1982

AN ANALYSIS OF THE IMPACT OF ENERGY PRICE ESCALATIONS DURING THE 1970'S ON HAWAII BEEF PRODUCTION AND PRICES

by

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July, 1982

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Presented at AAEA meetings, Logan, Utah, Aug. 1-4, 1982.

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Abstract

This paper explores the impact of the rapid energy price increases during the 1970's on beef production and prices in Hawaii by performing two simulations of a quarterly econometric model of the Hawaii beef industry. With energy prices increasing at pre-oil embargo rates, Hawaii could have produced 37 percent more grain-fed beef and 46 percent less grass-fed beef in 1980, for an increase in total beef production of 7 percent.

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Introduction

With the oil embargo in late 1973 and the continued influence of the Organization of Petroleum Exporting Countries (OPEC) came unprecedented increases in crude petroleum prices. Undoubtedly, many shifts occurred in American agriculture as relative input and product prices changed. An example is the search in the beef industry by both producers and researchers for less energy-intensive means of production. The hypothesis underlying this paper is that energy price increases during the 1970's significantly influenced both the composition and quantity of beef production in Hawaii. The major objective is to explore the impacts of the rapid energy price escalations of the 1970's on the Hawaii beef cattle industry.

Historical Production Trends

Historical trends in Hawaii beef production provide some indicators of how local producers might have responded to the rapid energy price increases of the 1970's. Between 1964 and 1973 Hawaii and the mainland United States maintained fairly constant shares of the Hawaii beef market, averaging 48 and 26 percent respectively. Figure 1 shows that Hawaii's competitive position with mainland imports began to erode in 1974, as Hawaii's share of the market dropped to 37 percent and the mainland's share rose to 42 percent. By 1975, Hawaii was producing only 31 percent of the beef consumed in the state, while 48 percent waw imported from the mainland. Hawaii's share increased to 36 percent in 1978, but again fell to 31 percent in 1980. By 1980, imports from the mainland accounted for 53 percent of the beef consumed in Hawaii, and

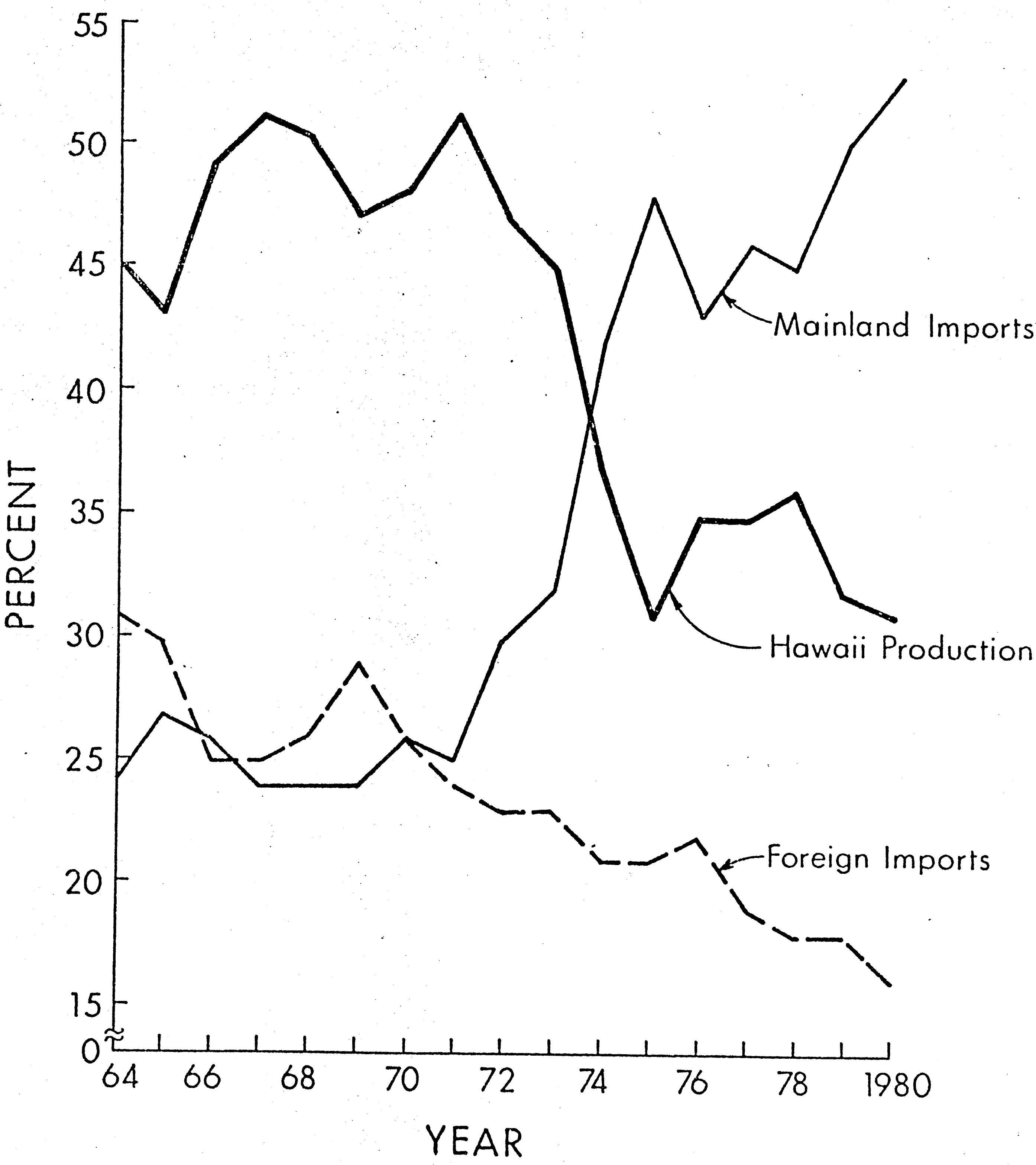

Figure 1. Percentages of Hawaii beef market supply contributed by Hawaii production, mainland imports, and foreign imports, 1964-80.

foreign beef imports dropped from 23 percent in 1973 to only 16 percent in 1980 (Hawaii Agricultural Reporting Service).

Figure 2 shows the dramatic changes in the composition of Hawaii beef production between 1969 and 1980. In 1969, 32 percent of the steer and heifer beef produced in Hawaii was grass-fed. The data demonstrate a definite downward trend to 1974 when only 17 percent of the steer and heifer beef was fed on grass. After 1974 the share of grass-fed steer and heifer beef trended upward to 32 percent in 1980 (Hawaiian Agricultural Reporting Service).

The contention of this paper is that rapidly increasing energy prices were a major cause of the trend reversals demonstrated in Figures 1 and 2. Of course, the authors recognize that there may have been other influences that contributed to changes in the structure of the Hawaii beef industry after 1973. For instance, the erosion of Hawaii's market share was probably influenced in a major way by physical constraints on beef production, as local supply was unable to keep pace with growth in population and tourist traffic. Also, higher relative feed costs, resulting from increases in U.S. grain prices, and shifts in consumer tastes toward leaner beef might have influenced the change in the composition of Hawaii beef production after 1973.

Against this background, an analysis of energy price impacts on the Hawaii beef industry is perfomed for the 1970's. A discussion is presented in the following pages of the various ways energy prices might influence Hawaii beef production. A quarterly econometric model of the Hawaii beef industry, which includes the influence of energy prices, is then presented. The model is used to perform two simulations from which the model is validated and the impacts of energy price increases are explored.

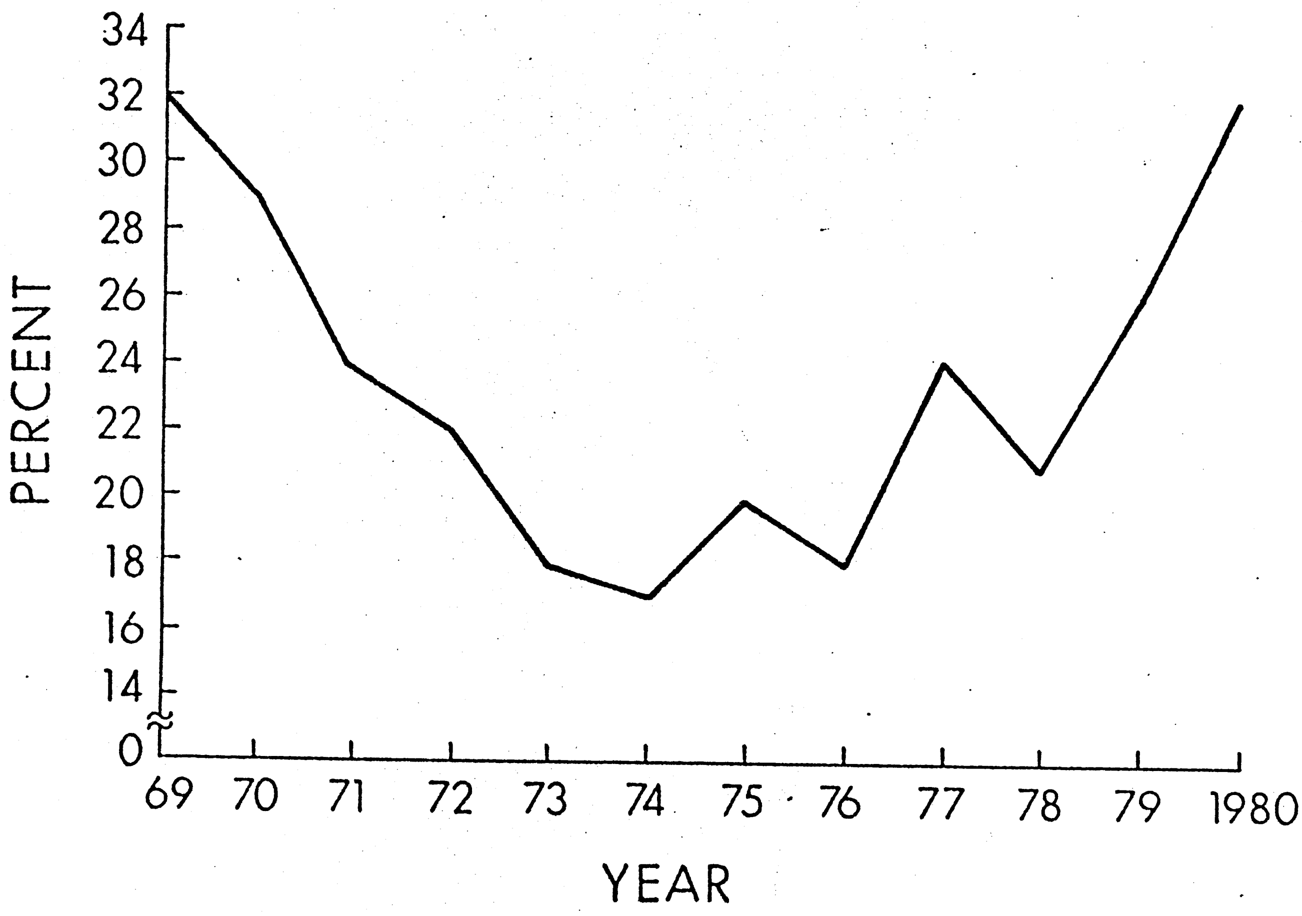

Figure 2. Hawaii range steer and heifer beef production as a percentage of total steer and heifer beef production, 1969-80.

Energy Prices and Hawaii Beef Production

Because of its isolation, the State of Hawaii provides a unique opportunity for examining the impacts of higher energy prices on beef production. The majority of beef consumed in Hawaii is imported from the U.S. mainland or from Australia and New Zealand, with transportation being a major cost. Virtually all of the grain used in Hawaii is imported from mainland sources and shipments of live animals in and out of Hawaii are insignificant. In 1980, the Hawaii Agricultural Reporting Service reported live cattle inshipments of less than 50 head. The gap between local beef production and consumption is filled with imports of beef products rather than live animals, and freight rates for beef and grain are readily available.

Changes in energy prices affect the Hawaii beef industry in six major ways. First, the prices ranchers receive are directly related to transportation costs. Most of the beef consumed in Hawaii is imported from distant locations and competes directly with locally produced beef. Consequently, base point pricing is prevalent. For example, the choice steer price in Hawaii is approximately equal to the Los Angeles choice steer price plus the cost of transporting beef to Hawaii.

Second, transportation costs are important in determining feed concentrate and roughage costs because most feeds are imported from the U.S. mainland. Some feeds, mostly roughages in the form of pineapple bran, corn silage, hay, pineapple green chop, and the like, are produced locally but again transportation is a significant cost due to interisland freight charges and hauling to and from the docks and feedlots.

Third, most other beef production inputs are imported and thus are related to transportation costs. This is especially true for inputs used to produce grain-fed beef because less locally produced range and pasture is used relative to other inputs.

Fourth, trucking and interisland freight costs are important in determining the composition of beef production. The vast majority of grain-fed beef is produced in one feedlot, which is close to grain storage facilities and the state's major population center and harbor on Oahu. But, only about 5 percent of all cattle slaughtered originate on Oahu, and most of them are cull dairy cows. Grass-fed steers and heifers are traditionally slaughtered to supply the local market on the island where they are produced. However, in 1980 approximately 20 percent of the grass-fed steers and heifers produced in Hawaii were shipped as carcasses from the outer islands to Oahu. Given perfect markets, theory suggests that the prices received by ranchers on the outer islands would be the Oahu price minus transportation costs. Accordingly, increases in energy-related transportation costs would either be reflected in the higher cost of transporting feeder animals to Oahu or in a lower price received by ranchers for grass-fed animals as meat packers pass on to ranchers the higher cost of transporting slaughtered beef to Oahu. However, the shipment of processed beef both to and from the outer islands and differences in the preferences among the island populations for yellow fat suggest that the grass-fed beef market is not perfect. Grass-fed beef competes more favorably with grain-fed beef on islands other than Oahu because fat color is less important. In addition, the cost of transporting feeders to Oahu is an out-of-pocket cost, tied closely to changes in energy prices. On the other hand, energy-related decreases in returns for grass-fed beef might not be perceived by ranchers as a cost until the animals are sold several months later. Even then ranchers might not associate the decrease in returns with higher energy costs. Thus, imperfect knowledge and other market imperfections might lead to an actual and/or perceived avoidance of higher energy-related interisland transportation costs.

Fifth, since transportation costs influence most commodity prices in Hawaii, higher energy prices probably influence ranchers' expectations of the future cost and return structure of beef production. For instance, higher energy prices might cause ranchers to expect feed costs to increase in the future. This expectation would be in addition to expectations of future feed costs formed when assuming a constant energy price. Thus, higher energy prices might cause ranchers to leave more steers and heifers on grass because costs are less directly influenced by energy prices, at least in the short term.

Expectations formed from higher current energy prices also play a part in the cost of transporting feeder animals to Oahu because of the risk associated with shrinkage during transport. It takes 4 to 6 weeks for feeder cattle to regain their pre-shipment weight in the feedlot (College of Tropical Agriculture and Human Resources). Higher energy prices increase the expected cost of shrinkage because feed costs are expected to be higher, and therefore the expected loss associated with regaining body weight is expected to be higher.

Sixth, not only do energy prices directly affect Hawaii beef production through transportation costs but also indireetly through the mainland prices themselves. Mainland prices are determined by the structure of the national beef and feed industries. Changes in energy prices that cause changes in national supply and demand conditions, and consequently changes in mainland prices, also influence the Hawaii beef industry.

Model Structure

The econometric model estimated for this analysis is presented in Table 1 and variable and symbol definitions are given in Table 2. Priority in

Table 1. Estimated Equations and Identities of the Hawaii Beef Econometric Model

Equation Number	Equation
	I. Quarterly Freight Cost and Price Transmisson Equations
1	$TRANB_t = \underset{(.070)^a}{2.610} + \underset{(.0004)}{.0020}OILP_t + \underset{(.005)}{.027}TIME,\ R^{2b} = .9926,\ DW^c = 1.479,\ ALS,\ \hat{\rho} = \underset{(.094)}{.784}.$
2	$TRANC_t = \underset{(.612)}{14.385} + \underset{(.005)}{.0180}OILP_t + \underset{(.052)}{.394}TIME,\ R^2 = .9879,\ DW = 1.756,\ ALS,\ \hat{\rho} = \underset{(.120)}{.607}.$
3	$TRANCM_t = .25TRANC_t + .5TRANC_{t-1} + .25TRANC_{t-2}$
4	$WPFC_t = \underset{(1.477)}{-6.831} + \underset{(.020)}{.980}USWPFC_t + \underset{(.782)}{4.548}TRANB_t,\ R^2 = .9964,\ DW = 1.676,\ OLS.$
5	$WPRC_t = \underset{(3.584)}{-4.770} + \underset{(.051)}{.362}USWPFC_t + \underset{(.056)}{.262}USWPFC_{t-1} + \underset{(1.965)}{4.343}TRANB_t + \underset{(.640)}{1.573}D1 + \underset{(.713)}{1.518}D2 + \underset{(.601)}{.041}D3,\ R^2 = .9882,\ DW = 1.616,\ ALS,\ \hat{\rho} = \underset{(.129)}{.516}.$
6	$WPC_t = \underset{(3.577)}{-14.725} + \underset{(.064)}{.227}USWPC_t + \underset{(.076)}{.412}USWPC_{t-1} + \underset{(.075)}{.175}USWPC_{t-2} + \underset{(.070)}{.131}USWPC_{t-3} + \underset{(1.702)}{5.120}TRANB_t,\ R^2 = .9870,\ DW = 1.879,\ ALS,\ \hat{\rho} = \underset{(.137)}{.425}.$
7	$PCF_t = \underset{(.299)}{.535} + \underset{(.140)}{1.686}USCPM_t + \underset{(.012)}{.145}TRANCM_t,\ R^2 = .9747,\ DW = 1.728,\ ALS,\ \hat{\rho} = \underset{(.144)}{.360}.$
8	$CFD_t = PCF_t/10.56$
	II. Annual Inventory and Calf Crop Equations
9	$CBI_L = \underset{(25.386)}{8.754} + \underset{(.047)}{.114}WPFC_{L-1}/CFD_{L-1} - \underset{(.010)}{.0130}ILP_{L-1}/CFD_{L-1} + \underset{(.242)}{.784}CBI_{L-1},\ R^2 = .8561,\ DH = -.583,\ OLS.$
10	$HI_L = \underset{(8.500)}{-10.528} + \underset{(.087)}{.449}CC_{L-1} - \underset{(.015)}{.623}WPFC_{L-1}/CFD_{L-1} + \underset{(.003)}{.1500}ILP_{L-1}/CFD_{L-1} + \underset{(.094)}{.532}HI_{L-1},\ R^2 = .8278,\ DH = -.922,\ ALS,\ \hat{\rho} = \underset{(.253)}{-.568}.$
11	$HOI_L = \underset{(3.106)}{-5.734} + \underset{(.070)}{.828}(HI_L - HDI_L) + \underset{(.009)}{.0008}WPFC_{L-1}/CFD_{L-1} - \underset{(.001)}{.0120}ILP_{L-1}/CFD_{L-1},\ R^2 = .9660,\ DW = 2.630,\ ALS,\ \hat{\rho} = \underset{(.261)}{-.499}.$
12	$HBI_L = HI_L - HOI_L - HDI_L.$
13	$SI_L = \underset{(8.035)}{-18.682} + \underset{(.115)}{.540}CC_{L-1} - \underset{(.020)}{.050}WPFC_{L-1}/CFD_{L-1} + \underset{(.108)}{.496}SI_{L-1},\ R^2 = .8670,\ DH = -1.184,\ ALS,\ \hat{\rho} = \underset{(.246)}{-.604}.$
14	$CC_L = \underset{(24.931)}{-34.757} + \underset{(.183)}{.899}(CBI_L + CDI_L) + \underset{(.375)}{.784}(HBI_L + HDI_L),\ R^2 = .7275,\ DW = 2.216,\ ALS,\ \hat{\rho} = \underset{(.273)}{-.426}.$
	III. Quarterly Slaughter Equations
15	$FCS_t = \underset{(1762.3)}{-4233.5} - \underset{(23.447)}{51.732}TSHOIQ_t{*}D1 - \underset{(16.149)}{57.63}TSHOIQ_t{*}D2 - \underset{(14.233)}{1.809}TSHOIQ_t{*}D3 + \underset{(22.84)}{103.5}TSHOIQ_t + \underset{(20.727)}{44.402}TSHOIQ_{t-4}{*}D1 + \underset{(507.72)}{221.42}RSHOIQ_t{*}D1 + \underset{(537.33)}{1489.1}RSHOIQ_t{*}D2 + \underset{(484.35)}{31.939}RSHOIQ_t{*}D3 + \underset{(905.65)}{2104.4}RSHOIQ_t + \underset{(11.96)}{37.9}WPFC_{t-1}/CFD_{t-1} - \underset{(16.516)}{39.359}WPRC_{t-1}/CFD_{t-1} - \underset{(1.634)}{3.741}OILP_{t-1}/CFD_{t-1} - \underset{(6.273)}{18.067}(WPFC_{t-1}/CFD_{t-1} - WPFC_{t-2}/CFD_{t-2}) + \underset{(2.549)}{8.816}(OILP_{t-1}/CFD_{t-1} - OILP_{t-2}/CFD_{t-2}) + \underset{(207.38)}{972.86}DUM1 + \underset{(195.4)}{593.36}DUM2 - \underset{(232.25)}{253.64}DUM3 - \underset{(136.11)}{372.88}W_t + \underset{(17.248)}{27.93}TIME,\ R^2 = .9485,\ DW = 1.861,\ ALS,\ \hat{\rho} = \underset{(.132)}{.563}.$
16	$RCS_t = \underset{(216.44)}{421.65} + \underset{(4.778)}{4.819}WPRC_{t-2}/CFD_{t-2} - \underset{(3.051)}{6.784}WPFC_{t-2}/CFD_{t-2} + \underset{(.469)}{.758}OILP_{t-2}/CFD_{t-2} - \underset{(3.786)}{5.914}TIME + \underset{(76.171)}{183.14}DUM3 - \underset{(52.237)}{5.317}D1 + \underset{(46.706)}{177.38}D2 + \underset{(52.57)}{71.284}D3 + \underset{(.069)}{.84}RCS_{t-1},\ R^2 = .8776,\ DH = -.427,\ ALS,\ \hat{\rho} = \underset{(.157)}{-.225}.$
17	$TFRCS_t = FCS_t + RCS_t.$
18	$CS_t = \underset{(848.1)}{3024.6} - \underset{(.409)}{.742}CIQ_t{*}D1 + \underset{(.438)}{.955}CIQ_t{*}D2 + \underset{(.374)}{.418}CIQ_t{*}D3 - \underset{(8.035)}{14.244}CIQ_t + \underset{(3.659)}{10.096}(WPC_t/CFD_t - WPC_{t-1}/CFD_{t-1}) - \underset{(2.017)}{5.161}(WPFC_t/CFD_t - WPFC_{t-1}/CFD_{t-1}) - \underset{(2.725)}{7.972}TIME + \underset{(42.543)}{105.38}W_t,\ R^2 = .6723,\ DW = 1.920,\ ALS,\ \hat{\rho} = \underset{(.141)}{.354}.$
19	$BS_t = \underset{(64.834)}{37.452} + \underset{(.038)}{.045}CS_t + \underset{(15.87)}{44.819}D1 + \underset{(15.923)}{21.158}D2 + \underset{(15.304)}{31.37}D3 + \underset{(.142)}{.46}BS_{t-1},\ R^2 = .3178,\ DW = 2.058,\ OLS.$
20	$TBEEFS_t = TFRCS_t + CS_t + BS_t.$
	IV. Period Transition Identities
21	$CFD_L = .25(CFD_t + CFD_{t+1} + CFD_{t+2} + CFD_{t+3}).$
22	$WPFC_L = .25(WPFC_t + WPFC_{t+1} + WPFC_{t+2} + WPFC_{t+3}).$
23	$OILP_L = .25(OILP_t + OILP_{t+1} + OILP_{t+2} + OILP_{t+3}).$
24	$CIQ_t = CBI_L + CDI_L,\ t = L{*}4-3$ through $L{*}4.$
25	$TSHOIQ_t = SI_L + HOI_L,\ t = L{*}4-3$ through $L{*}4.$
26	$RSHOIQ_t = SI_L/HOI_L,\ t = L{*}4-3$ through $L{*}4.$

[a] Numbers in parentheses are standard errors.

[b] R^2 in ALS equations is calculated by subtracting the ratio of the sum of squares residual to the total sum of squares from one. It is used only as a measure of goodness-of-fit.

[c] DW and DH are calculated from the residual of ALS equations after correcting for autocorrelation.

Table 2. Variable and Symbol Definitions[a]

Variable or Symbol	Definition
	Endogenous Variables
BS	Dressed weight bull slaughter (1000 pounds).
CBI	January 1 beef cow inventory (1000 head).
CC	Annual calf crop (1000 head).
CFD	Index of Hawaii cattle feed price (1980 = 1.0).
CIQ	January 1 beef plus dairy cow inventory for each quarter of the current year (1000 head).
CS	Dressed weight cow slaughter (1000 pounds).
FCS	Dressed weight feedlot steer and heifer slaughter (1000 pounds).
HBI	January 1 inventory of heifers held for beef cow replacement (1000 head).
HI	January 1 heifer inventory (1000 head).
HOI	January 1 inventory of heifers not held for beef or dairy cow replacement (1000 head).
PCF	Price paid by ranchers for cattle feed in Hawaii (dollars/ton).
RCS	Dressed weight range steer and heifer slaughter (1000 pounds).
RSHOIQ	Ratio of January 1 inventory of steers to January 1 inventory of heifers not held for replacement, for each quarter of the current year.
SI	January 1 steer inventory (1000 head).
TBEEFS	Total beef production in Hawaii (1000 pounds).
TFRCS	Total dressed weight steer and heifer slaughter (1000 pounds).
TRANB	Cost of transporting boxed beef from the U.S. West Coast to Hawaii in Matson Navigation Company containers (dollars/100 pounds).
TRANC	Cost of transporting animal feeds and feed ingredients from the U.S. West Coast to Hawaii in Matson Navigation Company containers (dollars/ton).
TRANCM	Three-year-weighted-moving-average of TRANC. The weights are 1/4, 1/2, and 1/4.
TSHOIQ	January 1 inventory of steers plus January 1 inventory of heifers not held for replacement for each quarter of the current year (1000 head).
WPC	Honolulu wholesale price for cow carcasses (dollars/100 pounds).
WPFC	Honolulu wholesale price for choice steer and heifer carcasses (dollars/100 pounds).
WPRC	Hawaii dressed weight price for range steers and heifers (dollars/100 pounds).
	Exogenous Variables
CDI	January 1 dairy cow inventory (1000 head).
D1	Equals 1 in the first quarter and 0 otherwise.
D2	Equals 1 in the second quarter and 0 otherwise.
D3	Equals 1 in the third quarter and 0 otherwise.
DUM1	Equals 1 in the second and third quarters of 1973 and 0 otherwise.
DUM2	Equals 1 from the first quarter of 1976 through the second quarter of 1977 and 0 otherwise.
DUM3	Equals 1 from the last quarter of 1978 through the last quarter of 1980 and 0 otherwise.
HDI	January 1 inventory of heifers held for dairy cow replacement (1000 head).
OILP	U.S. crude petroleum wholesale price index (1967 = 100.0).
TIME	Equals 1 in the first quarter of 1970, 2 in the second quarter of 1970 to 44 in the last quarter of 1980.
USCPM	Three-year-weighted-moving-average of the average price received by U.S. farmers for corn (dollars/bushel). Same weights as for TRANCM.
USWPC	Los Angeles wholesale carcass price of utility cows (dollars/100 pounds).
USWPFC	Los Angeles wholesale carcass price of choice steers (dollars/100 pounds).
W	Equals 1 in quarters when droughts occurred and 0 otherwise.
	Other Symbols
R^2	One minus the ratio of the sum of squares residual to the sum of squares total.
DW	Durbin-Watson statistic.
DH	Durbin H statistic.
OLS	Ordinary least squares.
ALS	Autoregressive least squares.
$\hat{\rho}$	Estimated first order autoregressive parameter.
t	Refers to the current quarter.
L	Refers to the current year.

[a]The data were obtained from the following sources: Hawaii Agricultural Reporting Service, Statistics of Hawaiian Agriculture, and worksheets; Hawaii Market News Service, Honolulu Prices: Wholesale Eggs, Poultry, Pork, Beef and Rice; U.S. Department of Commerce, Business Statistics, 1977, and Survey of Current Business; Matson Navigation Company, Tariffs 14-B through 14-G; U.S. Department of Agriculture, Agricultural Prices, Annual Summary; California Federal-State Market News Service, Livestock and Meat Prices and Receipts at Certain California and Western Area Markets; National Weather Service, Honolulu, Hawaii, worksheets from Saul Price, Staff Meterologist.

structure estimation was given to goodness-of-fit and to special characteristics of the Hawaii beef industry, given the available data. For example, because of inadequate data on mainland imports, the model includes no market clearing identity requiring the quantities supplied and demanded to be equal.

A characteristic of the Hawaii beef industry which greatly simplifies estimation procedures is that all prices are determined exogenously. Consequently, the model exhibits no simultaneity and it is assumed that the industry can be represented by a recursive model structure. Ordinary least squares and autoregressive least squares estimation methods were used to estimate the structural equations of the model. Two different autoregressive least squares techniques were employed, depending upon whether or not geometric distributed lags were assumed (White). For those equations estimated as distributed lags, partial adjustment was assumed (Nerlove). Each equation was estimated with autoregressive least squares and ordinary least squares. If the estimated autoregressive parameter was significantly different from zero at the 5 percent level, the autoregressive least squares equation was retained for use in the model. In some cases, if model validation results were improved, an autoregressive least squares equation with an insignificant autoregressive parameter was retained over on. ordinary least squares equation. The quarterly equations were estimated with data for the first quarter of 1970 through the last quarter of 1980 and the annual inventory equations used observations for 1970 through 1981. The sample period for the annual calf crop equation was 1970 through 1980.

Table 1 presents the structural equations and identities of the model in four sections. Section I consists of two equations determining mainland-to-Hawaii transportation costs, four price transmission equations and two identities. In equations 1 and 2, the U.S. crude petroleum wholesale price index (OILP) is used to represent the influence of energy prices on transportation costs. The time trend is a proxy for a combination of other variables that might cause freight rates to change over time. Equation 3 simply forms a weighted-moving-average of the cost of transporting feed to Hawaii. It is later used in equation 7.

In equations 4-6, energy prices influence Hawaii beef prices through transportation costs. The formulation of equation 4 is rather straightforward. Since most of the grain-fed beef consumed in Hawaii is imported from the mainland, the price in Hawaii should theoretically be the mainland price plus freight costs. Actual practice follows this formula quite closely. Once a week the major Hawaii packing plants call Los Angeles for price quotations. Hawaii prices of steers and heifers are based on these quotations plus a markup for freight costs.

The specifications of equations 5 and 6 are not so obvious because foreign imports of cow and grass-fed steer and heifer beef distort the relationship. Most of the unprocessed lower quality beef imported into the State comes from Australia and New Zealand, while almost none comes from the mainland United States. Therefore, Hawaii range and cow beef production competes more directly with foreign imports than with mainland imports. In the absence of beef import quotas and mainland imports of processed low quality beef products, theory suggests that the cow price in Hawaii would be the price in Australia and New Zealand plus freight costs. The U.S. mainland also imports large quantities of Australian and New Zealand beef, and again in the absence of import quotas, theory suggests that the mainland cow price would be the Australian and New Zealand price plus freight costs. This logic implies that changes in the Australian and New Zealnd cow prices are reflected in both the mainland and Hawaii cow prices. If freight costs are the same to Hawaii or the mainland from Australia and New Zealand, the Hawaii cow price should equal the mainland cow price. Through this reasoning, the need to use foreign prices is eliminated because their influence is captured in the mainland price. Given equal freight costs, the equality of mainland and Hawaii cow prices also holds when beef import quotas are imposed. Because the beef import quota does not differentiate between U.S. ports, any price differential would soon be eliminated as Australian and New Zealand exporters seek to market their quota beef in the U.S. ports where the highest return can be realized.

In determining the Hawaii cow price and the range steer and heifer price, three additional points must be considered. First, even though little if any cow and grass-fed unprocessed beef is imported from the mainland, large unspecified quantities of lower quality processed beef are imported in the form of hamburger, and the like, by fast food and other enterprises. This also competes with locally-produced range and cow beef. Second, a significant portion of the lower quality processed beef from the mainland probably originates in Australia and New Zealand. Therefore, equations 5 and 6 include the freight cost variable. Third, lagged prices in equations 5 and 6 are included to reflect delays in price transmission caused by the great distances involved and by pricing practices of local packing plants which are less obvious than the pricing of grain-fed beef.

Equation 7 expresses the price of cattle feed in Hawaii as a function of the moving averages of the U.S. average corn price (USCPM) and the cost of freight (TRANCM). Moving averages were used to avoid multicollinearity problems. Equation 8 simply converts the Hawaii cattle feed price into an index with 1980 equal to 1.0. This index is used as a deflator for all prices in the remainder of the model. A preferred index would have been an index of prices paid by farmers for production inputs in Hawaii but such an index does not exist. Rather than use a U.S. average index, the Hawaii cattle feed price is used as the numeraire.

January 1 cattle inventories and the annual calf crop are estimated in Section II of Table 1 (equations 9-14). The influence of energy price changes on Hawaii beef inventories is captured by including the deflated U.S. crude petroleum wholesale price index (OILP) where appropriate. OILP is used to represent ranchers' expectations of changes in the cost of feedlot relative to range feeding. Because of market imperfections and imperfect knowledge, as mentioned earlier, it also reflects the desire of ranchers to avoid inter-island transportation costs. It is highly significant in explaining January 1 inventories of all heifers (HI, equation 10), and of heifers not held for herd replacement (HOI, equation 11). In equation 10, higher energy prices discourage the shipment of heifers to the feedlot, slowing animal growth to slaughter weight as more are kept on pasture. For a given level of heifer inventory, equation 11 suggests that higher energy prices encourage ranchers to hold more of their heifers in the breeding herd, at least in the short run, rather than transport them to the feedlot. The price of choice slaughter beef (WPFC) is included to represent expected returns. It has an influence on January 1 cattle inventories opposite that of OILP. The annual calf crop (equation 14) is determined by the number of cows on farms and by the inventory of heifers held for breeding herd replacement. The annual calf crop is then lagged and used to determine steer and heifer inventories.

Section III of Table 1 contains equations 15-20 which estimate quarterly beef slaughter in Hawaii. Equation 15 allows the sum of the January 1 inventory of steers and heifers not held for herd replacement (TSHOIQ) to have different effects in each quarter. Also, RSHOIQ and associated dummy variables are included to reflect higher carcass weights for steers relative to heifers. Price and cost variables capture profit expectations and the simultaneity in deciding whether to feed in the feedlot or on the range. The coefficient for DUM1 is positive, suggesting that animals were held to heavier weights during the 1973 price freeze. Conversely, the weather variable (w) has a negative coefficient, implying that the available animals were slaughtered at lighter weights during drought periods.

The shipment of cattle on open barges ended in July 1977 because of EPA regulations against washing cattle wastes into the ocean. Thereafter, cattle were shipped in cattle trailers which could be removed from ships and washed at appropriate land sites. DUM2 represents ranchers' anticipation of the higher cost of transporting live cattle and cleaning trailers. The coefficient is positive, suggesting that ranchers shipped their feeder animals at earlier ages as they attempted to get them to the feedlot before trailers became mandatory. DUM3 has a negative coefficient in equation 15 and a positive coefficient in equation 16, suggesting that the higher cost of transporting feeder animals encouraged ranchers to feed more of their steers and heifers on grass rather than pay the extra cost of shipping feeders in trailers to Oahu.

The remainder of equation 16, which determines range cattle slaughter, is fairly straightforward but the cow and bull slaughter equations require further discussion. It would seem that the coefficient for CIQ in equation 18 has an incorrect sign. The negative coefficient could be explained if culling rates changed substantially during different phases of the cattle cycle. For example, during the herd rebuilding phase, culling rates might decrease enough to offset the increase in cow numbers. The coefficient is not significant at the 5 percent level. The positive coefficient for W suggests that more cows are culled during droughts. Bull slaughter is estimated as a proportion of cow slaughter in a partial adjustment framework with quarterly intercept shifting dummy variables.

The final section of Table 1 needs little explanation. The identities contained therein simply convert quarterly prices to annual averages for use in the equations of Section II, or they convert annual inventories into a quarterly form for use in Section III of Table 1.

Model Validation and Simulation Results

The model is used to perform two simulations. The first (Simulation 1) demonstrates the model's forecasting ability and is used as the base with which the second is compared. Simulation 1 is a dynamic simulation with all right-hand-side endogenous variables, whether current or lagged, set equal to their predicted values. The simulation is performed from the first quarter of 1972 through the fourth quarter of 1980.

Table 3 presents two measures of the model's forecasting ability as derived from the base simulation. The first is the root-mean-square simulation error divided by the variable mean, and the second is a form of Theil's Inequality Coefficient (Leuthold). Given the results of Table 3, we conclude that movements in the Hawaii beef industry are represented adequately by the model.

To determine the impact of the energy price escalations of the 1970's on the model, a second simulation was performed. In Simulation 2, the U.S. crude petroleum wholesale price index (OILP) was assumed to increase at its pre-oil embargo rate of approximately 2% per quarter. This was the average quarterly rate for the first quarter of 1968 through the last quarter of 1973. Given this assumption, OILP averaged 30 percent and 35 percent below

Simulation 1 in 1974 and 1975 respectively, and averaged about 32 percent below Simulation 1 for the 1975-78 period. Finally, for 1979 and 1980 the differences were 41 and 57 percent respectively.

Table 3. Forecasting Accuracy of the Hawaii Beef Model, Simulation 1, 1972I-1980IV

Variable[a]	RMSSEM[b]	U_2^c	Variable	RMSSEM	U_2	Variable	RMSSEM	U_2
TRANB	.023	.942	FCS	.073	.552	CBI	.021	.646
TRANC	.034	.956	RCS	.096	.856	HI	.035	.547
WPFC	.015	.196	TFRCS	.065	.672	HOI	.063	.641
WPRC	.034	.571	CS	.072	.591	HBI	.039	.535
WPC	.038	.537	BS	.148	.884	SI	.058	.604
PCF	.036	.629	TBEEFS	.052	.697	CC	.041	.721

[a]Variables are defined in Table 2.

[b]Root-mean-square simulation error divided by the mean of the variable.

[c]Theil-U_2 Coefficient.

Table 4 presents percentage deviations for Simulation 2 from Simulation 1 for selected variables. With energy prices increasing at pre-oil embargo rates, prices of feedlot (WPFC), range (WPRC) and cow (WPC) beef decline from base levels. The Hawaii cattle feed price (PCF) also decline from base levels but by more than beef prices. Substantial alternations in the composition of slaughter occur as relative prices change and as expected energy-related grain feeding costs decline from Simulation 1 levels. In general, the differences between the two simulations increase the fastest in 1974-75 and again in 1979-80. These years are of interest because sharper changes from the base simulation result from the initial rapid energy price escalation in 1974 and again in 1979. Between 1975 and 1978, crude petroleum prices increased much less rapidly than immediately before or after.

Table 4. Percentage Deviations for Simulation 2 from Simulation 1 for Selected Variables, 1974-80 Annual Averages

Year	WPFC[a]	WPRC	WPC	PCF	FCS	RCS	TFRCS	CS	BS	TBEEFS
1974	-0.9[b]	-1.2	-1.3	-1.4	0.4	- 4.1	-0.3	-0.0	-0.0	-0.3
1975	-1.0	-1.4	-2.1	-2.2	7.2	-18.0	1.9	-1.1	-0.5	1.2
1976	-1.1	-1.5	-1.7	-2.4	8.9	-28.0	1.7	-2.1	-0.9	0.9
1977	-1.2	-1.6	-1.9	-2.6	10.6	-30.1	1.8	-3.0	-1.5	0.8
1978	-1.1	-1.5	-1.7	-2.8	15.2	-35.3	3.8	-3.6	-1.8	2.2
1979	-1.4	-1.9	-2.0	-3.5	18.3	-35.5	4.6	-4.8	-2.3	2.6
1980	-2.6	-3.6	-3.9	-6.9	37.6	-45.8	11.0	-6.5	-3.1	7.1

[a]Variables are defined in Table 2.

[b]Negative signs indicate a decrease from Simulation 1.

Total steer and heifer slaughter (TFRCS) increases above Simulation 1 levels by 1.9 percent in 1975 and 11.0 percent in 1980. Increases in TFRCS result as the actual and/or expected profitability of grain feeding increases, causing feedlot steer and heifer slaughter (FCS) to increase. The absolute increase in feedlot slaughter outweighs the absolute decrease in range slaughter (RCS), causing TFRCS to increase above base levels. In simulation 2, range steer and heifer slaughter constitutes an average of 15 percent of total steer and heifer slaughter. Thus, Simulation 2 shows that the historical trend toward a larger portion of range steer and heifer slaughter after 1974 would not have occurred had energy prices increased at pre-1974 rates. In 1980, under Simulation 2 assumptions, only 16 percent of total steer and heifer slaughter would have been grass-fed, while historically 32 percent was grass-fed. Cow (CS) and bull (BS) slaughter decline as breeding herds are enlarged relative to Simulation 1 level. Still, total Hawaii beef production is higher with lower than historical energy prices because the increase in FCS greatly overshadows the combined reductions in RCS, CS and BS.

Conclusions

Several conclusions can be drawn from the results. First, the energy price increases during the 1970's curtailed grain-fed beef production by as much as 38 percent in 1980, and the historical trend toward a larger portion of grass-fed beef production would not have occurred. This can be attributed to higher cattle feed prices relative to choice beef prices, as the cost of transporting feed increased in relation to the cost of transporting beef from the mainland. With these changes, the abundant grasslands of Hawaii provided an economically more attractive source of feed than did imported grains relative to the return.

A possibly more important reason for the shift away from feedlot feeding was the expectation of cost increases caused by rapidly increasing energy prices. Higher costs of transporting feeders to Oahu and expectation of higher feed and other imported input costs encouraged ranchers to send fewer animals to the feedlot. More grass-fed beef was produced even though higher energy prices probably also reduced returns for grass-fed animals.

Second, it may be concluded that higher energy prices curtailed total Hawaii beef production by about 7 percent in 1980 even though cow, bull, and range steer and heifer slaughter rose. This happened because inventories of cows, steers and heifers all fell, as did the annual calf crop. With reduced herd size, steers and heifers available for slaughter declined. Grain-fed beef production received most of the impact because fewer animals were being produced for feedlot feeding, and of those available, more were being left on the range. Because grass-fed cattle are usually slaughtered at lighter weights and require more time to reach slaughter weight, total steer and heifer slaughter declined. The increase in cow and bull slaughter caused by more rapid herd liquidation was small relative to reduced feedlot slaughter; and, therefore, total Hawaii beef production declined.

Third, because reliable data on mainland imports do not exist, it is difficult to assess whether Hawaii-produced beef could have maintained its share of the local market under a pre-oil embargo energy price scenario. It is clear from the analysis that Hawaii beef production would have higher between 1974 and 1980 had energy prices increased at pre-1974 rates rather than at historical 1974-80 rates. However, it is difficult to say whether mainland imports would have been lower or higher. Lower freight costs would encourage an increase in mainland imports. Alternatively, the shift to more feedlot production would tend to reduce the demand for mainland imports of grain-fed beef. Also, foreign imports would increase because of lower transportation costs and less competition from locally produced grass-fed beef. In the absence of rapidly increasing energy prices, it is also unlikely that producers could have maintained their market share at pre-1974 levels because of physical constraints on beef production resources in Hawaii. The limited capacity of the local beef industry probably would not have kept pace with rapidly increasing demand generated by increases in resident population and tourist traffic. Finally, some of the loss in Hawaii's competitive position with mainland imports was probably caused by higher grain prices irrespective of freight costs.

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