Agricultural Economics Report No. 232 January 1988

Econometric Analysis of Livestock Products Demand in Korea and Its Implications in the Korean Feed Grain Industry

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Preface

The authors are indebted to many people who have helped in the presentation of this report. We are especially grateful to Ms. Darla Christensen for typing the manuscript. Dr. David Cobia, Dr. Gordon Erlandson, Dr. Thor Hertsgaard, Mr. Tim Petry, Dr. Roger Johnson, and Mr. Yong-Woo Kwon were very helpful in reviewing the manuscript and making helpful suggestions. The authors are grateful to these and the entire Department of Agricultural Economics for their cooperation.

The study was made possible through the funding of the North Dakota Agricultural Experiment Station.

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Highlights

The main objective of this study was to examine the demand structure for livestock products and feed grains in Korea. Single equation demand models for each livestock product were estimated using a general functional form on the basis of the Box-Cox transformation. Elasticities obtained from the estimated demand models showed that income was the dominant factor affecting the livestock demands, especially for beef and pork.

Demands for livestock products and feed grains were projected for 1996 on the basis of the estimated livestock demand models. Total meat demand was projected to increase 87 percent during the period 1985-1996. Demand for total concentrate feed in 1996 was projected to be 12 million metric tons, which is 88 percent greater than that in 1985. Projected demand for concentrate feed would require 7.6 million tons of feed grains and 1.6 million tons of soybeans in 1996 under an assumption that the Korean government will maintain its traditional policy of encouraging domestic beef production. Although the traditional policy is very expensive, not only for the Korean government but also for Korean consumers, the Korean government could likely maintain the traditional policy because about one million farmers are involved in beef production and it is an important income source for small farmers.

If Korea liberalizes beef imports in the near future, most domestic production would be replaced with imports, resulting in a substantial reduction in farm income in Korea. Most beef imports will come from Australia and New Zealand rather than from the United States because these countries have a comparative advantage over the United States in exporting beef to Korea in terms of both production and transportation costs. In addition, liberalization of beef imports in Korea will result in a substantial reduction in feed grain imports from the United States since less beef production would occur in Korea while more beef is imported. This implies that a Korean beef liberalization policy would lead to a reduction in feed grain imports from the United States and a barely perceptible increase in United States exports of beef to Korea.

ECONOMETRIC ANALYSIS OF LIVESTOCK PRODUCTS DEMAND IN KOREA AND ITS IMPLICATIONS IN THE KOREAN FEED GRAIN INDUSTRY

Won W. Koo and Chang J. Park[1]

Consumption of livestock products grew sharply during the period 1965-1985 in Korea. Per capita consumption of meat, including beef, pork, and chicken, increased more than fourfold from 4 kg to 19 kg during the same time period (Korean Ministry of Agriculture and Fisheries). With the rapid growth in livestock demand, livestock production soared: meat production increased from 89 thousand tons in 1965 to 593 thousand tons in 1985.

The expansion of livestock production resulted in a sharp increase in demand for feed grain. In the early 1960s when livestock was raised as a sideline to food grain production, most animal feed was supplied by farm by-products. As livestock production became an independent activity, producers increasingly used grain-based feeds. Grain used for feed was only 225 thousand tons in 1965, but rose to 635 thousand tons in 1975 and to 4,707 thousand tons in 1985 (Korean Ministry of Agriculture and Fisheries). Since domestic grain production was not even sufficient for food use, increase in demand for feed grains could be met only by a rapid increase in imports of feed grains. During the 1975-1985 period, imports of feed grains increased from 0.4 million tons to 4.8 million tons, while those for food grain increased from 2.6 million tons to 2.8 million tons. Consumption of livestock products and feed grains likely will continue to increase as a result of expected increases in per capita income in Korea in the near future.

This implies that the growing demand for livestock products has crucial impacts, not only on the agricultural economy in Korea, but also on nonagricultural sectors of the economy. The projected demand for livestock products and feed grains and information about the factors affecting the demand will be useful to public decision makers in evaluating current policies and in developing policies for the future. The information is also beneficial to livestock-related businesses, such as feed manufacturers and livestock producers.

The objective of this study is to analyze the demand structure for livestock in Korea. The study specifically focuses on the following issues.

1. To identify the major factors influencing the demand for livestock products including beef, pork, chicken, eggs, and milk,

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2. To make projections of the demand for livestock products and for feed grains.

3. To analyze the impact of changes in the demand for livestock products on the Korean feed grain industry.

Special attention is given to the effects of increases in per capita income on demand for livestock products in Korea.

Many studies on meat demand have been completed with different functional forms: a linear formulation (Fuller and Ladd; Hayenga and Hacklander; and Tryfos and Tryphonopoulo), a log-linear formulation (Hassan and Katz; Chavas; Taizo; Wohlgenant and Hahn), and general functional formulation (Chang; Kalshreshtha; Moschini and Meilke; and Pope and Green). Special attention has been given to specification of the demand model to determine if there have been structural changes in the demand model (Moschini and Meilke; Chavas). Moschini and Meilke used a general functional form to analyze structural changes in the demand model while Chavas employed a constant elasticity model (a log-linear model) in his study.

A limited number of studies have been conducted to analyze demand for livestock products in Korea (Kim; Chu et al.), partly because livestock was not important in the Korean diet until the mid 1970s. Both studies used a log-linear functional formulation in estimating a static demand function for livestock products in Korea. The study by Kim used time series data from 1961 to 1976, while the other study by Chu et al. used data from 1965 to 1985.

In contrast to demand studies for livestock, a few studies have been devoted to feed demand. Demand for grain as feed is generally postulated as a function of feed price, livestock price, and some measure of livestock production (Foote; Richardson and Ray). On the other hand, Taizo projected Japanese feed demand for 1975 by multiplying the projected number of livestock by the standard feed ration for various types of livestock. A projection of feed grain demand in Korea was made by using a similar method to that in the Taizo study (Chu and Yoo). In the study by Chu and Yoo, feed grain requirements were estimated by multiplying the projected livestock demand by the corresponding feed conversion rate.

LIVESTOCK-FEED SITUATION IN KOREA

Characteristics of Livestock Demand

Livestock products were uncommon foods for Korean people until the middle of this century. Up to that time, Korean dietary patterns had been heavily dependent on cereals, especially rice. As is common in almost all Asian countries, vegetable foods comprise the overwhelming majority of food items. Animal food items have been limited mainly to fish.

The Korean dietary pattern was rapidly changed as a result of the economic recovery from the disastrous Korean War in the 1950s. This period was characterized by consumers' pursuing food quantity rather than quality - both the consumption of cereals and the consumption of livestock products increased throughout the 1960s.

In the 1970s and years following, the increase in the consumption of livestock products accelerated even more (Table 1). Cereal consumption reached a saturation point in the early 1970s and began to decline gradually. Food demand patterns moved toward favoring higher quality food stuffs as more income for food became available. High value foods, including meats, fruits, and vegetables, increasingly substituted for cereal food stuffs. Among the cereals, consumption of inferior items such as barley decreased sharply.

TABLE 1. ANNUAL PER CAPITA CONSUMPTION OF FOOD, KOREA, SELECTED YEARS

Food items	1965	1970	1975	1980	1985
			kilograms		
Cereals	181.5	208.2	200.2	188.8	178.6
Rice	121.8	136.4	123.6	132.4	128.1
Barley	36.8	37.3	36.3	13.8	4.6
Others	12.8	13.9	17.5	23.9	23.0
Livestock Products					
Meat	3.4	5.3	6.4	11.3	14.4
Egg	1.7	4.2	4.5	6.5	7.2
Milk	0.4	1.6	4.6	10.8	23.3
Vegetables	45.5	59.9	62.5	120.6	121.3
Fruits	7.5	10.0	14.0	16.2	23.7

SOURCE: Ministry of Agriculture and Fisheries, Agricultural Policy Handbook. Seoul, Korea. 1985.

Annual per capita consumption of livestock products increased three to sixfold in the last 20-year period, and milk consumption increased fivefold during the last 10 years (Table 1). As a result, the contribution of livestock products to total calorie and protein intake became significant. The portion of daily calorie consumption coming from livestock products increased from 1.5 percent in 1965 to 7.5 percent in 1985, and the portion of protein increased from 3.5 percent to 14.9 percent during the same period (Table 2).

TABLE 2. CONTRIBUTION OF LIVESTOCK PRODUCTS TO TOTAL NUTRITION, KOREA, SELECTED YEARS

Item	1965	1970	1975	1980	1985
Calorie consumption per capita per day (kcal)	2,189	2,370	2,390	2,485	2,610
Percentage of calories by source					
Cereals	85.7	83.3	79.4	70.4	69.5
Livestock products	1.5	2.8	3.1	5.7	7.5
Other foods	12.8	13.9	17.5	23.9	23.0
Protein consumption per capita per day (gram)	57.7	65.1	71.1	73.6	80.5
Percentage of protein by source					
Cereals	74.6	74.3	69.4	62.3	59.1
Livestock products	3.5	6.2	6.9	12.9	14.9
Other foods	21.9	19.5	23.7	24.8	26.0

SOURCE: Ministry of Agriculture and Fisheries (Korea), Food Balance Sheets. Seoul, Korea. 1985.

Despite the substantial increase in meat consumption in the last two decades, per capita livestock consumption in Korea is far less than that in Western countries and neighboring Asian countries. Per capita meat consumption in 1985 was 19 kg compared to 31 kg in Japan, 49 kg in Taiwan, and 111 kg in the United States (Table 3).

Even though the overall consumption level of livestock products has increased along with the increase in income level, there are great differences in consumption levels among different income groups. Monthly expenditures for food by different income groups in urban areas are presented in Table 4. There is no significant difference in expenditures for cereal food stuffs among the income groups. The small differences in the expenditure for cereal reflect only the fact that higher income groups consume higher-quality cereals. The situation is quite different in expenditures for livestock products. The middle income group's expenditure for livestock products is twice that of the lowest group and 73 percent less than the highest income group. Differences between the two extremes are even more striking. This comparison is based on expenditures for livestock products as a whole, and thus it may not reflect the exact per capita consumption, but great differences in livestock product consumption seem to

TABLE 3. ANNUAL PER CAPITA CONSUMPTION OF LIVESTOCK PRODUCTS, SELECTED COUNTRIES

Country	Meat				Eggs
	Beef	Pork	Chicken[1]	Total	
	kilogram				
Korea (1985)	4.1	10.5	4.4	19.0	7.2
Japan (1984)	6.1	14.2	10.7	31.0	13.3
Taiwan (1984)	1.5	34.0	13.1	48.6	NA
U.S.A. (1985)	49.4	29.9	31.8[1]	111.1	14.0

[1]Includes turkey (5.5 kilogram)

SOURCE: Ministry of Agriculture and Fisheries (Korea), Feed Handbook. Seoul, Korea. Various issues. USDA, Livestock and Poultry Situation and Outlook Report, LP-20, May 1986.

TABLE 4. PER CAPITA EXPENDITURE FOR FOOD, KOREA, 1983

Income Group	Expenditures for			
	Cereal Food	Livestock Products	Other Food	Total Food
	1,000 won			
A (lowest)	6.6	2.8	5.7	15.1
B	7.3	4.3	8.2	19.8
C	7.5	5.5	9.9	22.9
D (middle)	7.7	6.5	11.2	25.4
E	8.0	8.1	13.3	29.4
F	8.8	9.8	15.2	33.8
G (highest)	8.0	11.3	17.0	36.3

SOURCE: Chu et al. A Study on Supply and Demand for Food in Korea, Research Report No. 102, Korean Rural Economic Institute, Seoul, Korea, December 1985.

be evident among income groups. This implies that many people with low income consume livestock products far below the average level and that demand will expand significantly when income rises.

Prices have played an important role in the overall increase in livestock product consumption as well as in the composition of livestock items consumed. Real prices of chicken, eggs and milk have declined over the last 20 years, and pork prices have been nearly constant for the last 10 years. Only beef prices have risen considerably throughout the years (Table 5). Since beef became expensive relative to pork and chicken, consumption of pork and chicken increased much faster than that of beef (Table 6).

TABLE 5. ANNUAL PERCENTAGE CHANGE IN REAL PRICE OF LIVESTOCK PRODUCTS, KOREA

Livestock Product	1965-70	1971-75	1975-80	1981-85	1965-85
			percent		
Beef	10.0	1.1	7.9	4.6	5.9
Pork	3.6	3.8	-1.2	0.1	1.5
Chicken	-1.1	-0.6	-0.3	-3.0	-1.4
Eggs	-3.6	-1.7	-6.1	1.7	-2.7
Milk	1.4	-2.4	1.6	-3.7	-0.7

SOURCE: National Livestock Cooperatives Federation (Korea), Statistics on Price Demand and Supply of Livestock Products, Seoul, Korea, various issues.

TABLE 6. ANNUAL PERCENTAGE CHANGE IN PER CAPITA CONSUMPTION OF LIVESTOCK PRODUCTS, KOREA

Livestock Product	1965-70	1971-75	1976-80	1981-84	1965-84
			percent		
Beef	4.1	11.4	5.6	0.1	5.5
Pork	5.6	1.8	17.8	7.2	8.0
Chicken	22.8	2.4	8.7	5.1	9.5
Eggs	20.6	1.5	7.7	0.5	7.7
Milk	33.3	23.4	19.7	17.4	22.3

SOURCE: National Livestock Cooperatives Federation (Korea), Statistics on Price Demand and Supply of Livestock Products, Seoul, Korea, various issues.

Consequently, pork and chicken have become increasingly important relative to beef in the Korean diet (Table 7).

Consumption of milk has grown more rapidly than any other livestock product. Milk was newly introduced to the commercial market in the 1960s and was unfamiliar to most Korean consumers until recently.

TABLE 7. COMPOSITION OF LIVESTOCK CONSUMPTION, KOREA, SELECTED YEARS

Livestock	1965	1970	1975	1980	1985
			percent		
Beef	28	23	31	23	20
Pork	57	50	44	56	58
Chicken	15	27	25	21	22
Meat Total	100	100	100	100	100

SOURCE: National Livestock Cooperatives Federation (Korea), Statistics on Price Demand and Supply of Livestock Products, Seoul, Korea, various issues.

Most milk is consumed in the form of fluid milk rather than processed into other dairy products, such as butter or cheese. Though the processed dairy products are still unfamiliar to Korean consumers, a rapid growth in milk consumption seems likely because there are many potential milk consumers who are not accustomed to milk.

Characteristics of Livestock Production

Livestock production in Korea has expanded in response to growing consumer demand for meat, eggs, and milk. At the same time the structure of livestock production has changed greatly over the last two decades.

In the early days, most livestock breeding was conducted for farm drafting power or merely as a subordinate occupation along with food grain cultivation. Because the livestock industry was an adjunct to the main enterprise of agriculture, the number of animals remained rather constant regardless of livestock price.

Korean native cattle were one of the most valuable assets for farmers until farm machinery was introduced in the 1970s. The cattle were rarely sold or slaughtered unless they were useless for farming. As the use of farm machinery spread widely during the late 1970s, the role of cattle as work animals declined. Since demand for beef increased sharply in the mid 1970s, the transitory surplus in working cattle assured an adequate supply of feeder stock for fattening and eventual slaughter. The role of native cattle was transformed within a short period of time.

At the same time government policies encouraged farmers to raise more cattle as a way to alleviate the depressed farm income. The number of cattle raised mainly for beef production increased from 1.60 million head in 1980 to 2.32 million in 1985 (Table 8). Even though average herd size per

TABLE 8. NUMBER OF LIVESTOCK, KOREA, SELECTED YEARS

Year	Beef Cattle		Dairy Cattle		Hogs		Chicken	
	Animals	Farms	Animals	Farms	Animals	Farms	Birds	Farms
	-000-							
1965	1,352	1,183	5	1	1,256	1,006	10,282	1,329
1970	1,206	1,025	18	2	1,338	990	22,651	1,199
1975	1,785	1,359	73	7	1,818	890	18,814	1,002
1976	1,556	1,277	86	9	1,247	654	20,939	1,094
1977	1,463	1,196	90	10	1,953	910	26,325	1,237
1978	1,508	1,173	109	14	1,482	689	30,224	1,179
1979	1,651	1,176	136	16	1,719	658	40,753	1,172
1980	1,599	1,092	163	17	2,843	758	41,120	923
1981	1,427	997	207	22	1,784	503	40,130	692
1982	1,312	858	194	18	1,832	425	42,999	628
1983	1,526	896	228	23	2,183	444	46,592	618
1984	1,940	971	275	30	3,649	539	49,239	538
1985	2,318	1,037	334	38	2,958	362	46,483	367

SOURCE: National Livestock Cooperatives Federation (Korea), Statistics on Price Demand and Supply of Livestock Products, Seoul, Korea, various issues.

Note: Animal numbers are based on January inventories.

farm has increased from 1.1 animals during 1970-75 to 2.2 during 1983-85, most of the beef cattle are still raised as a sideline to other agricultural activities. Beef farmers, recently over one million, depend mostly on self-produced farm by-products and roughage gathered from limited grassland for feed supply. For these farmers the capacity for raising beef cattle is restricted to one to two animals per farm mainly due to limited feed supply. Further increase in herd size requires the purchase of concentrate feed, which is commercially manufactured and traded. Expansion of herd size in a small range may be possible either by increasing the use of concentrate feed or by increasing the production of forage crops, but greater specialization with larger herd size is not expected due to the shortage of pasture land and forage supplies.

Dairy production is relatively new in Korea. Farmers began to raise dairy cattle in the early 1960s, but their product, milk, was so new that it took a long time to attract consumers. The number of dairy cattle did not exceed 100 thousand until 1977. Once the new product captured consumers' attention, demand for milk grew faster than that of any other item, and dairy numbers expanded accordingly. The number of dairy cattle increased from 73 thousand in 1975 to 334 thousand in 1985. The relatively high level of beef prices has partly played a role in boosting the dairy sector, because dairy farmers receive secondary income from sales of culled milk cows and dairy bull calves for fattening. The portion of beef coming from dairy cattle is not significant yet, but the subordinate income is important for individual dairy farmers. Thus, future demand for beef and beef prices seem to affect the development of the dairy sector.

Dairy cattle have been raised by a relatively small number of ranchers and farmers in suburban areas who had skills in raising and milking cows. A few milk processing firms, located near dairy farms, collected the milk produced from the dairy farms and marketed the final product. Production has been specialized from the outset partly due to the skills required for milk production and partly due to the limited marketing channels. The main restriction for larger operations is the same restriction beef production faces -- the limited pasture and forage supply. Average herd size has remained nearly constant at 10 animals, although the number of dairy farms has expanded.

Hogs, like other livestock, were raised as a subordinate enterprise up to the early 1970s. The number of hogs raised per farm usually was determined by the availability of self-produced feed stuffs, such as brans and food garbage. One to two animals per farm was the most common case in the early days, and raising the hog was basically a housewife's job.

This traditional pattern of hog production changed rapidly throughout the 1970s and the years that followed. The number of highly specialized hog farms has increased while traditional hog farms gradually disappeared. About one million farms raised 1.3 million hogs in the 1960s, but recently only 362 thousand farms raised 3 million hogs. This rapid transformation was possible because hog production, unlike cattle production, does not require large space or roughage feed. The fewer but more efficient hog farmers have reduced fattening periods and increased slaughter weight by using high quality feed. As a result, pork production increased five fold during the 1965-1985 period.

The development of the egg and chicken sector was very similar to that of the pork sector. Egg producers began to specialize production in the early 1960s. Most of them were new entrants who began business in small farming towns. Because they did not have any other income source, other than chicken raising, their efforts for increased efficiency were more aggressive than those of multi-enterprise farmers. Up to the end of the 1970s egg production was spread over one million farms, but almost all the eggs marketed were supplied by a small number of specialized farms.

Chicken meat in the 1960s was derived from culled layers and fattened pullets. Chickens raised only for meat production were not common at that time, and broilers began to be raised in the early 1970s. Since broiler production required higher feeding technology and an efficient marketing strategy, production was specialized from the beginning. Broiler production requires less space with a cage system and a shorter time period for capital turnover. Thus, increasing the scale of operation is relatively easy. As a result, the number of broilers increased from 8.6 million in 1976 to 16 million in 1985. With the increased inventory, most chicken meat is supplied by broilers.

As noted above, livestock production in Korea has grown rapidly within a relatively short period of time. At the same time, livestock production has become increasingly specialized, especially in the production of poultry and hogs (Table 9). The number of fowl, together with layers and broilers, was 51 million at the end of 1985, and the number of chicken farms was 303 thousand. The simple average flock size per farm, 168 birds, is rather moderate, but 77.4 percent of all chickens (39.6 million) are raised by 0.9 percent (2.8 thousand farms) of chicken farms. Average flock size for the specialized chicken farms is 14,129. The remaining 11.5 million chickens are raised by 300 thousand farms having an average of 38 per farm.

TABLE 9. SPECIALIZATION IN LIVESTOCK PRODUCTION, KOREA, 1986

Item	Beef Cattle	Dairy Cattle	Hogs	Chickens
Number of farms (in thousands)				
Total farms	1,048	43.7	251.2	302.8
Specialized farms	5	12.8	4.8	2.8
Nonspecialized farms	1,043	30.9	246.4	300.0
Percentage of specialized farms	0.5	29.2	1.9	0.9
Number of animals (in thousand)				
Total number of animals	2,553	390	2,853	51,081
Raised by specialized farms	213	254	1,709	39,562
Raised by nonspecialized farms	2,340	136	1,114	11,519
Number of Animals per farm (head)				
Average	2.4	8.9	11.4	168
Specialized farm	42.6	19.8	356.0	14,129
Nonspecialized farm	2.2	4.4	4.5	38

SOURCE: National Livestock Cooperatives Federation (Korea), *Statistics on Price Demand and Supply of Livestock Products*, Seoul, Korea, various issues.

In the production of hogs, 1.9 percent of the hog farms hold 60 percent of total hog inventories with an average of 356 animals per farm. The remaining 40 percent of the hog inventory is raised by 246 thousand farms with an average of 4.5 animals per farm. For these small-size hog farms, hog raising is still a side job adjunct to other agricultural activities.

In the case of dairy production, concentration is rather moderate. This is because large operations in dairy cattle are restricted due to limited pasture land. However, less than one-third of the dairy farms raise two-thirds of the total dairy cattle.

Unlike other livestock, beef cattle production is still dispersed among numerous nonspecialized farms. The number of beef cattle is currently 2.5 million, which are raised by more than one million farms. Actually, there has been no change in production patterns. Since many farms are engaged in beef production, the beef sector has attracted more political concern than other livestock sectors, and great efforts have been placed on stabilizing the producer's price.

As livestock production expands over time, its contribution has been increasingly important to total agricultural production and farm income. Livestock production expressed in market value accounted for 11.3 percent of total agricultural production in 1965; this increased to 27.6 percent in 1985 (Table 10). On the other hand, gross agricultural income from livestock production was only 2.6 percent in 1965 (Table 11). Currently, the portion of farm income derived from livestock amounts to 19.4 percent. Though livestock production is concentrated in fewer farms, livestock production has emerged as an important source of farm income.

TABLE 10. THE CONTRIBUTION OF LIVESTOCK TO TOTAL AGRICULTURAL PRODUCTION, KOREA, SELECTED YEARS

Item	1965	1970	1975	1980	1985
	- - - - - billion won - - - - -				
Total agricultural production	380	808	2,651	6,415	11,463
Livestock production	43	118	303	1,227	3,166
Percentage of livestock production (%)	11.3	14.6	11.4	19.1	27.6

SOURCE: Chu et al. A Study on Supply and Demand for Food in Korea, Research Report No. 102, Korean Rural Economic Institute, Seoul, Korea, December 1985.

Feed Situation

Feed encompasses a wide range of animal foods from grasses to grains, protein meals and food by-products. What is considered to be feed opposed to human food or wastes changes over time with changes in economic conditions. Thus, it is confusing to assess a country's feed supply capacity at any given time. But this problem may be less conspicuous in Korea because Korea's grain production has been short of human needs, and thus most of its feed is imported.

TABLE 11. FARM INCOME FROM LIVESTOCK PRODUCTION, KOREA, SELECTED YEARS

Source of Income	1965	1970	1975	1980	1985
	- - - - - -	-	billion won	-	- - - - - -
Income from agriculture	116	248	891	2,342	5,277
Income from livestock	3	8	66	284	1,023
Portion of income from livestock (%)	2.6	3.2	7.4	12.1	19.4

SOURCE: Chu et al. A Study on Supply and Demand for Food in Korea, Research Report No. 102, Korean Rural Economic Institute, Seoul, Korea, December 1985.

In the 1960s, when most livestock was raised as a sideline along with the main enterprise of food grain production, animal feeds were farm by-products comprised of waste stems, rice and barley bran, food garbage, and roughage gathered from nearby grassland. The quantity of grains used for feed was negligible since grains were fed only occasionally when animal nutrition was critical (for example, during the breeding season).

The traditional feed supply, basically farm by-products, was too restrictive to support the expanding animal population. Most high-priced land has been cultivated for high income crops, such as rice and vegetables, and no land was available for low income feed crops. As a result, feed supply has been increasingly dependent on imported feed materials, and livestock production has increasingly depended on concentrate feed.

A dramatic change in the feed demand structure is observed in the consumption of concentrate feed, which is manufactured by using imported grains and protein meals. As specialization in livestock production proceeded, farmers demanded more high quality feeds, which provided more efficient feed conversion and less labor requirement.

Concentrate feed, which accounted for less than 10 percent of the total feed supply in the 1960s, now provides about 60 percent of animal nutrients in terms of total digestible nutrients (TDN).

The changing trend of concentrate feed consumption per animal since 1967 is shown in Table 12. Concentrate feed per animal for dairy cattle and chickens increased up to the middle of the 1970s and has been stable thereafter. This reflects the fact that specialization in the production of dairy cattle and chickens was already made in the middle of the 1970s and thus their rate concentrate feed consumption has nearly stabilized. Meanwhile, increases in concentrate feed consumption for hog and beef cattle were moderate until the 1970s, and have grown rapidly up to now. Current survey results show that poultry and hogs depend entirely on feed concentrates while beef cattle and dairy cattle depend on forage and other

TABLE 12. AVERAGE ANNUAL CONCENTRATE FEED CONSUMPTION PER ANIMAL, KOREA, 1967 TO 1985

Industry	1967-70	1971-75	1976-80	1981-85	1985
	- - - - -	- - - - -	kilograms	- - - - -	- - - - -
Beef cattle	NA	68	121	496	522
Dairy cattle	876	2,051	2,934	2,923	2,973
Hogs	14	72	259	632	650
Chickens	13	27	48	46	49

Note: January inventory numbers and annual concentrate feed amounts are used for calculating the per animal consumption.

SOURCE: National Livestock Cooperatives Federation (Korea), *Statistics on Price Demand and Supply of Livestock Products*, Seoul, Korea, various issues.

simple feed for a considerable part of their nutritional requirements (Table 13). Concentrate feed consumption per animal for hogs and chickens is not likely to increase anymore, but that for beef cattle will fluctuate depending on the forage supply.

TABLE 13. SOURCE OF ANIMAL NUTRITION, KOREA, 1984-85 AVERAGE

Industry	Concentrate feed	Simple feed[1]	Forage	Total
	- - - - -	percent	- - - - -	- - - - -
Beef cattle	26.3	11.5	62.2	100
Dairy cattle	53.3	3.1	43.6	100
Hogs	98.0	2.0	-	100
Chickens	99.8	0.2	-	100

[1]Simple feed include brans, vegetable meals not mixed with high value feed materials.

SOURCE: Ministry of Agriculture and Fisheries, *Livestock Handbook*. Seoul, Korea. 1985.

The increased feed conversion rates together with expanding animal populations accelerated the demand for concentrate feed. Total concentrate consumption in 1965 was 47 thousand tons. This increased to 901 thousand tons in 1975 and to 6,451 thousand tons in 1985 (Table 14).

TABLE 14. PRODUCTION OF CONCENTRATE FEED FOR VARIOUS LIVESTOCK INDUSTRIES, KOREA, SELECTED YEARS

Year	Beef Cattle	Dairy Cattle	Hogs	Poultry	Total
	------------- 1,000 tons -------------				
1965	-	-	-	-	47
1970	0	19	10	460	508
1975	33	151	136	569	901
1980	306	514	769	1,872	3,462
1981	415	471	761	1,842	3,490
1982	673	592	1,151	1,980	4,420
1983	871	710	2,013	2,246	5,852
1984	1,072	853	1,987	2,065	5,985
1985	1,209	994	1,924	2,310	6,451

SOURCE: National Livestock Cooperatives Federation (Korea), Statistics on Price Demand and Supply of Livestock Products, Seoul, Korea, various issues.

The poultry sector was the leader in concentrate feeding in Korea and still remains the largest user of feeds, although its lead has been narrowed by faster growth in pork production. Recently, concentrate use for beef cattle production has increased even faster, from 415 thousand tons in 1981 to 1209 thousand tons in 1985, and shows great potential for further increases. Since production of concentrate feed depends on its raw material, mainly imported feed grains, imports of feed grains have grown along with an increase in concentrate feed demand. Total grain imports (including soybean) for feed production rose from 62 thousand tons in 1965 to 414 thousand tons in 1975 and to 4,781 thousand tons in 1985 (Table 15).

Korea frequently purchased modest amounts of sorghum and feed wheat. Most of the imported feed grains consisted of corn, and most were imported from the United States, Barley imports for feed were not allowed in consideration of domestic barley producers' complaints.

The Korean government has stimulated forage production to alleviate ever-increasing feed imports. These include adding pastureland by reclamation and increasing forage crops planted on paddy land following the rice harvest. Because forage is consumed primarily by ruminants, feed grain imports for beef and dairy cattle could be reduced if forage production increases. However, there are a variety of technical and economic problems in expanding forage production. Most of the land proposed for pasture development is steeply sloped, and water supply would be extremely difficult. Relatively flat land is very high priced and is segmented by numerous small owners who are not usually farmers. Even if this land is converted into pastureland, productivity is questionable.

TABLE 15. IMPORTS OF FEED GRAINS, KOREA, SELECTED YEARS

Year	Grains					Soybean	Total
	Corn	Sorghum	Wheat	Others	Total		
1965	62	-	-	-	62	-	62
1970	284	-	-	-	284	15	299
1975	373	-	-	-	373	41	314
1980	1,881	-	-	-	1,881	374	2,255
1981	1,848	95	-	18	2,061	344	2,405
1982	2,430	403	-	20	2,853	474	3,327
1983	3,556	178	69	200	4,003	636	4,539
1984	2,377	338	844	403	3,770	603	4,373
1985	2,471	324	1,039	150	3,984	734	4,781

SOURCE: Ministry of Agriculture and Fisheries, Livestock Handbook. Seoul, Korea. 1985.

Forage production based on double cropping may be easier technically than the development of new pastureland. Because of subsidies, forage crop production has increased moderately in recent years, but forage production seems economically irrelevant for farmers if it is not subsidized by the government. Barley production decreased sharply within a short period of time (Table 3) as the price subsidy was eliminated. For forage crops to be planted on the same land from which barley disappeared, government subsidies should perhaps be more than those given to barley production in the 1970s.

Another important factor that hinders domestic forage production is cheap concentrate feed. Feed grain imports require a government license but it is not designed for import restriction. Feed grains have been imported without limitation with lower tariffs, which are currently 7 percent. The government sometimes exempts tariffs to stabilize feed prices. As long as feed prices remain at current levels, forage production is unlikely to expand.

DEVELOPMENT OF MODELS

Demand models for livestock items are developed on the basis of the theory of consumer behavior with consideration of seasonality, dynamics, and functional form. Then demand models for feed grain are specified on the basis of the estimated demand for livestock items.

Specification of the Conceptual Demand Model for Livestock

Individual consumers' demand for final products can be derived by maximizing the individual's utility function subject to his budget constraints as follows:

$$\max U_i = f_i(x_1, x_2, \ldots x_n) \qquad (1)$$

$$\text{subject to} \quad \sum_{j=1}^{n} P_j X_j = Y \qquad (2)$$

where U_i is the utility function of individual i, X_i is commodity j available to the consumer, P_j is the price of commodity j, and Y is the consumer's disposable income.

Optimizing Equation 1 subject to Equation 2 yields the individual's demand functions for commodities, $x_1, x_2, \ldots x_n$ as follows:

$$X_{ij} = f_{ij}(P_1, P_2, \ldots P_n, Y) \qquad (3)$$

where X_{ij} is individual i's demand for commodity j. This equation indicates that demand for the j^{th} product is determined by its own price, prices of all other products, and the consumer's disposable income. This demand function should satisfy the following first order condition:

$$\frac{f_{i1}}{P_1} = \frac{f_{i2}}{P_2} = \ldots \frac{f_{in}}{P_n} \qquad (4)$$

where f_{ij} is the first order partial derivative of the utility function with respect to commodity j.

The sufficient condition for the consumer's utility maximization subject to his budget constraints is expressed using a bordered Hessian

determinant as ($|\bar{H}|$) follows:

$$|\bar{H}| = \begin{vmatrix} 0 & P_1 & P_2 & \cdots & P_n \\ P_1 & f_{11} & f_{12} & \cdots & f_{1n} \\ P_2 & f_{21} & f_{22} & \cdots & f_{2n} \\ \cdot & & & & \\ \cdot & & & & \\ \cdot & & & & \\ P_n & f_{n1} & f_{n2} & \cdots & f_{nn} \end{vmatrix} \qquad (5)$$

The consumer's utility is maximum if $|\bar{H}_2|>0$, $|\bar{H}_3|<0$, $|\bar{H}_4|>0$ ....

Based on the basic demand theory, conceptual consumer's demand model for the i^{th} meat product (beef, pork, chicken, milk, or eggs) can be specified under an assumption of linearity between dependent and independent variables as follows:

$$Q_i = \alpha_0 + \alpha_1 P_i + \alpha_2 Y + \sum_{j=1}^{n} \beta_j P_j + e_i \qquad (6)$$

where

Q_i = consumer's demand for the i^{th} meat product
P_i = price of the i^{th} meat product
Y = consumer's disposable income
P_j = prices of closely related products

It is expected that, according to the theory of consumers demand, the sign of α_1 is negative, that of α_2 positive and that of P_j can be either positive or negative depending upon nature of the j^{th} product.

Homogeneity conditions associated with the demand model can be stated as follows:

$$E_{ii} + E_{i1} + E_{i2} + ..E_{ij} + ..E_{in} + E_y = 0 \qquad (7)$$

where

E_{ii} = price elasticity of the i^{th} product with respect to its own price
E_{ij} = cross-price elasticity of the i^{th} products with respect to the price of the j^{th} product
E_y = income elasticity

Homogeneity condition indicates that the sum of the own-price and cross-price elasticities and the income elasticity for a particular commodity is, taking account of signs, zero.

Development of Empirical Demand Model for Livestock

Livestock demand models for this study are specified on the basis of equation 6. Livestock products considered in this study are beef, pork, and chicken. In addition, demand models for eggs and milk are also estimated in this study. Prices of close substitutes are included directly, with all other prices captured in an aggregate price index. Deflating prices and income by the price index allows imposition of the homogeneity condition on the models. The demand function is specified assuming a single representative consumer, and thus per capita consumption is used as a dependent variable.

An important issue in specifying an empirical demand model is the simultaneity problem. It is commonly recognized in estimating demand functions that statistical deviation may arise in regression coefficients if supply conditions are not considered. As Chang and Pope argued, when the demand relations are considered on the basis of a representative consumer, prices and income can be taken as exogenous. If per capita consumption and per capita income are used along with the given price, a direct single-equation regression will produce a reasonable estimate without serious problems associated with simultaneity. Furthermore, the supply of agricultural products is highly variable because of dependence on weather conditions. Usually production decisions are made on the basis of prices in preceding years. Hence supply is affected by past prices rather than current prices. In this context, short run supply can be treated as a given.

Domestic production of livestock products in Korea has grown rapidly and structural changes have occurred, especially in recent years. Therefore, little is known about the response of supply to changes in price. The supply of beef has been more often affected by government policy such as the importation of beef and live animals. Consequently, overall supply conditions in Korea have been unstable. With these considerations, the livestock demand model in this study will be specified without considering supply conditions.

Dynamics in Demand Model

Various types of dynamic models have been developed to capture the effects of habit formation on consumer behavior. Some of these models are the state adjustment model by Houthakker and Taylor; the adaptive expectation model by Cagan, and the partial adjustment model by Nerlove. The dynamic model most commonly used in demand analysis for livestock is either the partial adjustment model or the state adjustment model. Based on consumers' consumption habits and general economic conditions in Korea, the authors concluded that the partial adjustment model is more appropriate than Taylor's state adjustment model.

The partial adjustment model, when applied to demand for agricultural products, assumes that the desired level of consumption of the i^{th} meat product in time t depends on current prices and income. Equation 6 can be restated as

$$Q_{it}^* = \alpha_0 + \alpha_1 P_{it} + \alpha_2 Y_{it} + \sum_{j=1}^{n} \beta_j P_{jt} \qquad (8)$$

where Q_{it}^* is desired level of meat product i in time period t, and other variables are as previously defined.

The realized change in consumption in any one period is only a fraction of the desired consumption due to habit persistence. In other words, there are continuous adjustments of desired consumption to the actual level. This adjustment process is expressed in the so-called "adjustment equation" or "habit formation equation" as follows:

$$Q_t - Q_{t-1} = \delta (Q_t^* - Q_{t-1}) + V_t \qquad (9)$$

where V_t is independent identifying distributed normal variates and δ is a real number between 0 and 1.0.

Combining Equations 8 and 9 yields

$$Q_{it} = \delta\alpha_0 + \delta\alpha_1 P_{it} + \delta\alpha_2 Y_t + \delta \sum_{j=1}^{n} \beta_j P_{jt} + (1-\delta)Q_{t-1} + V_t \qquad (10)$$

This equation can be rewritten as

$$Q_t = a_o + a_1 P_{it} + a_2 Y_t + \sum_{j=1}^{n} b_j P_j + a_3 Q_{t-1} + V_t \qquad (10\text{-a})$$

Equation 10 contains the consumer's dynamic behavior; current actual consumption is a function of current prices, current income and the level of previous consumption.

Functional Form

Since there are no theoretical restrictions concerning demand functions, various types of functional forms have been used in empirical demand analysis. The choice of functional form is an important decision because of different implications with respect to price and income elasticities. For example, a logarithmic function, in which all the variables are transformed into log values, implies that income and price elasticities for meat are constant at any level of income and price. Such an implication might be too restrictive if the sample contains a large variation in price and income (Chang). On the other hand, a linear functional form implies that income elasticity, if it is less than one, is rising and tends toward unity as consumer income increases over time (Chang). Both of these implications are not consistent with the theoretical effects of changes in price and income. Thus, an arbitrary choice of functional form may result in unwanted restrictions on price and income elasticities.

The Box-Cox parametric transformation allows the estimation procedure to select a functional form which maximizes the likelihood function of given sample data. The selected function may be linear or log-linear depending on parameter value, but it is not predetermined. It is a general conclusion based on the previous studies (Chang) that the general functional form based on the Box-Cox transformation performs better in estimating demand function than any other predetermined one. Accordingly, static and dynamic models for livestock products in Korea are respecified on the basis of the general functional form.

Equation 6 can be rewritten with the Box-Cox transformation as follows:

$$Q_{it}^* = a_0 + a_1P_{it}^* + a_2Y_t^* + \sum_{j=1}^{n} b_jP_{jt}^* + e_{it} \qquad (11)$$

The variables with asterisk in Equation 11 are defined as

$$\begin{aligned} Q_{it}^* &= (Q_{it}^{\mu} - 1)/\mu \\ P_{it}^* &= (P_{it}^{\mu} - 1)/\mu \\ P_{jt}^* &= (P_{jt}^{\mu} - 1)/\mu \\ Y_t^* &= (Y_t^{\mu} - 1)/\mu \end{aligned} \qquad (12)$$

The parameter of transformation (μ) to be estimated determines the shape of the function. When μ is equal to 1, Equation 11 becomes a linear form; as μ approaches zero, Equation 11 approaches a log functional form (Kmenta). Different values of μ lead to different functional specifications of the equation.

Similarly, based on Equation 10-a, the dynamic demand model for the i^{th} livestock product is specified as

$$Q_{it}^* = a_0 + a_1P_{it}^* + a_2Y_t^* + \sum_{j=1}^{n} b_jP_j^* + a_3Q_{t-1}^* + e_t \qquad (13)$$

Equations 11 and 12 are the same except for inclusions of Q_{t-1}^* as an independent variable in Equation 13. The empirical models are specified for five livestock classes; beef, pork, chicken, egg, and milk.

The demand function for each livestock product specified in Equations 11 and 13 are estimated by using the maximum likelihood procedure.

Dependent and independent variables in the models are transformed with different values of μ between 2.0 and -2.0, at intervals of 0.02. Then the least squares estimation of the transformed dependent variable on the transformed explanatory variables is performed on the set of transformed data with each μ. The value of maximum likelihood, Lmax(μ), is calculated for each regression by using the following formulas:

$$\text{Lmax}(\mu) = -n/2 \log \sigma^2(\mu) + (\mu-1) \sum_{t=1}^{n} \log Q_t^* \qquad (14)$$

where:

$\sigma^2(\mu)$ = estimated error variance of the regression of Q^* on the independent variables for the given value of μ

n = number of sample observations

The procedure for finding the optimum value of μ over the entire parameter space is iterative in nature as follows: (1) Select a range of trial values of μ, (2) estimate $\sigma^2(\mu)$ from the estimated regression model with a particular value of μ, (3) calculate Lmax(μ) for each μ from Equation 14, and (4) then choose a μ which maximizes the value of maximum likelihood function.

An approximate (1-α) confidence interval for μ can be constructed. This is then used for testing whether the confidence interval around the estimated value of μ includes zero or one, that is, whether the function is a log or a linear form.

Since 2[Lmax($\hat{\mu}$) - Lmax (μ)] is approximately distributed as Chi-square (χ^2) with one degree of freedom, (1-α) confidence interval for μ is obtained by finding the value of μ on either side of μ such that:

$$2(\mathrm{Lmax}(\hat{\mu}) - \mathrm{Lmax}(\mu)) = X^2(\alpha) \text{ with one-degree of freedom} \qquad (15)$$

$$\text{or} \quad \mathrm{Lmax}(\mu) = \mathrm{Lmax}(\hat{\mu}) \pm 1/2\ X^2(\alpha)$$

If the (1-α) confidence interval includes one, the function can be linear. If it includes only zero the function can be logarithmic. When the confidence interval includes both one and zero, both the linear and logarithmic functional forms are acceptable for the given sample.

Feed-Livestock Relationship

In the framework of general feed demand relationship, the demand function for concentrate feed by a specific type of livestock can be expressed as:

$$QF_t = \beta_0 + \beta_1 QL_t + \beta_2 PL_t + \beta_3 PF_t + \beta_4 T + e_t \qquad (16)$$

where:

QF_t = concentrate feed demanded
QL_t = livestock production in weight
PF_t = price of concentrate feed
PL_t = price of livestock
T = time trend
e_t = error term

Livestock production (QL) in empirical studies has been measured in different ways depending on data availability; either animal units fed (Foote), live weight of livestock output (Richardson and Ray), or final product weight of livestock output (Chu).

When price of livestock and price of feed are assumed constant, and further, the effects of technological change such as feeding efficiency are assumed negligible, the feed demand function (equation 16) is reduced to a direct physical relationship as follows:

$$QF_t = \beta QL_t \qquad (17)$$

where the coefficient β represents the feed-livestock conversion rate which is defined as the quantity of feed required to produce a unit of livestock product. This has been frequently used for feed demand projections with a given quantity of projected demand for livestock products.

Common problems encountered in empirical analyses of feed demand relations are the limited data on the feed-livestock sector including feed consumption, livestock numbers, and the unknown extent of errors involved in those data. Since the history of livestock production in Korea is far shorter than that of other Western countries, data deficiency is more serious. Hence, somewhat arbitrary judgments are inevitable in estimating future feed demand.

THE ESTIMATED DEMAND MODELS AND FUNCTIONAL FORMS

The empirical models for five livestock products (beef, pork, chicken, eggs, and milk) were estimated with the general functional form based on the Box-Cox transformation. Since dynamics in consumer behavior are not conclusive, we estimated both static (Equation 11) and dynamic models (Equation 13). A dummy variable is included in the beef and pork models to capture the effects of the price ceiling on beef and pork. The presence of serial correlation was tested by using Durbin-Watson statistics. The hypothesis of no serial correlation in error terms was accepted for the beef model, but inconclusive for the pork and egg demand models at $\alpha = 0.01$ level. The hypothesis of no serial correlation was rejected for the milk and chicken demand models. The Hildreth-Lu procedure was used to correct the serial correlation problems.

The static demand models estimated for five livestock items are presented in Table 16. The models have high adjusted R^2 ranging from 0.95 to 0.99. The signs of the independent variables in the estimated models are consistent with consumer demand theory as well as *a priori* expectations. A demand model should have a negative sign on its own price and have positive signs on the variables representing substitute goods. Income may have either a positive or negative sign in the demand model, depending upon the nature of the product in question. In this study the income variable should have a positive sign.

The income variables in all the models have high t-values, indicating that income has been the most certain factor that has shaped the demand for livestock products in Korea. In general, the price variables are statistically significant at $\alpha = 0.05$. However, chicken price in the pork demand model and pork price in the chicken demand model are not

TABLE 16. RESULTS OF STATIC DEMAND MODEL FOR LIVESTOCK PRODUCTS IN GENERAL FORM

Variable	Beef (μ=1.52)	Pork (μ=0.84)	Chicken (μ=1.38)	Eggs (μ=0.88)	Milk (μ=0.28)
Constant	-0.6961 (4.14)**	0.7572 (1.65)	-0.1224 (0.53)	6.2907 (6.56)**	-4.4514 (2.64)**
PB	-0.3330E-05 (2.87)**	0.1243E-02 (2.08)*	0.7659E-05 (1.99)*	-	-
PP	0.5089E-05 (1.85)*	-0.5040E-02 (6.18)**	0.4485E-06 (0.06)	-	-
PCH	0.1102E-04 (2.14)**	0.8635E-03 (0.88)	-0.3742E-04 (2.40)**	-	-
PEG	-	-	-	-0.1629E-01 (6.07)**	-
PMLK	-	-	-	-	-0.1383 (1.57)
Y	0.1124E-03 (11.49)**	0.1332E-01 (8.54)**	0.1676E-03 (5.82)**	0.4128E-02 (5.53)**	0.4833 (7.78)**
Dummy	0.7571 (6.55)**	-0.7622 (5.96)**	-	-	-
R^2	0.979	0.977	0.973	0.957	0.988
D-W	2.08	1.60	2.07	1.87	1.34
SSE	0.167	0.233	0.160	0.276	0.201

Note: Numbers in parentheses are "t" values
* significant at least at 5 percent level
** significant at least at 1 percent level

statistically significant, which indicates that there is limited substitution between chicken and pork in Korea.

The dynamic demand models estimated for the five livestock items are presented in Table 17. The regression results show that the lagged dependent variable is statistically significant in all models except in the egg demand model. The values of R^2s for the dynamic demand models are nearly the same as those for the static models. In the dynamic specification, the sign of pork price in the chicken demand model is negative and is statistically insignificant.

TABLE 17. RESULTS OF DYNAMIC DEMAND MODEL FOR LIVESTOCK PRODUCTS IN GENERAL FORM

Variable	Beef (μ=1.70)	Pork (μ=1.02)	Chicken (μ=1.50)	Eggs (μ=0.90)	Milk (μ=0.56)
Constant	-0.4942 (2.70)**	0.6344 (1.57)	-0.1232 (0.67)	4.9747 (3.74)**	1.2054 (0.82)
PB	-0.9130E-06 (3.33)**	0.3304E-03 (2.31)**	0.3469E-05 (2.38)**	-	-
PP	0.2081E-05 (2.75)**	-0.1387E-02 (6.25)**	-0.4441E-06 (0.14)	-	-
PCH	0.2202E-05 (1.38)	0.3267E-03 (1.17)	-0.8918E-05 (1.32)	-	-
PEG	-	-	-	-0.6394E-02 (3.26)**	-
PMK	-	-	-	-	-0.2709E-01 (1.03)
Y	0.3028E-04 (6.74)**	0.4125E-02 (6.74)**	0.4198 (1.99)*	0.1829E-02 (3.35)**	0.1145E-01 (0.92)
Dummy	0.8635 (6.86)**	-0.6459 (4.09)**	-	-	-
Q_t	0.2193 (2.30)**	0.2820 (3.05)**	0.4197 (2.38)**	0.2247 (1.47)	0.9721 (12.05)**
R^2	0.981	0.986	0.973	0.954	0.991
D-W	2.55	1.46	1.94	2.07	3.43
SSR	0.179	0.237	0.17	0.302	0.246

Note: Numbers in parentheses are "t" values
* significant at least at 5 percent level
** significant at least at 1 percent level

The dynamic effects in livestock demand, however, do not seem to be significant in Korea due mainly to the following reasons: (1) meat is not a mainstay in Korean diet and (2) the demand model is based on annual time series data. Even if there are dynamic elements in the demand model, dynamic adjustments will take less than one year in Korea, indicating that demand model will be static with annual time series data.

Analysis of the demand for livestock products in Korea is, therefore, based on the estimated static model rather than dynamic demand model. The dynamic model is simply presented for a comparison with the static model.

Test of Hypothesis About Functional Form

Demand functions were chosen at a value of μ where Lmax(μ) was the highest. This does not mean that the linear or logarithmic functional forms are rejected. Maximum likelihood ratio tests based on Equation 14 were performed for each livestock demand model to determine whether 95 percent confidence intervals of the estimated transformation parameter (μ) include one or zero; in other words, whether the function can be linear or logarithmic.

Results of the tests in the static model are presented in Table 18. The confidence interval for μ is 1.02-1.88 for beef demand, 0.60-1.04 for pork demand, 0.84-1.80 for chicken demand, 0.64-1.14 for egg demand, and 0.10-0.44 for milk demand.

TABLE 18. 95 PERCENT CONFIDENCE INTERVAL FOR μ

Demand for	Optimum Value of μ	Confidence Interval		Hypothesis for	
		Lower limit	Upper limit	Linear	Log
Beef	1.52	1.02	1.88	Rejected	Rejected
Pork	0.84	0.60	1.04	Accepted	Rejected
Chicken	1.38	0.84	1.80	Accepted	Rejected
Egg	0.88	0.64	1.14	Accepted	Rejected
Milk	0.28	0.10	0.44	Rejected	Rejected

For beef demand, the hypothesis of a linear or a log functional form was rejected. This conclusion is based on the fact that a 95 percent confidence interval does not include either $\mu = 1$ or $\mu = 0$. Only the general functional form transformed by optimum transformation parameter (μ) is relevant for the given sample data. For pork, chicken, and egg demand, the null hypothesis of a linear form was accepted. This indicates that demand functions for pork, chicken, and egg can be linear.

The linear functional form was rejected for beef and milk demand, and the logarithmic form was rejected for the livestock demand models. The linear or log-linear functional form would have been incorrectly accepted in the demand models if demand estimation had been estimated only based on the linear or logarithmic function. The incorrect choice of functional form results in biased estimates of parameters (Chang).

Test of Parameter Stability

This study was designed to make projections of livestock demand for the future based on the estimated demand functions. Thus, the major concern is whether the estimated functions will perform equally well outside the sample data which have been used for the estimation of coefficients. If the parameters are stable over the entire sample range, we can assume stability will extend over future periods. Conversely, if the parameters are unstable over time, the estimated function is not appropriate for use in estimating the future level of livestock demand.

The restricted and unrestricted 'F' (Chow test) is probably the best known test method for detecting parameter stability. It tests whether a regression equation is the same between two disjointed sub-periods. For this test, the sample should be divided into two parts, and demand equations are estimated separately based on each set of samples. The breaking point of the sample is usually based on arbitrary judgment, but when the number of sample observations in time series data is small the Chow test is restricted due to the shortage of degrees of freedom in estimating the model. The Chow test slightly modified by Koutsoyiannis is used to test parameter stability. The test procedures are as follows:

First, from the full sample observations, obtain the regression:

$$Y_t = \beta o + \beta_1 \mu_{1t} \ldots \beta_k \mu_{kt} + e_t$$

from which the residual sum of squares is calculated $\Sigma e_t^2 = \Sigma(y_t - y_t)^2$ with (n_1+n_2-K) degrees of freedom.

where

n_1 = number of original sample observations
n_2 = number of added sample observations

Second, from the original sample size of n_1,

$$\Sigma e_{1t}^2 = \Sigma(y_{1t} - y_{1t})^2 \text{ with } (n_1-K) \text{ degrees of freedom.}$$

Third, the difference in the two sums of residuals is

$$\Sigma e_t^2 - \Sigma e_{1t}^2 \text{ with } (n_1+n_2-K)-(n_1-K) = n_2 \text{ degrees of freedom.}$$

Finally, the F* ratio is formed as

$$F^* = \frac{(\Sigma e_t^2 - \Sigma e_{1t}^2)/n_2}{\Sigma e_{1t}^2/(n_1-K)}$$

The tests for parameter stability of the estimated livestock demand functions were performed by using the above method. Egg and milk demand models were excluded from tests since those models were estimated from more restricted sample data. The demand models for the three meat items based on time series data from 1961 to 1975 were additionally estimated. Residual sums from the estimation, together with those from full sample, were used in the tests. Test results are presented in Table 19. The hypothesis of no structural change for the three items of livestock demand functions can not be rejected at $\alpha = 0.05$. This conclusion is somewhat tenuous for beef and chicken demand models. However, the conclusion is that the parameters for all the models are stable.

TABLE 19. RESULTS OF PARAMETER STABILITY TESTS

Demand for (Ho;=b)	F-statistics 1961-75 1976-84	Critical Value Degrees of Freedom	Results =0.05
Beef Accepted	2.513	(9,10)	3.02
Pork Accepted	-0.013	(9,9)	3.18
Chicken Accepted	2.937	(10,10)	2.98

Price and Income Elasticities

Because all demand models are specified with the general functional form based on the Box-Cox transportation as shown in equations 11 and 13. Own price, cross-price and income elasticities are calculated by using the following formulas (Chang):

$$e_i = a_1(P_i/Q_i)^{u_i} \tag{18}$$

$$e_{ij} = b_j(P_j/Q_i)^{u_i} \tag{19}$$

$$e_{iy} = a_2(y/Q_i)^{u_i} \tag{20}$$

where

e_i = price elasticity of the i^{th} meat product
e_{ij} = cross-price elasticity of the i^{th} meat product with respect to the price of the j^{th} product
e_{iy} = income elasticity of the i^{th} meat product with respect to income
P_i = price of the i^{th} meat product
P_j = price of the j^{th} meat product
Q_i = per capita consumption of the i^{th} meat product

Own price, cross-price, and income elasticities are calculated at their means from the estimated demand models in Table 16 and are presented in

Tables 20 and 21. These price and income elasticities are compared with those from the linear and log functional forms.

TABLE 20. OWN PRICE AND INCOME ELASTICITIES AT THE MEANS

Livestock items	General Form		Linear Form		Log Form	
	Own price Elast.	Income Elast.	Own price Elast.	Income Elast.	Own price Elast.	Income Elast.
Beef	-0.386	0.849	-0.454	0.936	-0.722	1.100
Pork	-1.004	0.965	-1.035	0.933	-1.021	1.021
Chicken	-0.354	0.609	-0.375	0.607	-0.483	0.675
Egg	-0.971	0.328	-0.939	0.334	-1.013	0.369
Milk	-0.431	1.723	-0.568	1.600	-0.493	2.230

TABLE 21. CROSS PRICE ELASTICITIES AT THE MEANS OBTAINED FROM GENERAL FORM

Demand for	Price of		
	Beef	Pork	Chicken
Beef	-0.386	0.228	0.246
Pork	0.417	-1.004	0.119
Chicken	0.327	0.085	-0.354

For pork, chicken, and eggs, the relative magnitude of income and price elasticities obtained from the general and linear functional forms are not greatly different. However, they are significantly different from elasticities obtained from log forms. Price and income elasticities for beef and milk obtained from general forms are considerably different from those either from linear or log forms. This happens because linear specification is acceptable for the pork, chicken and egg models, while both linear and log forms are rejected for the beef and milk models.

Price elasticity for beef demand obtained from the log form is larger than that from the general form by 0.336. If the log form is used, the price elasticity of beef demand would be overestimated by 87 percent. By the same token, income elasticity of beef demand will be overestimated by 30 percent. This indicates that demand elasticity can be over or underestimated, depending on the functional form chosen.

Among the three meat items, price elasticity for pork is the largest in absolute value, followed by those of beef and chicken. These elasticities reflect Koreans' habits in meat consumption. Price elasticities for meat items reflect not only consumers' response to the price of a product but also characteristics of consumer groups who commonly consume the meat items. Beef is generally consumed by a high income group. Consumption of beef is, therefore, not very sensitive to changes in beef price. As a result, demand for beef is inelastic at -0.386. On the other hand, pork is consumed by middle and low income groups in Korea whose consumption is generally sensitive to price of pork. Demand for pork is elastic at -1.004. Demand for chicken is very inelastic mainly because (1) chicken is a commonly consumed meat item in Korea, and (2) price of chicken is low relative to other meat items. Just like beef, milk is still consumed by a small high income group whose consumption is not very sensitive to changes in milk price. Eggs are a very common food item in Korea and are largely consumed by middle and low income groups whose consumption is generally sensitive to changes in egg prices.

Income elasticity for pork is the largest in absolute value among three meat items. This indicates that demand for pork is more sensitive to changes in consumer's income than other meat items. Income elasticity for beef is more inelastic than that for pork although beef is more luxurious than pork in Korea. This is mainly because beef is consumed by the high income group while pork is consumed by middle and low income groups. As income levels increase in Korea, demand for beef is expected to increase because of (1) increase in per capita consumption of beef and (2) increase in the size of the beef consuming population. On the other hand, income elasticity for chicken is smaller than other meat items because the price of chicken is cheaper than beef and pork in Korea and is the most commonly consumed meat item in Korea.

The income elasticities indicate that, as income level increases, demand for beef and pork will grow faster than for chicken in Korea. The increase is mainly due not only to an increase in per capita consumption but also to an increase in the beef and pork consuming population.

Income elasticity for milk is 1.7, indicating that demand for milk grows much faster than that for meat items due mainly to an increase in the milk consuming population and an increase in per capita consumption of milk. Income elasticity for eggs is very inelastic because the price of eggs is low relative to prices of meat items. The estimated income elasticities indicate that beef, pork, and milk are preferred to chicken and eggs in Korea.

Cross price elasticities obtained from the general functional model (Table 21) show that pork and chicken demand are relatively sensitive to beef price, while beef demand is less sensitive to pork and chicken prices. This is because beef is considered a superior meat item, and beef has been very expensive relative to pork and chicken. The cross price elasticity of pork with respect to chicken, and that of chicken with respect to pork, is very low, indicating a relatively weak substitution relationship.

It is apparent that estimated price, cross price, and income elasticities for each meat item do not satisfy the homogeneity condition specified in equation 7. The sum of these elasticities are not equal to zero. This is mainly because the price of meat products have been controlled by the Korean government. The government control nullified price effects on meat consumption while accelerating income effects.

Changing trends for price and income elasticities are summarized in Table 22 and Table 23, respectively. Price elasticities of demand for livestock products have, without exception, declined over time. Price elasticity of beef demand obtained from general functional model decreases

TABLE 22. PRICE ELASTICITY OF DEMAND FOR LIVESTOCK PRODUCTS, SELECTED YEARS

Demand for	Year	General form	Linear form	Log form
Beef	1961	-0.969	- 0.832	- 0.748
	1971	- 0.619	- 0.619	- 0.748
	1981	- 0.404	- 0.468	- 0.748
	1985	- 0.274	- 0.362	- 0.748
Pork	1961	-0.920	-0.933	-1.013
	1971	-1.458	-1.613	-1.013
	1981	-0.989	-1.016	-1.013
	1985	-0.602	-0.563	-1.013
Chicken	1962	-1.165	-0.888	-0.483
	1971	-0.375	-0.391	-0.483
	1981	-0.240	-0.282	-0.483
	1985	-0.127	-0.178	-0.483
Eggs	1971	-1.039	-1.015	-1.103
	1981	-0.643	-0.588	-1.103
	1985	-0.560	-0.503	-1.103
Milk	1971	-0.636	-2.292	-0.493
	1981	-0.358	-0.293	-0.493
	1985	-0.304	-0.164	-0.493

from -0.969 in 1961 to -0.274 in 1985. Price elasticity for pork declines from 0.920 to 0.602, and that for chicken declines from 1.165 to 0.127 during the same period of time. This decreasing trend of price elasticity implies that livestock products are more familiar to Korean consumers than they were before, and that livestock products have become increasingly important in Korean diets, while the prices of livestock products have been controlled by the Korean government.

TABLE 23. INCOME ELASTICITY OF DEMAND FOR LIVESTOCK PRODUCTS, SELECTED YEARS

Demand for	Year	General form	Linear form	Log form
Beef	1961	0.741	0.856	1.100
	1971	0.789	0.893	1.100
	1981	1.033	1.066	1.100
	1985	1.116	1.122	1.100
Pork	1961	0.484	0.411	1.021
	1971	0.974	0.944	1.021
	1981	1.043	1.025	1.021
	1985	0.887	0.845	1.021
Chicken	1962	0.468	0.501	0.675
	1971	0.376	0.428	0.675
	1981	0.690	0.665	0.675
	1985	0.668	0.649	0.675
Egg	1971	0.227	0.220	0.369
	1981	0.350	0.361	0.369
	1985	0.384	0.401	0.369
Milk	1971	2.175	3.676	2.230
	1981	1.573	1.155	2.230
	1985	1.472	0.912	2.230

The decreasing trend of price elasticities is also observed in the linear and logarithmic functional form; price elasticities obtained from the general function form are greatly different from those obtained from the logarithmic functional form and are similar to those from the linear functional form. Because the logarithmic functional form assumes constant elasticity over the entire sample period, it does not reflect the changing trend of price elasticities over time. When the log form is used, price elasticities are underestimated for the earlier period and are overestimated for the recent period. In the beef demand model the price elasticities obtained from the general form are -0.969 in 1961 and -0.274 in 1985. Since price elasticity is assumed constant at -0.748 in the log form, it is underestimated by 25 percent in 1961 and overestimated by more than twofold.

Contrary to the decreasing trend of decreasing price elasticities, changing trends of income elasticities are somewhat diverse. Income elasticities for beef and egg have steadily increased over time. This implies that increases in per capita income has been larger than those in meat consumption over the time period. For pork and chicken, income elasticity increased up to 1981 and decreased slightly in recent years. On the other hand, income elasticity for milk has decreased gradually.

However, high income elasticities for beef, pork, and milk indicate a great potential for further demand expansion in the future as income increases.

PROJECTIONS OF DEMAND FOR LIVESTOCK PRODUCTS

The demand functions presented in Table 16 were used to estimate the per capita consumption of livestock products in 1991 and in 1996. Total demand for each livestock product was calculated by multiplying the estimated per capita consumption by the population in the target years.

The estimated parameters of the demand functions for each livestock product were assumed to remain stable up to the years for which demand was estimated. As discussed before, per capita consumption of livestock products has increased along with income. It is difficult to foresee how far and for how long the trend will continue. Considering the still low level of livestock product consumption, however, the increasing trend seems likely to continue at least for the next 10 years. The results of parameter stability tests in the previous section show that there have not been any significant structural changes in livestock demand. All these facts suggest that the consumption pattern of livestock products will develop in the future as it has developed up to now and that the estimated demand functions are expected to perform well for the estimation of future demand for livestock products.

Real prices of livestock products were assumed to remain at current levels throughout the projection period. This means the price of livestock is assumed to rise by the same amount as the overall price level, and the price rise does not affect real prices and relative prices with respect to prices of other consumer goods.

Annual rates of real GNP growth (7 percent) and population growth (1.6 percent), reflected in Korea's Sixth Social Economic Development Plan for the period 1987-1991, were used in calculating per capita income growth, and the same income growth was assumed to continue to 1996. Annual GNP growth in Korea since 1970 has ranged from 6.2 to 14.1 percent. Even though economic growth in Korea is mainly dependent on exports, GNP annual growth rate of 7 to 8 percent seems plausible considering the economic performance during the last decade. With the assumptions discussed above, the factors which will govern the level of future livestock demand are presented in Table 24.

Per capita consumption of each livestock product for the years 1986-1996 was estimated by using the demand model in Table 16 together with the projected variables in Table 24. The estimated per capita consumption of livestock products is shown in Table 25.

Per capita consumption of beef is projected at 4.1 kilograms (kg) for 1991 and 5.5 kg for 1996, which is higher than that for 1985 by 41 and 90 percent, respectively. Projected per capita pork consumption increases from 8.4 kg in 1985 to 10.6 kg in 1991 and to 13.6 kg in 1996, 26 and 62 percent higher, respectively, than the 1985 level. Reflecting the relatively low

TABLE 24. VARIABLES USED IN PROJECTION OF LIVESTOCK DEMAND

Year	Price					Real Personal GNP	Population
	Beef	Pork	Chicken	Eggs	Milk		
	won/kg	won/kg	won/kg	won/doz	won/kg	1000 won	1000 people
1986	6,044	2,036	1,108	394	380	1,263	41,703
1987	6,044	2,036	1,108	394	380	1,336	42,204
1988	6,044	2,036	1,108	394	380	1,412	42,710
1989	6,044	2,036	1,108	394	380	1,483	43,223
1990	6,044	2,036	1,108	394	380	1,579	43,742
1991	6,044	2,036	1,108	394	380	1,670	44,267
1992	6,044	2,036	1,108	394	380	1,765	44,798
1993	6,044	2,036	1,108	394	380	1,866	45,335
1994	6,044	2,036	1,108	394	380	1,793	45,880
1995	6,044	2,036	1,108	394	380	2,086	46,431
1996	6,044	2,036	1,108	394	380	2,206	46,988

NOTE: Price and income are measured in 1980 constant won.

TABLE 25. PROJECTIONS OF PER CAPITA CONSUMPTION FOR LIVESTOCK PRODUCTS

Livestock Product	1985 (actual)	1991 (projection)	1996 (projection)
	kilogram		
Beef	2.9	4.1	5.5
	(100)	(141)	(190)
Pork	8.4	10.6	13.6
	(100)	(126)	(162)
Chicken	3.1	3.7	4.6
	(100)	(119)	(14)
Meat Total	14.4	18.4	23.7
	(100)	(128)	(164)
Eggs	7.2	7.9	9.0
	(100)	(110)	(125)
Milk	23.3	28.6	42.3
	(100)	(123)	(182)

NOTE: (1) Retail weight basis
(2) Numbers in parentheses are the index (1985=100)

income elasticity, the increase in per capita consumption of chicken and eggs is rather moderate, increasing by 48 and 25 percent, respectively, during the next 10 years. The growth of milk consumption is significant, nearly doubling during the 1985-1996 period.

Projection of total demand for livestock products is shown in Table 26. Total demand growth for each livestock product is slightly higher than per capita growth, reflecting the population growth. Demand for beef, pork, and milk approximately doubles during 1985-1996, and demand for chicken and eggs increases by 73 and 43 percent, respectively.

PROJECTION OF FEED DEMAND

Projection of Concentrate Feed Demand

The quantities of concentrate feed demanded by each type of animal in 1991 and 1996 were estimated on the basis of the corresponding livestock demand estimated in the previous section. Since feed grain is a component of concentrate feed, the quantity of feed grain demanded was calculated by using the percentage of grains contained in concentrate feed.

In estimating feed demand, all livestock product demands were assumed to be supplied by domestic production. This assumption may not be plausible considering the uncertainties pertaining to future trade policy and the

TABLE 26. PROJECTIONS OF TOTAL CONSUMPTION OF LIVESTOCK PRODUCTS

Livestock Product	1985 (actual)	1991 (projection)	1996 (projection)
	1000 tons		
Beef	120.4	183	256
	(100)	(152)	(213)
Pork	346.1	469	640
	(100)	(136)	(185)
Chicken	126.2	166	218
	(100)	(132)	(173)
Meat Total	592.7	818	1,114
	(100)	(138)	(188)
Eggs	296.4	351	424
	(100)	(118)	(143)
Milk	1,047	1,266	1,990
	(100)	(122)	(190)

NOTE: Numbers in parentheses represent index (1985=100) restrictive production conditions. But the feed grain demand estimated under this assumption can be easily revised with alternative estimates for domestic supply.

Recognizing the difficulties in estimating equation 16, feed demand was estimated on the basis of equation 17 using feed-livestock conversion rates in recent years. The feed-livestock conversion rate refers to the amount of feed used for producing one kilogram of livestock product. The conversion rate for each livestock product was calculated by dividing the total quantity of concentrates fed by the quantity of livestock product produced. It was recognized that the feed-livestock conversion rates would not exactly reflect the amount of feed fed due to time lags between feeding and the marketing of livestock, but the discrepancy is not significant when year-to-year production is repeated with similar time sequences.

Feed conversion rates for each type of animal during the period of 1970-1985 are shown in Table 27. The feed-livestock conversion rates for all livestock products except dairy and poultry have changed greatly throughout the 1970s. The feed-livestock conversion rates for dairy and poultry have stabilized since the late 1970s. The feed conversion rate of

TABLE 27. FEED CONVERSION RATES, KOREA, 1970-1985

Year	Beef	Pork	Chicken	Eggs	Milk
1970	-	0.12	1.54	2.89	0.33
1975	0.48	1.26	1.67	2.98	0.96
1976	0.58	1.75	2.43	4.29	0.89
1977	1.17	2.40	3.29	4.69	1.04
1978	3.14	2.91	5.49	5.76	1.00
1979	3.08	5.07	6.37	6.32	1.15
1980	3.28	3.27	4.95	5.69	1.14
1981	5.99	3.68	5.94	5.35	0.92
1982	10.95	4.84	6.52	5.38	1.03
1983	13.17	6.82	6.65	5.33	1.00
1984	11.81	5.83	5.32	5.30	1.01
1985	10.51	5.57	5.23	5.50	0.99
Avg. (84-85)	11.83	5.70	5.26	5.40	1.00

SOURCE: National Livestock Cooperatives Federation (Korea), Statistics on Price Demand and Supply of Livestock Products. Seoul, Korea. Various issues.

pork has become stable only in recent years as specialization occurred. According to a recent survey (Table 9), hog and poultry production is entirely dependent on feed concentrates. This implies that feed-livestock conversion rates for pork, chicken, and eggs have reached a peak level, and the feed conversion rates may decrease if feeding efficiencies increase in the future. Even though dairy cattle consume considerable amounts of forage, the feed conversion rate for milk seems to have reached a saturated level considering the fact that it has been nearly constant for the last 10 years. The feed conversion rate in the beef sector, having recently begun to use concentrates, is likely to be volatile as herd size per farm increase and as roughage supply declines. The feed conversion rates for beef jumped sharply in 1982, but there is no clear trend.

Projections of feed-livestock conversion rates were made assuming that conversion rates for each livestock item will remain at current levels (average of the 1984 and 1985 rates); 11.8 for beef, 5.7 for pork, 5.3 for chicken, 5.4 for eggs, and 1.0 for milk.

Based on the conversion rates, demands for concentrate feed for 1991 and 1996 were projected. As shown in Table 28, total concentrate feed demand increases from 6.4 million tons in 1985 to 12.1 million tons in 1996. Concentrate demand for beef, even under a moderate assumption regarding feed conversion rate, increases from 1.2 million tons to 3 million tons during the same period. Concentrate demand for pork and milk production also show significant growth, nearly doubling during the next 10 years. Concentrate feed demand for poultry shows a moderate growth rate reflecting the low income elasticity of demand for eggs and chicken.

TABLE 28. PROJECTIONS OF CONCENTRATE FEED DEMAND BY LIVESTOCK TYPE

Livestock Product	1985 (actual)	1991	1996
		1000 tons	
Beef	1,209	2,123	2,970
	(100)	(165)	(245)
Milk	994	1,266	1,990
	(100)	(130)	(200)
Pork	1,924	2,720	3,712
	(100)	(142)	(190)
Chicken	660	890	1,170
	(100)	(127)	(177)
Eggs	1,648	1,895	2,290
	(100)	(115)	(139)
Total	6,437	8,894	12,132
	(100)	(138)	(193)

NOTE: Numbers in parentheses represent an index (1985=100)

Projection of Feed Grain Demand

Poultry are known to consume more grain than hogs, and hogs to consume more grain than beef cattle. But, data on the mix of feed components for each type of animal are not available. Therefore, feed grain demand was projected assuming a single aggregate feed composition for the whole livestock sector. The mix of specific feed types in total concentrate feed depends, in large part, on the relative price of feed grain and other feed stuffs. However, as shown in Table 29, the share of grains in concentrates has been stable -- an average of 64 percent during the 1981-1985 period. Under the assumption that the portion of grain in feed production will remain at the current level, feed grain demand was projected to increase 90 percent from 4.1 million tons in 1985 to 7.8 million tons in 1996 (Table 30).

TABLE 29. AGGREGATE USE OF COMPONENTS FOR CONCENTRATE FEED IN KOREA, SELECTED YEARS

Year	Grains	Vegetable[1] Meal	Animal Protein Meal	Bran	Others[2]	Total
	1,000 tons					
1975	422	98	50	262	62	914
	(48.3)	(10.7)	(5.5)	(28.7)	(6.8)	(100)
1980	2,077	416	101	685	206	3,485
	(59.6)	(11.9)	(2.9)	(19.7)	(5.8)	(100)
1981	2,086	447	94	680	203	3,150
	(59.4)	(12.7)	(2.7)	(19.4)	(5.8)	(100)
1982	2,831	569	118	661	260	4,439
	(63.8)	(12.8)	(2.7)	(14.9)	(5.8)	(100)
1983	3,895	832	127	667	350	5,871
	(66.3)	(14.2)	(2.2)	(11.3)	(5.9)	(100)
1984	3,949	737	133	831	355	6,005
	(65.8)	(12.3)	(2.2)	(13.8)	(5.9)	(100)
1985	4,095	848	124	1.000	401	6,400
	(63.3)	(13.1)	(1.9)	(15.4)	(6.2)	(100)

SOURCE: Ministry of Agriculture and Fisheries (Korea) Feed Handbook. Seoul, Korea. 1985.

NOTE: (1) Soybean meal currently accounts for 80-85% of total vegetable meals.
(2) Additives such as bone powder, salt, vitamins.

In addition to feed grain demand, demand for vegetable meal and equivalent soybean demand was projected. The share of total vegetable meal in concentrate feed was assumed to remain at 13 percent, which translates to 1.6 million tons of vegetable meal demanded in 1996.

TABLE 30. PROJECTIONS OF DEMAND FOR FEED GRAINS AND VEGETABLE MEAL IN KOREA

Items	1985 (actual)	1991	1996
	1000 tons		
Feed grains	4,095	5,690	7,760
Vegetable Meal	848	1,156	1,580
		(1,460)	(2,000)
Others	1,544	2,046	2,790

NOTE: Numbers in parentheses are quantities of soybean converted by using the soybean-soybean meal conversion rate, 0.79.

As discussed in the previous sections, the domestic capacity of agricultural production is limited. As a result, domestically produced grain that can be used for feed is unlikely to exceed 0.1 million tons. As shown in Table 31, the domestic supply of feed grain was less than 0.1 million tons annually until 1983. The figures in 1984 and 1985 only reflect the disposition of barley stocks owned by the government for feed use. The production of oil

TABLE 31 ORIGINS OF FEED MATERIALS, KOREA, SELECTED YEARS

	Grains			Vegetable Meal		
Year	Domestic Supply	Foreign Supply	Total	Domestic Supply	Foreign Supply	Total
	1000 tons					
1975	24	418	442	74	24	98
1980	69	2,008	2,077	73	343	416
1981	73	2,013	2,086	74	363	447
1982	54	2,777	2,831	84	485	569
1983	99	3,796	3,895	89	743	832
1984	191	3,758	3,949	96	641	737
1985	346	3,749	4,095	105	743	848

Source: Ministry of Agriculture and Fisheries, Livestock Handbook. Seoul, Korea. 1985.

seeds has faced constraints similar to those facing grains. Therefore, nearly all the projected demand for feed grain and vegetable meal will come from increased imports.

SUMMARY AND IMPLICATIONS

Summary of Study

The objective of this study is to examine the livestock-feed demand relationships in Korea, specifically

1. To identify the major factors that have shaped the demand for livestock products.

2. To make projections of demand for livestock products and for feed grains over the next decade.

Single equation static and dynamic demand functions were specified for per capital consumption of each livestock product as a function of its own price, the prices of other competing products, and per capita income. Box-Cox transformations were applied to the demand functions in order to allow for more flexible functional forms. The demand functions were estimated by using the maximum likelihood estimation technique.

The hypothesis that the functional form is logarithmic was rejected for all livestock demand models, and the hypothesis of linear form was accepted for the pork, chicken, and egg demand models. Price and income elasticities from linear or logarithmic functional forms are different from those obtained from general forms. This indicates that the choice of functional form is important in estimating the demand models.

Tests for parameter stability of estimated demand functions were conducted to examine whether there had been structural changes in livestock products demand relations. The results show that the estimated parameters in the models are stable over time and thus indicate no structural changes in meat demand.

Dynamic demand models for the livestock products were also developed on the basis of the partial adjustment hypothesis. The static model, however, appears to be more appropriate than the dynamic model in estimating demand models for livestock products in Korea in terms of R^2, Durbin-Watson statistics and "t" values associated with the estimated parameters. This is mainly because (1) meat is not a mainstay in Korean diets and (2) the demand model is estimated on the basis of annual time series data which nullify the dynamic effects in meat demand.

Elasticities obtained from estimated demand functions for various livestock products show that income is the dominant factor affecting demand. Income elasticities for beef, pork, and milk are much larger than those for eggs and chicken. This implies that beef, pork and milk are more luxurious products in Korean diets than chicken and eggs, and that demands for beef, pork and milk will increase faster than those for chicken and eggs as consumer's income rises.

Price elasticity for pork is the largest in absolute value, followed by that of eggs. Price elasticities for beef and milk are very inelastic because beef and milk are generally consumed by a high income group whose consumption of these products is not very sensitive to changes in prices of the products. On the other hand, pork and eggs are consumed by all income groups in Korea whose consumption is still generally sensitive to prices of these products. Price elasticity for chicken is the lowest indicating that chicken is considered to be a necessity and is the most commonly consumed livestock product in Korea.

Cross price elasticities show that Korean consumers tend to substitute beef for chicken and pork, but they do not like to substitute chicken and pork for beef. This is mainly because beef is considered as a superior meat item. The cross price elasticity of pork with respect to the price of chicken and that of chicken with respect to the price of pork is very low, indicating that a relatively weak substitution between these two meat items.

Per capita demand for each livestock product over the next decade was projected on the basis of static demand models. For the projection of livestock product demand, it was assumed that real prices will remain at current levels through the projection period, and that per capita income will grow at a rate of 5.4 percent annually. Under these assumptions, per capita beef consumption was projected to increase 90 percent during the 1985-1996 period and consumption of pork and chicken to increase 62 percent and 48 percent, respectively. Projected per capita milk consumption would increase by 82 percent, while egg consumption would increase by only 25 percent, reflecting low income elasticity for eggs. Among the meat items, beef shows the most significant increase in consumption, followed by pork and chicken as income increases.

Total demand for beef was projected to increase 113 percent, and that for pork and chicken were projected to increase 85 percent and 73 percent, respectively, during the 1985-1996 period. Total demand for eggs and milk would increase 43 percent and 90 percent, respectively, during the same period.

Demand for each livestock product was converted into demand for concentrate feed by using feed conversion rates. The feed conversion rate for each livestock product was assumed to remain constant at current levels; 11.6 for beef, 5.7 for pork, 5.3 for chicken, 5.4 for eggs, and 1.0 for milk. Concentrate feed demand for beef production would increase from 1,209 thousand tons in 1985 to 2,970 thousand tons in 1996, and that for pork from 1,924 thousand tons to 3,712 thousand tons. During the same period, total concentrate demand increases from 6,437 thousand tons to 12,132 thousand tons, or 93% greater than that in 1985.

Demand for feed grains and vegetable meal (soybean meal) were projected by using the shares of grains and vegetable meal in total concentrate feed. The shares of grains and vegetable meals were assumed to be 64 percent and 13 percent, respectively. Total feed grain demanded in 1996 would then be 7,760 thousand tons, and vegetable meal demand would be 1,580 thousand tons (equivalent to 2 million tons soybean meal), which are substantially higher than the 1985 level. Because domestic production of grains and oil seeds is basically limited to food use, most of the projected increase in feed grains and vegetable meal (or soybean meal) must come from imports.

Policy Implications

Beef production requires more than twice the concentrate feed required by pork and chicken on the basis of the feed-livestock conversion rates. This implies that substitution of pork and chicken for beef results in a considerable decrease in feed requirements. For instance, if the projected increase in beef demand (136,000 tons) is substituted by pork or chicken, 0.8 million tons of concentrate feed can be saved in 1996. The substitution in meat consumption could be accomplished by maintaining a reasonably high beef price relative to pork and chicken prices. However, price policy alone may not be sufficient for the substitution because of a strong preference for beef.

The price of beef in Korea is much higher than the world price due mainly to the high costs of domestic beef production compared to production costs in the United States and Australia. In spite of inefficient beef production in Korea, the Korean government has maintained and will maintain its traditional policy of encouraging domestic beef production, mainly because about one million farmers are involved in beef production and it is an important income source for small farmers.

If the Korean government pursues an open market policy for beef trade, the domestic beef price would decline to approximately one half of the current level. Because domestic beef is produced at marginal profits, the open market policy would result in an eventual extinction of domestic beef production. On the other hand, a decrease in beef price due to a change in beef trade policy would lead to changes in prices of other meat items. Considering the high preference for beef, beef consumption would increase even more rapidly, replacing pork and chicken consumption. As a result, hog and poultry farmers will be forced to cut down their operations or curtail projected expansion. This implies that liberalizing beef imports will result in a substantial reduction in farm income in Korea. It is therefore likely that the Korean government will maintain its traditional policy of encouraging domestic beef production rather than the open market policy, although the traditional policy is a very expensive not only for the Korean government, but also for Korean consumers.

The policy direction being adopted by the Korean government in the near future could alter the bilateral trade relationship between the United States and Korea. If the Korean government decides to maintain its traditional policy of encouraging domestic beef production, huge imports of feed grains and soybeans would be needed to feed beef cattle. The total imports are projected to reach about 7 million metric tons of feed grains and 2 million metric ton of soybeans in 1996. Most imports of these grains would come from the United States because the United States has a comparative advantage over other feed grain and soybean exporting countries such as Argentina and Brazil. On the other hand, if Korea liberalizes beef imports in the near future, most domestic beef production would be replaced with imports. Most beef imports will come from Australian and New Zealand rather than from the United States simply because these countries have a comparative advantage over the United states in exporting beef to Korea in terms of both production and transportation costs. In addition, liberalization of beef imports in Korea will result in a substantial reduction in feed grain imports from the United States since less production would occur in Korea while more beef is imported. In the other word, a Korean beef liberalization policy would lead to a reduction in feed grain imports from the United States and increase in United States exports of beef to Korea.

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APPENDIX

APPENDIX TABLE 1. PER CAPITA CONSUMPTION OF LIVESTOCK PRODUCTS, KOREA

Year	Beef	Pork	Chicken	Eggs	Milk
	---------- kilograms ----------				
1961	0.52	2.33	0.72	-	-
1962	0.64	1.43	0.59	-	-
1963	0.77	2.00	0.74	-	-
1964	1.14	2.23	0.67	-	-
1965	0.95	1.95	0.50	2.98	0.36
1966	1.01	2.26	0.64	4.45	0.48
1967	1.06	2.39	0.80	4.48	0.62
1968	1.16	2.00	1.09	4.88	0.78
1969	1.05	2.41	1.34	7.70	1.11
1970	1.16	2.56	1.40	7.62	1.54
1971	1.20	2.46	1.52	7.71	1.89
1972	1.20	2.69	1.62	8.33	2.38
1973	1.32	2.64	1.52	7.33	3.05
1974	1.48	2.75	1.54	7.94	3.66
1975	1.99	2.80	1.58	8.21	4.40
1976	2.11	3.17	1.70	8.51	5.55
1977	2.24	4.02	2.01	9.75	6.98
1978	3.10	4.81	2.22	10.12	8.81
1979	3.03	6.00	2.39	11.27	9.98
1980	2.62	6.34	2.38	11.92	10.80
1981	2.41	5.42	2.34	11.18	14.40
1982	2.71	6.04	2.52	11.45	15.07
1983	2.89	7.38	3.00	12.35	18.24
1984	2.63	8.37	2.91	12.17	20.54
1985	2.92	8.40	3.06	13.08	23.30

APPENDIX TABLE 2. PRICES OF LIVESTOCK PRODUCTS, KOREA

Year	Beef	Pork	Chicken	Eggs	Milk
	won/kg	won/kg	won/kg	won/dozen	won/kg
1961	138	78	68	-	-
1962	148	96	77	-	-
1963	156	102	87	-	-
1964	182	140	123	-	-
1965	240	190	181	87	55
1966	268	196	202	89	58
1967	356	238	241	99	78
1968	524	334	259	102	83
1969	600	336	237	102	89
1970	660	386	287	123	100
1971	886	528	304	122	111
1972	1006	518	270	128	128
1973	1096	586	327	154	150
1974	1306	702	468	186	167
1975	1488	992	595	240	189
1976	2126	1332	820	255	225
1977	2760	1370	885	293	225
1978	3460	1962	1010	336	267
1979	3858	1810	882	321	411
1980	4820	2028	1301	387	453
1981	6464	3526	1629	495	520
1982	7432	3420	1461	493	536
1983	8236	3208	1386	555	536
1984	8316	2802	1583	571	536
1985	7056	3520	1563	556	550

APPENDIX TABLE 3. PER CAPITA GNP AND CONSUMER PRICE INDEX, KOREA

Year	Per capita GNP	CPI
	1,000 won	1980=100
1961	11.41	6.80
1962	13.41	7.20
1963	18.45	8.60
1964	25.59	11.60
1965	28.06	12.46
1966	35.56	13.86
1967	42.52	15.37
1968	53.60	17.03
1969	68.30	19.13
1970	84.36	21.18
1971	102.64	25.20
1972	123.98	28.10
1973	157.71	29.00
1974	216.28	36.10
1975	286.05	45.20
1976	387.21	52.10
1977	497.51	57.38
1978	655.29	65.66
1979	832.54	77.68
1980	975.89	100.00
1981	1182.12	121.30
1982	1316.69	130.10
1983	1462.38	134.50
1984	1636.55	137.60
1985	1754.88	141.00