Effect of Calf Health on Feedlot Performance and Carcass Value

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Abstract

This paper addresses if calf health does affect feedlot performance and carcass value. The physiological aspects of this question as well as a regression analysis to further evaluate this problem will be addressed in this paper. A large set of data that can help to explain this health and value question has been made available for this study. These data were collected from the years 1990 - 2005 from a cattle feeding and carcass program in Coyle, Oklahoma as part of an Oklahoma State University program entitled the OK Steer Feedout (University 2004-2005).

The information found in the physiological examination of this question indicates that calf health greatly affects feedlot performance and carcass value. The loss of muscle and fat deposits due to the immune response launched by the calf to fight disease, suggests a loss in marbling and carcass weight. The decrease in appetite creates a lower average daily gain, affecting the out weight of the calf. The symptoms seen as a result of infection affect feedlot performance, yield grade, and quality grade. The extent of the influence of sickness on the characteristics that determine performance characteristics was determined by the regression models. The models indicate medical costs (which indicate sick cattle) negatively affect performance characteristics. To cow/calf producers, this creates the opportunity to provide healthy cattle and to be justified in receiving a premium for their product. For feedlots and stockers, it means a more valuable consistent product, cattle with better average daily gains, and fewer days on feed. Economically, the cattle industry stands to benefit from the promotion of healthy cattle. How much they stand to benefit requires further research.

Introduction

The beef industry in the United States generates nearly $35 billion a year and is one of the top five commodities for 32 of the 50 states . Of the 1.07 million cattle operations in the US, Oklahoma ranks 4th based on cattle numbers. In the United States, beef cash receipts account for 38.9% of all animal agriculture and are the number one source of agricultural cash receipts in Oklahoma . From these statistics alone, it is obvious how important cattle are to the economy of Oklahoma. While the success of the beef industry is a major economic concern, the health of cattle is always an issue for producers because of food safety; however, it is now beginning to take on a greater meaning.

Currently, little is known about the connection between calf health and its effect both on feedlot performance and on the carcass value of cattle, which can dramatically affect profit for the producer. In the past, it was believed that carcass value was largely related to the genetics of the animal and the nutrition system the producer used. There has lately been limited research suggesting that preconditioning, the use of management practices implemented around the time of weaning, can actually have a large effect on improving calf health, which is thought to be directly correlated to carcass value . Preconditioning promotes the use of practices that are intended to "optimize the animals' immune system," and, by promoting good health in calves, may improve profits by producing a healthy animal with a higher carcass value . One study found that calves treated only once for disease "returned $40.62 less, those receiving 2 medical treatments returned $58.35 less, and those receiving 3 or more treatments returned $291.93 less than calves that were not treated" (Galyean 2006). Knowing that healthy calves have a higher carcass value may increase the incentive to purchase healthy cattle. Without this incentive, there is little motivation to produce or purchase preconditioned cattle. This is largely due to the fact that preconditioning requires more time and input cost and currently there is not consistent premiums provided for preconditioned calves to offset the added costs.

Studies suggest calf health is directly correlated to feedlot performance and carcass value, but little research has been conducted to provide evidence of this claim. The Ranch to Rail study, conducted at Texas A&M, indicates that sick cattle gain significantly less weight, which translates to less "saleable carcass weight." Ranch to Rail also suggests that "sickness reduced the number of carcasses grading choice by 12%" . This drop decreased the average return on the cattle nearly $88 compared with return for non-sick cattle . These studies suggest there is an incentive for producers to buy healthy cattle that are the product of good management practices over cattle that are not managed as well. There is also the issue of asymmetric information between the different industry sectors. This issue is addressed in different studies, suggesting that improved information flow regarding the background of the cattle, might stimulate the demand for preconditioned calves (Galyean 2006). Such statements are made for many reasons, most significantly that only 32.4% of surveyed feedlots receive information regarding the health history of the cattle they purchase (Galyean 2006).

The remainder of this paper addresses if calf health does affect feedlot performance and carcass value. The physiological aspects of this question as well as a regression analysis to further evaluate this problem will be addressed in this paper. A large set of data that can help to explain this health and value question has been made available for this study. These data were collected from the years 1990 - 2005 from a cattle feeding and carcass program in Coyle, Oklahoma as part of an Oklahoma State University program entitled the OK Steer Feedout .

The OK Steer Feedout is an educational program that allows cow-calf producers an opportunity to learn more about their calf crop and the traits that influence value in the beef industry. The program is conducted by the Oklahoma Cooperative Extension Service to provide information to cattlemen about the post-weaning performance and carcass merit of their calves. The data is provided to ranch owners as a genetic selection or management tool, not as a contest. The OK Steer Feedout provides information on "important economic traits that assist ranchers as they determine the genetic and/or management changes desired for their cow herd as they strive to meet their ranch goals and provide a product in demand by the beef industry" .

The OK Steer Feedout data were given to the Agricultural Economics department at OSU for several different study purposes. For this project I will perform the appropriate statistical tests and a regression analysis to verify or reject my hypothesis that healthier calves perform better in feedlots and lead to higher valued carcasses.

Background

Beef cattle performance is evaluated in several ways for different purposes. There are three ways that performance is measured in this study. These are feedlot performance and two types of carcass performance, one for quality grade and one for yield grade. Feedlot performance is measured in terms of average daily gain and feed intake. Carcass performance for quality grade is measured in terms of marbling and maturity. Carcass performance for yield grade is measured in terms of carcass weight, ribeye area, and fat thickness .These three types of performance are what this study will focus on, determining if sickness in cattle has a negative effect on these performance measures. To fully understand what traits could be affected by sickness, it is important to understand how carcass performance is determined.

Carcass characteristics include marbling (internal fat), fat thickness, carcass weight, quality grade and ribeye area. Each of these characteristics is important for various carcass evaluations, which are the primary indicators of carcass value. For this study, feedlot performance and carcass value are the main areas of focus, allowing us to determine how these traits are affected by illness within cattle.

Official US Department of Agriculture quality grades are Prime, Choice, Select, and Standard. These grades are determined from two factors, maturity and degree of marbling. The marbling score is taken on the ribeye muscle at the 12^{th} rib. Marbling is the fat deposited within the muscle (lean) of cattle. This dispersion of fat accounts for the palatability of the meat and is used to assign the quality grade to the carcass. The degree of marbling and corresponding quality grade can be seen in Table 1.

Yield grade is determined by several factors: ribeye area, carcass weight, fat thickness, and kidney-heart-pelvic fat. Ribeye area is a trait that is dependent upon the weight of the animal's hot carcass (before chilling and cooling). Table 2 is a chart for ideal ribeye area values . Yield grade is assigned on a numerical basis from 1-5. It is based on the yield of boneless, closely trimmed, retail cuts from the round, loin, rib and chuck. Yield grade is computed as follows:

Yield Grade = 2.5 + (2.5*FatThk) + (0.0038*CarcWt) + (.2* %KPH) – (.32*REA)

The yield grade values (1-5) correspond to the % retail cuts shown in Table 3.

Carcass index is a composite of quality and yield grade and is assigned based on a base value of 100 points attainable from the above characteristics. Points are added or subtracted depending on how the animal's characteristics deviate from the trait "ranges." The index system used by the OK Steer Feedout uses 600 to 850 lbs as their standard carcass weight. Carcasses outside this range do not meet the majority of industry specifications . For ribeye area, 5 points are added to the index for each square inch the carcass is above the REA requirement or subtracted for each square inch below. The ranges and each trait that is evaluated to determine carcass index can be seen in Table 4.

Physiology

The cattle industry can be most simply divided into three main segments, the cow/calf industry, the stocker industry, and the feedlot/finishing phase, ultimately leading to the harvesting segment. The health of the animal relies primarily on the health and success of the calf as it emerges from the cow/calf sector. Second to genetics, the healthiness of the calf is what secures higher average daily gains and higher carcass scores. Calf health has become a more prevalent concern among producers as consumers continue to demand consistent beef products. It is the stocker and feedlot sectors that are most affected by calf health, but it is the cow/calf industry that must provide healthy calves to these sectors .

The health of the calf relies heavily on the management of the cattle and starts with a vaccination program. Vaccinations are given to prevent many of the diseases that affect cattle including Bovine Respiratory Disease and Black Foot, which are the most common. It should be noted here that vaccinations do not eliminate disease; they instead minimize risk of infection and minimize severe clinical symptoms of disease . Typically, all cattle vaccinations are given at a young age and should be given with the mindset of preparing the cattle for where they are going, not where they currently are. Calf vaccinations are typically given at branding time (2 to 4 months) and at weaning (5 to 9 months). While cattle that may be acting as replacement heifers will continue to be vaccinated, stocker calves may be given only one booster as they enter the feedlot to maintain the herd's population health. At branding time, a fundamental vaccination program would include Clostridial, 7 to 8 way (depending on the location) and a parasite control program. Then, at weaning, calves in a basic vaccination program should be vaccinated for Clostridial again, and with a 4-way/5-way respiratory diseases vaccine that includes IBRV, BVDV, PI3V, BRSV, Leptospirosis, and continue with parasite control. This vaccination program is essential to the success of the calf throughout the various sectors of the cattle industry to ensure the calf's risk of infection from disease is lowered . While some consumers may consider this vaccination program extreme and possibly harmful to the meat, when it is compared to vaccination programs children undergo, it is about half the amount of vaccines children receive. It is also about half of the amount of vaccinations needed to protect calves to the extent parents protect their children (U.S. Department of Health and Human Services 2006).

Upon infection, a calf's body, like any mammal, will initiate an immune response. This immune response consists of two parts, cell mediated immunity and a humoral response. Upon the launch of the calf's immune response, immediate physiological effects include fever, depression, and a decrease in appetite and water intake. The decrease in food, the increase in cell energy demand to function under a fever, and the increase in protein demand to increase antibody production, results in a loss of energy stores by the calf. This includes muscle and fat, which in beef cattle are valuable assets as they affect each of the performance characteristics. As previously mentioned, however, vaccinations serve only to minimize the risk of infection; disease itself is the result of many factors .

Each disease is different, but each basic response to the disease leads to the above immune response and corresponding effects. Bovine Respiratory Disease Complex is the disease most detrimental to Oklahoma and cattle operations in most states. This disease is the result of a combination of circumstances. These include viral, bacterial/mycoplasmial, and stress components. Cattle that undergo a proper vaccination program and/or a preconditioning program are better prepared to ward off each of these causes.

Recall preconditioning refers to a program generally implemented after cattle are weaned (around 5 – 9 months) that prepares the calf's immune system while minimizing stress. In a management program that does not precondition, the calf would normally be sold and transported to a stocker or feedlot at weaning, generally depending on the size of the calf. At this time, the calf is removed from its mother, put on a completely different diet, placed with a large number of cattle and often in an entirely new climate. The calves are put into large communities and taken from their homes, leading to high exposure to viral and bacterial agents and very stressful environments. This practice almost assuredly puts the calf in the perfect position to meet all three of the necessary conditions where it is vulnerable to disease: viral, bacterial, and stress. Preconditioning programs allow cattle to adjust to many of the changes they are faced with during this vulnerable time and are another way to improve calf health and avoid losing valuable returns through poor feedlot performance and low carcass scores .

Many producers in the cow calf sector know little about the benefits of vaccination, or simply do not feel it should be their problem when the calves leave their hands when they are 5–9 months old. The organization of the cattle industry creates a disconnect between production sectors, and cow/calf producers cannot see the benefit of producing cattle they sell to have higher average daily gains and higher carcass scores because it does not benefit them directly. This benefit, however, is substantial and can easily be obtained from implementing a vaccination program that cost around $5-$7 a head .

In a paper entitled, "Ten-year trends at Superior Livestock Auction": Calves in value-added health programs consistently receive higher prices", the premiums received for calves in extensive vaccination programs are tracked (King and Seeger 2005). The premiums all increase linearly from 1995 to 2004 and the premiums seen in calves in preconditioning programs are all substantially higher then those in other vaccination programs. For example in 2004, the premium was $7.91 for preconditioned cattle while in 1995 it was $2.47, still two dollars more then the premium received from non preconditioned cattle. Using a spread sheet created for the Avent, Ward, Lalman article (2004), the premiums seen in 2004 for preconditioned cattle were inserted and the return was estimated for producers that implement preconditioning programs. The gross revenue per head seen on cattle that receive a viral vaccination only is $504.48, compared to the gross revenue per head seen on cattle that were preconditioned which is $538.96 as estimated by the spreadsheet. This data indicate the return of more than $30 more per head on preconditioned cattle is worth the extra $5-$7 cost.

Data and Procedures

While physiologically, it makes sense that calf health would have an impact on feedlot performance and carcass value, it was necessary to approach this question from a statistical standpoint. To do so, data were obtained from the OK Steer Feedout program. These data were collected over the course of 16 years. Data included: Year, Season, ID, Birthdate, In Height, In Frame, In Weight, In Date, Check Weight, Check Date, Sale Date, Sale Weight, Out Height, Out Frame, Age, Days on Feed, Average Daily Gain, Carcass Weight, Fat Thickness, Rib Eye Area, KPH, Marbling, Sire Breed, Dam Breed, Feed Intake, Medical Costs, and Carcass Index. For this study, several of these characteristics were not used, but many were. In addition, Feed Conversion was created as a way to evaluate how efficient cattle were at converting feed, rather then assuming a high number of days on feed meant they were less efficient. This was done using the formula: Feed Conversion = Feed Intake/ (Sale Weight – In Weight). Table 5 indicates the variables used and the abbreviations found in this paper.

The data were divided into three groups. These groups were divided into the entire set of data, the first two years of data, and the last two years of data. The choice for this division was based on making a comparison between the starting period of the data collection and the ending period of the data, in addition to the results that would be obtained from the entire data set. Unless otherwise indicated, it can be assumed that the results being discussed were obtained using the entire data set, but they will be reported for all three groups.

Means of each performance variable from the data of animals with medical costs compared to those with no medical costs were first performed on the data and can be viewed in Table 6 for all three group periods. Some cattle may have been treated once, and some more than once. Note the data do not include information on cattle that died within the feedlot. Following the performance variable mean calculation, a correlation analysis was preformed to determine which relevant characteristics were highly correlated with one another and should thus be used for regression analysis. Regression models were then estimated from the data and used to determine the validity of the proposed hypothesis. Regressions were run using SAS. Tables 7-9 present the results of the regression analysis.

Results

Table 6 shows a comparison of many performance variable averages as seen in cattle with medical costs and in cattle with no medical costs. For each variable the average was lower in the cattle that incurred medical costs, except for days on feed and feed intake, where cattle with medical costs were actually on feed longer and fed more. Average daily gain, as might be anticipated by the longer days sick cattle were kept on feed, is less in cattle with medical costs, as are marbling scores, carcass weight, fat thickness, and therefore carcass index scores. In most cases, there was more variability in performance for treated calves as shown by the higher standard deviations for variables such as marbling. Many other factors can affect differences in performance. These factors were accounted for with the regression models.

Feed intake (FdIntake) or amount consumed affects sale weight and carcass weight. Feed intake or how much animals eat was believed to be affected by factors in addition to animal health, as measured here by medical costs. These include weight when calves were placed on feed (InWt), number of days on feed (DOF), average daily gain (ADG), and weight when harvested (SaleWt). To evaluate feedlot performance the dependent variable FdIntake was assessed using the variables SaleWt, InWt, DOF, MedCost, and ADG which can be seen in Table 7. The adjusted R^2 term for this model is 0.825, showing these variables accurately explain 82% of the variability in feed intake. For this paper's purpose, an R^2 term greater then 0.7 is considered to show the variables in the model explain well the variation in the dependent variable. Most variables within this model are statistically significant. Medical costs in the model have a positive coefficient, indicating that increases in medical costs reflect increases in feed intake and thus feedlot performance. ADG uses the variables SaleWt, InWt, DOF, FdIntake, and MedCost. It has an R^2 value of 0.994, suggesting ADG can be explained very well by the variables within the model, each of which is significant. Medical costs for this model have a positive coefficient and are similar in both the first and last year. InWt, MedCosts, SaleWt, DOF, and ADG were the independent variables used to evaluate Feed Conversion. The R^2 for this model is 0.470, meaning the variables do not adequately represent the variation in feed conversion. The coefficient medical costs has a small positive coefficient.

Components of yield grade were evaluated separately (Table 8). Carcass weight was evaluated using the variables ADG, MedCost, FdIntake, DOF, and InWt. Each of these variables are significant and the R^2 value for this model is 0.922, indicating the variables are excellent indicators of carcass weight. The coefficient of medical costs is negative in two of the three groups, indicating that as medical costs go up, carcass weight goes down, and thus so does yield grade. The fat thickness model used the variables DOF, CarcWt, Marb, REA, and MedCost. This model has an R^2 value of 0.288 and most variables were significant. Medical Costs for the model has a negative coefficient that is small. The REA model has the variables CarcWt, Medical Costs, DOF, OutFrm, and FatThk. It has an R^2 value of 0.425 and most of the variables are significant.

To evaluate quality grade, the dependent variable marbling (Marb) was evaluated (Table 9). The marbling model included the variables CarcWt, DOF, MedCost, REA, and FatThk, which were each significant except for medical costs, and had an R^2 of 0.114, and is therefore not considered to be an accurate explanation of marbling. Again, though, medical costs have a negative coefficient, indicating increases in medical costs decrease marbling scores, the major determinant of quality grade.

Aside from the three measures of performance, CarcNdex was evaluated individually using the variables Marb, MedCost, FatThk, REA, and CarcWt. The adjusted R^2 for the model is 0.543 and each of the variables is significant. Medical costs for the model have a negative coefficient, indicating that increased medical costs decrease the carcass index score. This is consistent for the first years data set as well.

Summary and Implications

Data made available from the OK Steer Feedout and information about the physiologic effects of disease on cattle were evaluated to determine how calf health affects feedlot performance and carcass value. The paper focused on the three measures of performance most commonly used to evaluate cattle: feedlot performance, yield grade, and quality grade. These were assessed both from how the areas are affected by the physiological impacts of the disease and how much certain variables are affected by medical costs in cattle.

Physiologically, the immune response to the disease most affected muscle and fat production and appetite. The increased energy demand needed to ward off the disease prevents the body from storing energy as muscle and fat, but the depression generated from the disease also decreases appetite, which would increase days on feed and decrease average daily gain. The statistical models indicate the same conclusion, with slightly more specificity to the exact traits most impacted by disease. Overall, however, medical costs had a negative impact on performance characteristics.

The information found in the physiological examination of this question indicates that calf health greatly affects feedlot performance and carcass value. The loss of muscle and fat deposits, due to the immune response launched by the calf to fight disease, suggests a loss in marbling and carcass weight. The decrease in appetite creates a lower average daily gain, affecting the out weight of the calf. The symptoms seen as a result of infection affect feedlot performance, yield grade, and quality grade. The extent of the influence of sickness on the characteristics that determine performance characteristics was determined by the regression models. The models indicate medical costs (which indicate sick cattle) negatively affect performance characteristics. To cow/calf producers, this creates the opportunity to provide healthy cattle and to be justified in receiving a premium for their product. For feedlots and stockers, it means a more valuable consistent product, cattle with better average daily gains, and fewer days on feed. It also provides an incentive to increase the sharing of information between the different sectors of the industry. It encourages feedlots to request information about the previous history of the calves, and provides cow/calf operations the motivation to share this information as it can mean a greater profit. It is obvious that economically, the cattle industry stands to benefit from the promotion of healthy cattle. How much they stand to benefit, however, requires further research.

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Table 1. Degree of marbling and corresponding quality grade.

Quality Grade	Degree of Marbling
Prime- (Low)	Slightly Abundant 0-90
Choice+ (High)	Moderate 0-90
Choice^0 (Average)	Modest 0-90
Choice- (Low)	Small 0-90
Select + (High)	Slight 60-90
Select- (Low)	Slight 0-50
No Roll (Standard)	Traces 40-90

Table 2. Ribeye Area for Hot Carcass Weight (1)

Hot Carcass Weight (Lbs)	Ribeye Area (Sq In)
600	11.0
650	11.6
700	12.2
750	12.8
800	13.4
850	14.0

Table 3. Yield Grade Values and Percent Retail Cuts.

Yield Grade	% Retail Cuts
1	54.6
2	52.3
3	50.0
4	47.7
5	45.4

Table 4. Carcass Index System

Trait	Ranges
Carcass Weight	600-850 lbs
Adjusted backfat	.25''- .39''
Internal fat	2.5%
Quality grade	Low Choice: penalties are given for ranking below Low Choice and bonuses are given for ranking above.
Ribeye area	Based upon weight, if the animal has a smaller REA then required, points are deducted. See the above table for the REA requirements

Table 5. Variable Abbreviations

Abbreviation	Variable
CarcWt	Carcass Weight (pounds)
CarcNdex	Carcass Index
FatThk	Fat Thickness (inches)
Marb	Marbling
REA	Rib Eye Area (square inches)
MedCost	Medical Costs (dollars)
ADG	Average Daily Gain (pounds per day)
DOF	Days on Feed (days)
InWt	In Weight (pounds)
FdIntake	Feed Intake (pounds)
OutFrm	Out Frame (hip height when harvested)
SaleWt	Sale Weight (pounds)
Conv	Feed Conversion

Table 6. Variable means by treated and non-treated cattle

	1990-2005		1990-1991		2004-2005	
Variable	Zero Medical Costs	Medical costs >0	Zero Medical Costs	Medical Costs >0	Zero Medical Costs	Medical Costs >0
CarcWt	721.6	702.2	712.5	685.7	730.5	700.60
CarcNdex	85.2	83.0	86.7	83.4	84.0	79.7
FatThk	0.36	0.34	0.37	0.32	0.41	0.39
Marb	410.7	403.1	414.3	404.7	426.5	400.8
REA	12.5	12.3	12.9	12.5	12.9	12.4
MedCost	0	30.00	0	18.12	0	111.3
ADG	3.42	3.39	3.32	3.18	3.39	3.30
DOF	165.7	167.7	167.4	172.0	165.1	169.7
InWt	617.3	591.5	618.8	596.2	643.2	597.5
FdIntake	4021.7	4039.5	3740.2	3715.9	4256.6	4061.9
Conv	7.13	7.14	6.78	6.83	7.63	7.30
OutFrm	6.2	6.0	6.5	6.5	5.8	5.8
SaleWt	1182.8	1159.2	1171.8	1142.2	1201.4	1155.8

Table 7. Regression results for feedlot performance[a]

Variable	1990-2005 (Coefficient)	1990-1991 (Coefficient)	2004-2005 (Coefficient)
FdIntake			
Intercept	-1572.802***	-1726.176**	-5669.42***
	(4.24)	(2.52)	(4.97)
SaleWt	7.381***	7.840***	1.118
	(11.56)	(1.21)	(0.57)
InWt	-4.391***	-5.294***	2.072
	(6.89)	(4.39)	(1.05)
DOF	1.328	-4.072	25.164***
	(0.60)	(1.00)	(3.75)
ADG	-188-860*	-339.611*	913.327***
	(1.78)	(1.66)	(2.78)
MedCost	71.400***	26.066	-84.186***
	(7.97)	(1.28)	(3.97)
n	4257	572	336
R^2	0.825	0.886	0.912
ADG			
Intercept	3.420***	3.221***	3.482***
	(306.98)	(77.65)	(86.72)
SaleWt	0.006***	0.006***	0.006***
	(382.23)	(110.89)	(92.16)
InWt	-0.006***	-0.006***	-0.006***
	(468.77)	(133.60)	(137.92)
DOF	-0.020***	-0.019***	-0.020***
	(385.45)	(109.82)	(120.17)
FdIntake	-0.000*	-0.000*	0.000***
	(1.78)	(1.66)	(2.78)
MedCost	0.001	0.006	0.006
	(1.12)	(1.52)	(1.54)
n	4257	572	336
R^2	0.994	0.994	(0.996)
Conv			
Intercept	3.76***	1.593	-1.788
	(5.47)	(1.26)	(0.86)
SaleWt	-0.001	-0.002	-0.010***
	(0.86)	(1.00)	(2.83)
InWt	0.006***	0.007***	0.016***
	(5.42)	(3.09)	(4.39)
DOF	0.007*	0.021***	0.041***
	(1.66)	(2.78)	(3.34)
ADG	-0.146	0.022	1.393**
	(0.74)	(0.06)	(2.33)
MedCost	0.134***	0.038	-0.147***
	(8.08)	(1.02)	(3.81)
n	4257	572	336
R^2	0.470	0.501	0.694

[a] Numbers in parentheses are absolute values of calculated t statistics; *=0.10, **=0.05, and ***=0.01 significance.

Table 8. Regression results for yield grade components[a]

Variable	1990-2005 (Coefficient)	1990-1991 (Coefficient)	2004-2005 (Coefficient)
CarcWt			
Intercept	-264.631***	-194.160***	-353.272***
	(27.63)	(5.83)	(8.23)
InWt	0.582***	0.573***	0.655***
	(108.13)	(33.59)	(29.49)
FdIntake	0.023***	0.030***	0.011*
	(18.93)	(6.67)	(1.88)
DOF	1.656***	1.270***	1.928***
	(37.96)	(8.12)	(9.96)
ADG	76.004***	68.776***	88.025***
	(52.73)	(14.58)	(13.23)
MedCost	-5.962***	-10.253***	1.065
	(8.21)	(4.60)	(0.48)
n	4257	572	336
R^2	0.922	0.916	0.940
FatThk			
Intercept	0.624***	0.882***	0.814***
	(19.31)	(8.75)	(6.57)
CarcWt	0.001***	0.001***	0.001***
	(25.65)	(8.05)	(9.60)
DOF	-0.003***	-0.005***	-0.004***
	(21.72)	(10.48)	(6.64)
REA	-0.032***	-0.034***	-0.050***
	(19.90)	(7.13)	(9.20)
Marb	0.000***	0.000***	0.000***
	(13.54)	(4.53)	(4.62)
MedCost	-0.004	-0.016	0.009
	(1.14)	(1.23)	(0.67)
n	4257	572	336
R^2	0.288	0.353	0.399
REA			
Intercept	5.036***	4.524***	11.766***
	(18.32)	(5.30)	(10.86)
CarcWt	0.012***	0.014***	0.013***
	(48.69)	(20.19)	(14.24)
DOF	0.001	0.003	-0.029***
	(0.65)	(0.81)	(5.77)
FatThk	-2.845***	-2.925***	-4.614***
	(21.60)	(8.81)	(10.71)
OutFrm	-0.060***	-0.203***	-0.224**
	(2.99)	(4.06)	(2.46)
MedCost	-0.051	-0.119***	-0.111
	(1.45)	(5.30)	(0.97)
n	4257	572	336
R^2	0.425	0.454	0.474

[a] Numbers in parentheses are absolute values of calculated t statistics; *=0.10, **=0.05, and ***=0.01 significance.

Table 9. Regression results for quality performance[a]

Variable	1990-2005 (Coefficient)	1990-1991 (Coefficient)	2004-2005 (Coefficient)
Marb			
Intercept	392.255***	303.387***	82.955
	(23.40)	(6.52)	(0.97)
CarcWt	0.149***	0.240***	0.259***
	(8.88)	(5.46)	(3.63)
DOF	-0.474***	0.059	1.105***
	(5.43)	(0.27)	(2.91)
FatThk	107.523***	83.984***	159.656***
	(13.54)	(4.53)	(4.62)
REA	-3.905***	-7.856***	-7.282*
	(4.34)	(3.54)	(1.85)
MedCost	-2.240	-1.718	-23.602***
	(1.09)	(0.29)	(2.85)
n	4257	572	336
R^2	0.114	0.136	0.203
CarcNdex			
Intercept	-15.408***	-15.683***	-15.345*
	(7.39)	(2.81)	(1.96)
CarcWt	-0.032***	-0.035***	-0.053***
	(10.15)	(4.02)	(4.48)
Marb	0.187***	0.207***	0.189***
	(65.63)	(25.26)	(21.05)
FatThk	-22.516***	-26.618***	-29.494***
	(15.67)	(7.89)	(5.34)
REA	4.357***	4.011***	5.410***
	(25.84)	(9.16)	(8.60)
MedCost	-0.964**	-2.323**	1.174
	(2.51)	(2.03)	(0.86)
n	4257	572	336
R^2	0.543	0.562	0.602

[a] Numbers in parentheses are absolute values of calculated t statistics; *=0.10, **=0.05, and ***=0.01 significance.