's cattle production and structural changes. Even though the

beef industry in Brazil is characterized by dispersion and lack of integration and is dominated by many small operations, cattle production has begun to shift and become more concentrated in large specialized operations. These changes have profound effects on the industry's performance, and measuring the impacts of these changes is therefore of great interest. The method used to assess these changes is presented below.

Analysis of structure and performance of cattle operations begins with the underlying production technology. This can be formalized by specifying a transformation function, $S(X_n,Y) = 0$, which minimizes the production frontier in terms of inputs X_n and output Y. Information on the production technology can be characterized via an input set, $F(Y,X_n)$, that represents the set of all inputs X_n that can produce Y.

An input distance function (denoted by superscript i) recognizes the least input use possible for producing the given output vector as defined by $F(Y, X_n)$:

(1) $$\mathbf{D^i(Y, X_n) = max\{\tau : (x/\tau) \in F(Y, X_n)\}}$$

where D_i is the distance of unit i, Y is output, X_n (n=6) are the inputs labor, feed expenses, expenses for purchasing animals (feeder cattle), other variable expenses, fixed cost, and other expenses (indirect cost). We use a programming method to estimate the input distance function and capture the distance from the frontier assuming a radial contraction of inputs to the frontier of cattle operations. The ratio of estimated potential efficient input use compared to the actual observed use provides an estimate of technical efficiency. Further, scale economies can be measured by identifying variations in the input and output ratio at different scale levels when variable returns to scale are allowed.

For our empirical implementation, the solutions to this problem were developed and computed in GAMS (General Algebraic Modeling Systems, Brooke et al., 1988).

Functional relationships of production or distance functions represent a foundation for data envelopment analysis (DEA) procedures, which use programming rather than econometric (parametric) techniques. Formally, an input-oriented programming problem may be written as:

$$(2) \qquad \min\theta,\lambda = \theta i, s.t. \sum_{j=1}^{J} \lambda j Ymj - Ymi \geq 0, \theta i Xni - \sum_{j=1}^{J} \lambda j Xnj \geq 0, \sum_{j=1}^{J} \lambda j = 1,$$
$$m = 1, n = 1,...,6,\ j = 1,...,J$$

There are J observations and the non-negative weights, λj, determine the reference points on the frontier for unit i, where unit in this study is represented by state or region or type of operation under evaluation. For notational simplicity, the unit index i is suppressed on the λ-weights. The input vector in (2) for unit i is adjusted by the efficiency score, θi, (Di = θi) and then compared with the reference point, $\sum_{j=1}^{J} \lambda_j x_{nj}$, on the frontier.

The Lagrangian of equation (2) is set up in such a way that the shadow prices of outputs and inputs, u_{mi} and v_{ni}, respectively, are non-negative:

$$(3) \qquad L = \theta_i - \sum_{m=1}^{M} u_{mi} (\sum_{j=1}^{J} \lambda_j y_{mj} - y_{mi}) - \sum_{n=1}^{N} v_{ni} (\theta_i x_{ni} - \sum_{j=1}^{J} \lambda_j x_{nj}) - u_i^{in} (\sum_{j=1}^{J} \lambda_j - 1)$$

where u_i^{in} is the shadow value of the equality constraint on the sum of the λ's. Since the value of the shadow value is unique for inefficient units, we utilize the radial projection

approach for calculating scale elasticity values (see Forsund, F.R and L. Hjalmarsson (1979).

Estimation of scale elasticities using non-parametric techniques, while straight forward for efficient points (i.e., points that satisfy F(Y,X) = 0), are ambiguous for inefficient points. Following Forsund et al. we use the radial projection approach and calculate for each farm the scale elasticity as follows:

$$\varepsilon(\mathbf{Y_i E_i X_i}) = \frac{\mathbf{E_i}}{\mathbf{E_i - u_i^{in}}}, \mathbf{i} \in \mathbf{I} \tag{4}$$

where Ei is the input-oriented efficiency score and u_i^{in} is the shadow price on the equality constraint $\sum_{j=1}^{J} \lambda_j = 1$. The farm exhibits increasing returns to scale if $u_i^{in} > 0$, constant returns to scale if $u_i^{in} = 0$, and decreasing returns to scale if $u_i^{in} < 0$.

Results

Using the survey data we employed the methods described in the previous section and constructed measures of efficiency and scale economies for our sample of cattle operations in Brazil. Our deterministic procedure estimates the best-practice production frontier from these data and compares individual state or region or type of operation to the estimated frontier composed by all states or all regions or all types of operations. For this purpose, we use programming to estimate an input distance function. Our model, as stated previously, is based on one output and six inputs.

Estimates of the scale (SEC) and efficiency performance (TE) indicators by region are presented in Table 6. The TE measures suggest that farms have a greater

potential to reduce costs by moving to a scale-efficient point as the SEC measures reveal scale economies (IRS). These results support the idea that performance across farms arises largely from efficiency and netput (output and input) composition changes accompanying growth. The efficiency or performance measures at the regional level reveal that cattle operations in the northern region are more efficient (0.975 on average) while operations in the central region have the lowest scores (0.957 on average). The detailed state-level results also find increasing returns to scale while TE exhibits low variability. This is the case because the frontier is estimated using all types of operations in each state. On a regional basis, the efficiency indicators (TE) for the southern region (Sao Paulo, Rio Grande do Sul and Parana) reflect highly mechanized commercial farming with infrastructure in place and high input intensity. Yet even in these regions, competitiveness has been constrained by a number of factors, including macroeconomic shocks, weakness in the financial system, and trade protection in other countries.

The estimates over the whole sample, by class size, and by region, display some interesting differences (Table 7). The overall efficiency estimate, using all 450 cattle operations, is 0.94, indicating low overall efficiency, but the scale elasticity shows increasing returns to scale (3.47). The most obvious differences are revealed by the measures of efficiency and scale elasticity by class size. For type III integrated operations (from calfing (birth) to slaughter) have the largest overall efficiency from 0.975 to 0.989 while the scale elasticity suggests increasing returns to scale. TE varies when the frontier is estimated by type (type I (Cria), type II (Recria/Engorda), and type III (Cria/Recria/Engorda)) and intensity.

In sum, the results indicate that integrated operations (type III-- calfing (birth) to slaughter) have higher performance and netput savings, as expected. The scale elasticity by region indicates potential to reduce costs by expanding operation rather than by rearranging input composition.

Summary and Conclusions

This paper examines the changing structure of beef production in Brazil and measures its efficiency and competitiveness (reduced costs). After analyzing the feed efficiency and structure of production costs directly from survey data and estimating the overall efficiency and scale economies of cattle operations in the sample, we can conclude that the most integrated operations (type III) are most efficient with increasing returns to scale economies. The overall efficiency estimate, using all 450 operations, is 0.945, indicating low overall efficiency. However, the scale elasticity (3.466) indicates increasing returns. For operations type I to type III , overall efficiency varies from 0.971 to 0.975, respectively. Overall efficiency, measured by the efficiency scores θi, is the highest for the integrated operations (type III). The estimated scale elasticity indicates increasing returns to all types of cattle operations.

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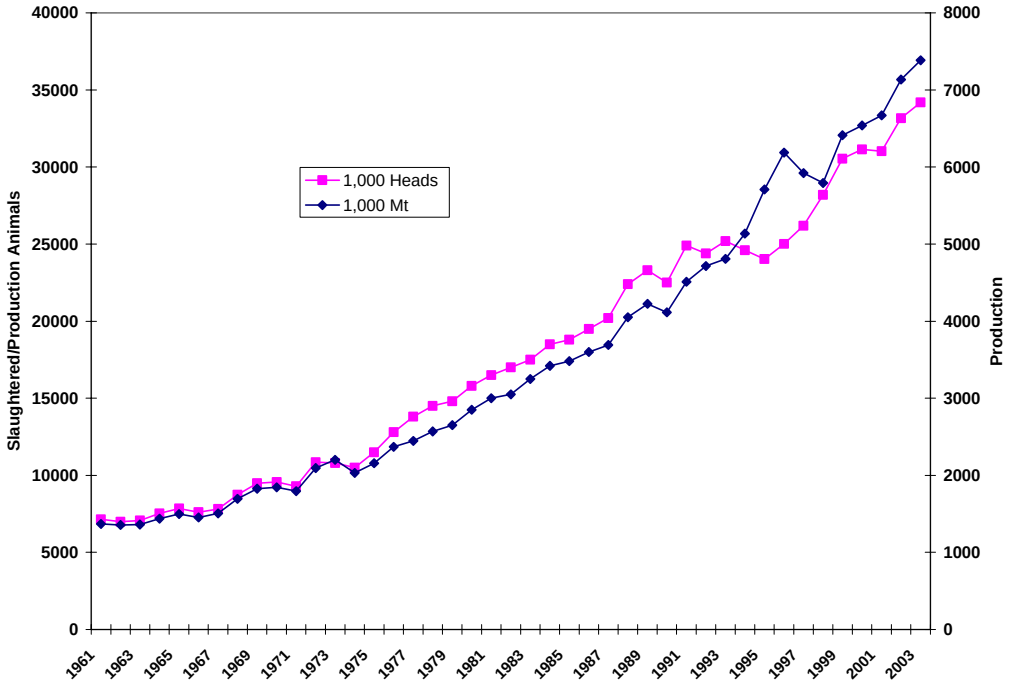
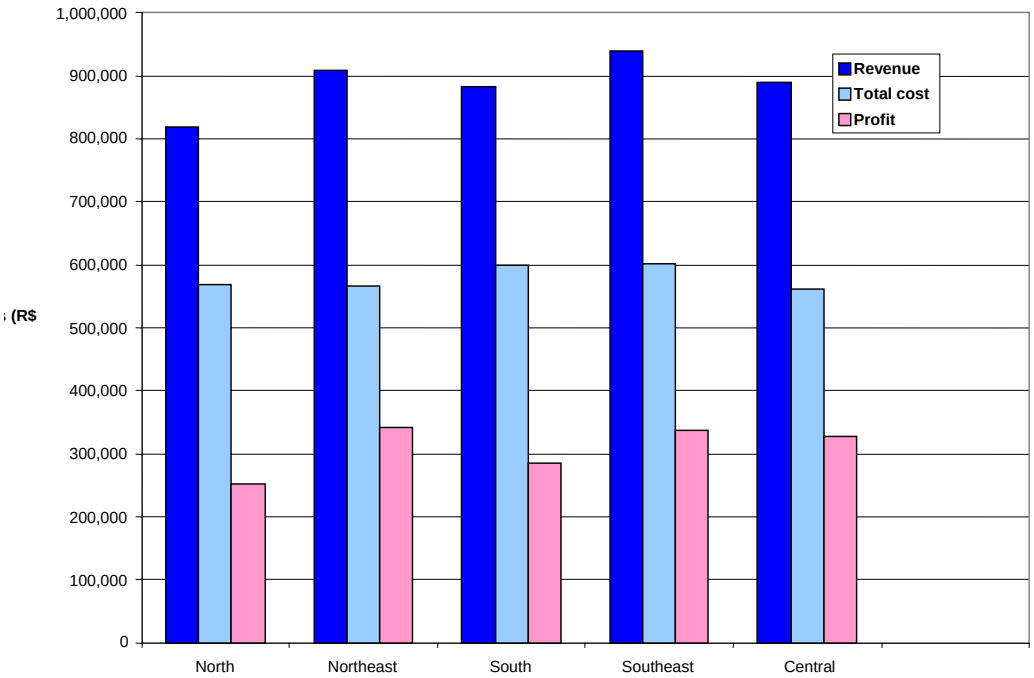
Figure 1. Brazil's Meat Production, 1961-2003



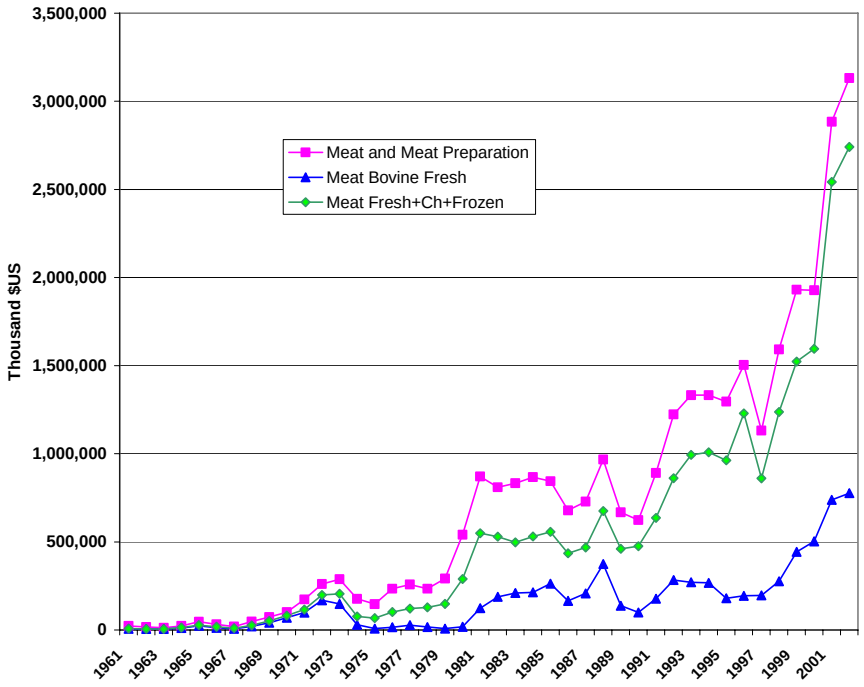
Source: FAOSTAT

Figure 2. Revenue, Cost, and Profit of Cattle Operations in Brazil by Region, 2002
Brazilian Reals (R$)



Source: FNP Survey, 2002

Figure 3. Exports of Brazil's Meat Products, 1961-2003



Source: FAOSTAT

Table 1. Leading beef exporting countries, 2000

Rank	Volume	Million metric tons	Value	Billion US$
1	U.S.	1.165	U.S.	3.252
2	Australia	1.128	Australia	2.111
3	EU	0.623	Canada	1.182
4	Canada	0.492	Brazil	0.783
5	New Zealand	0.457	New Zealand	0.730
6	Brazil	0.411	EU	0.677
7	Argentina	0.302	Argentina	0.662
8	India	0.288	Uruguay	0.376
9	Uruguay	0.224	India	0.307
10	Ukraine	0.152	Ukraine	0.209

Includes preparations of bovine meat.
Data: FAOSTAT, bovine meat.

Table 2. Balance Sheet of Production and Cost of Cattle Operations by Region, 2002 *(in Reals R$)*

Region	Revenue	Labor expenses	Variable expenses	Feed	Cattle purchased	Fixed cost	Other expenses	Total cost	Returns (above total cost)
North	819,518	69,013	13,846	119,965	59,708	208,055	97,626	568,213	251,305
Northeast	908,534	67,521	134,164	54,751	197,862	98,294	14,148	566,740	341,793
South	882,906	82,637	102,808	53,239	222,831	117,024	19,699	598,239	284,667
Southeast	940,470	76,417	123,176	55,704	223,763	106,008	17,264	602,332	338,139
Central	890,553	71,226	111,531	52,905	208,619	102,531	15,177	561,988	328,565

Data Source: FNP Survey, 2002

Table 3. Balance Sheet of Revenue and Cost by State, 2002 *(in Reals R$)*

Item	State	State name	Revenue	Labor expenses	Variable expenses	Feed	Cattle purchased	Fixed cost	Other Cost	Total cost	Returns (above total cost)
North	TO	Gurupi	817,866	68,343	133,382	63,335	186,554	95,615	13,565	560,794	257,072
North	TO	Araguaína	858,190	71,108	113,437	49,781	217,057	97,186	14,113	562,682	295,508
North	PA	Redenção	811,362	69,648	118,556	60,881	214,966	95,491	13,057	572,599	238,764
North	PA	Paragominas	783,409	69,334	124,699	80,516	206,508	98,327	14,529	593,912	189,497
North	RO	Ariquemes	826,761	66,632	109,751	44,029	215,190	101,512	13,964	551,077	275,684
Northeast	BA	Barreiras	913,166	67,673	133,584	57,335	200,532	97,989	14,179	571,291	341,875
Northeast	BA	Itapetinga	903,902	67,369	134,744	52,166	195,192	98,600	14,117	562,190	341,712
South	RS	Alegrete	790,335	81,892	81,826	48,830	211,415	110,534	19,518	554,016	236,318
South	PR	Paranavaí	975,477	83,382	123,789	57,648	234,248	123,514	19,879	642,461	333,015
Southeast	SP	P. Prudente	1,013,756	88,636	125,376	57,234	252,895	120,719	21,491	666,351	347,404
Southeast	RJ	Campos	940,437	74,390	100,980	58,571	217,265	109,693	16,405	577,304	363,133
Southeast	MG	Ituiutaba	967,749	76,666	133,870	60,069	236,150	105,124	17,751	629,631	338,118
Southeast	MG	7 Lagoas	895,970	72,943	129,144	57,453	203,348	104,558	16,890	584,335	311,635
Southeast	MG	M. Claros	884,439	69,448	126,511	45,195	209,156	89,945	13,783	554,038	330,401
Central	MS	Camapuã	942,026	74,196	128,455	59,240	221,198	102,665	16,363	602,117	339,909
Central	MS	C. Grande	923,585	77,394	127,877	57,790	221,983	96,372	17,064	598,481	325,104
Central	MS	Corumbá	737,912	61,510	59,330	32,808	163,751	95,814	12,204	425,418	312,494
Central	MS	Naviraí	990,928	74,504	114,398	48,089	252,112	91,754	17,252	598,109	392,818
Central	MT	B. Garças	890,730	71,021	131,833	58,617	194,058	93,930	15,663	565,122	325,608
Central	MT	A. Floresta	878,405	70,466	106,163	54,872	218,889	102,800	13,989	567,178	311,227
Central	MT	P. Lacerda	917,873	70,022	100,785	53,423	227,840	99,778	13,900	565,747	352,126
Central	MT	Poconé	702,101	61,897	57,209	34,825	157,614	120,200	12,283	444,028	258,073
Central	GO	Caçu	951,442	75,898	135,886	61,948	217,096	107,311	15,896	614,034	337,408
Central	GO	Goiânia	924,405	73,489	134,479	60,848	207,774	111,584	17,016	605,190	319,215
Central	GO	N. Crixás	936,673	73,087	130,429	59,498	212,492	105,627	15,311	596,445	340,229

Data Source: FNP Survey, 2002

Table 4. Balance Sheet of Revenue and Cost by Type of Cattle Operation, 2002 *(in Reals R$)*

	Revenue	Labor expenses	Variable expenses	Feed	Cattle purchased	Fixed cost	Other expenses	Total cost	Returns (above total cost)
Type I (Cow/calf)									
Intensive	1,718,698	199,978	310,662	257,792	5,708	251,120	418,824	1,068,761	649,937
Semi-Intensive	1,449,871	161,254	232,998	65,147	11,275	208,452	65,887	714,197	735,674
Extensive	1,194,243	133,660	189,731	92,361	20,172	182,467	99,179	646,711	547,532
Type II (background/feedlot)									
Intensive	2,704,381	137,781	181,492	139,501	1,497,490	209,650	1,686,806	2,195,594	508,788
Semi-Intensive	2,703,375	126,859	216,480	47,988	1,274,690	191,172	1,065,616	1,884,495	818,879
Extensive	2,110,030	101,894	188,477	52,973	980,726	166,081	913,333	1,511,682	598,349
Type III (calfing (birth) to slaughter)									
Intensive	1,505,291	175,719	316,177	191,046	3,448	239,379	422,657	963,974	541,317
Semi-Intensive	1,421,801	147,637	255,774	59,226	6,681	213,272	69,315	714,691	707,110
Extensive	1,161,116	119,099	208,084	83,967	12,411	193,591	123,625	642,370	518,746

Data Source: FNP Survey, 2002

Table 5. Balance Sheet of Revenue and Cost by Type and Size of Cattle Operation, 2002 *(in Reals R$)*

		Revenue	Labor expenses	Variable expenses	Feed	Cattle purchased	Fixed cost	Other expenses	Total cost	Returns (above total cost)
Type I (Cow/calf)										
	Small (500 UA)	396,518	86,850	67,744	34,982	4,634	111,530	250,634	323,576	72,942
	Large (5,000 UA)	3,966,293	408,042	665,646	380,317	32,521	530,509	333,256	2,106,093	1,860,201
Type II (background/ feedlot)										
	Small (500 UA)	676,193	73,430	54,404	21,057	348,178	99,549	546,098	611,146	65,047
	Large (5,000 UA)	6,841,593	293,104	532,045	219,405	3,404,728	467,354	3,119,657	4,980,625	1,860,968
Type III (calfing (birth) to slaughter)										
	Small (500 UA)	368,583	82,977	71,345	24,797	1,999	112,253	252,265	310,424	58,159
	Large (5,000 UA)	3,719,625	359,478	708,691	309,443	20,542	533,988	363,333	2,010,612	1,709,013

Data Source: FNP Survey, 2002

Table 6. Efficiency and Scale Estimation by Region

		Regions	Efficiency (TE)	Scale Elasticity (SEC)
		North	0.975	1.713497778
		Northeast	0.999	1.269708333
		South	0.995	1.275583333
		Southeast	0.973	1.551515556
		Central	0.957	1.700104545
1	RS	Alegrete	1.000	1.231
2	PR	Paranavaí	0.996	1.537
3	MS	Camapuã	1.000	1.001
4	MS	C. Grande	1.000	1.001
5	MS	Corumbá	1.000	1.297
6	MS	Naviraí	0.995	1.069
7	MT	B. Garças	1.000	1.351
8	MT	A. Floresta	0.993	1.572
9	MT	P. Lacerda	0.996	1.456
10	MT	Poconé	1.000	1.904
11	SP	P. Prudente	0.996	1.497
12	RJ	Campos	0.992	1.062
13	MG	Ituiutaba	1.000	1.264
14	MG	7 Lagoas	1.000	2.613
15	MG	M. Claros	1.000	1.154
16	GO	Caçu	1.000	1.094
17	GO	Goiânia	1.000	1.720
18	GO	N. Crixás	1.000	1.328
19	TO	Gurupi	1.000	1.196
20	TO	Araguaína	0.985	1.641
21	PA	Redenção	0.984	2.016
22	PA	Paragominas	0.984	2.468
23	RO	Ariquemes	0.995	2.574
24	BA	Barreiras	1.000	1.209
25	BA	Itapetinga	1.000	1.934

Data Source: Model results

Table 7. Efficiency and Scale Estimation by Type and Size of Cattle Operations

	Farms	Efficiency (TE)	Scale Elasticity (SEC)
All Farms	450	0.945	3.466
All Intensive	150	0.967	1.629
All Semi-Intensive	150	0.966	2.732
All Extensive	150	0.965	2.261
All Type I (Cow/calf)	150	0.971	3.160
Intensive	50	0.981	1.879
Semi-Intensive	50	0.975	1.708
Extensive	50	0.979	2.487
All Type II (background/feedlot)	150	0.936	1.600
Intensive	50	0.971	2.071
Semi-Intensive	50	0.972	1.707
Extensive	50	0.974	1.472
All Type III (calfing (birth) to slaughter)	150	0.975	3.506
Intensive	50	0.989	1.510
Semi-Intensive	50	0.983	2.677
Extensive	50	0.979	2.691

Data Source: Model results.