IMPLICATIONS OF STRUCTURAL CHANGE IN U.S. DEMAND FOR MEATS ON U.S. LIVESTOCK AND GRAIN MARKETS

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LAURENCE DAVID CORNELL

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ABSTRACT

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Structural changes in regression coefficients were identified and quantified using graphical analysis, qualitative shift and interaction variables, linear and cubic spline functions within a discontinuous time-varying switching regression model, and Legendre polynomials within

a continuous time-varying parameter model. A major conclusion of this study, supported by considerable evidence, is that a constant parameter formulation for the retail demand functions of table beef, hamburger beef and broilers is not appropriate and is likely to result in misleading structural coefficients of retail demand. A notable and consistent exception throughout this analysis was aggregate pork demand for which the null hypothesis of fixed coefficients was accepted in each parameter variation model tested. The hypothesis of irreversibility of demand for beef is one testable hypothesis explaining systematic changes in the slopes of retail demand curves and in the derived flexibilities. This hypothesis was accepted: direct flexibilities were higher during periods of beef cattle cycle or inventory upturns and lower in cycle downturns.

Over the past several years direct flexibilities for table beef have risen while for hamburger they have declined. The lower the direct flexibility, the greater the extent to which increases in quantities available per person are absorbed by demand and hence, the smaller the price adjustment required to clear the market. This means that, recently, quantities of hamburger beef have been more readily absorbed by demand than have table beef or poultry meats. This result for chicken is consistent with the observations that the market for chicken is becoming saturated and that the impact of gains from technology in the broiler industry, which have helped keep real prices down, may be slowing. The implication is that the preference for hamburger beef has been growing vis-a-vis other meats.

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The inclusion of the preferred retail meat demand models into a model of U.S. agriculture permitted simulations of the impacts of identified structural changes on the livestock and feedgrain markets of the U.S. For example, results of simulations run individually, of a declining consumer preference for table beef, an increasing cross-effect on table beef from a growing hamburger and broiler demand, and a declining income flexibility of demand for table beef, each indicated substantial impacts on table beef demand and on the levels of production and prices of feedlot produced beef. In another analysis, the impacts indicated by a simulation of a proposed dairy herd reduction program on cow beef production and hence imports of processing quality beef were also shown to be considerable.

IMPLICATIONS OF STRUCTURAL CHANGE

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LIVESTOCK AND GRAIN MARKETS

by

Laurence David Cornell

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To my parents

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CHAPTER 1

INTRODUCTION

1.1 Focus of the Problem

One of the important tasks of demand and price analysis has been to identify and to quantify the structure of consumer markets by estimating demand functions for various goods. The coefficients or parameters of the estimated demand functions are known as the structural coefficients or parameters. The quest for accurate and reliable estimates of these parameters arises from their use for public policy analysis and for forecasting. The journals of economics and econometrics are filled with attempts to overcome the many formidable obstacles arising during their estimation.

Typically, economists have operated with some version of the classical linear statistical model, a model which assumes that tastes and preferences, habits, expectations and various other sociological and psychological phenomena remain constant over time. In particular, the assumption is usually made in time series analysis that the structure of demand and the values of the true coefficients remain unchanged over the period under investigation. Despite this simplifying assumption, casual empirical observation will quickly show that the structure may change over time, gradually or abruptly. The difficulties which market analysts have experienced in understanding the recent developments in the retail markets for meats illustrate clearly the nature of the problem.

Economists have long been plagued by the lack of a fundamental explanation for these shifts in price-quantity relationships, typically observed over time. To some extent this absence of an adequate explanation has been due to a preoccupation with the traditional theory. It was concluded by Tomek and Robinson (1977, p. 388) in their extensive review that

> in the literature of agricultural price analysis, as in much of the economic literature, own-price elasticities have received more emphasis than is justified by their economic importance. The large changes in consumption, production and price have occurred as a result of shifts in demand and supply functions rather than as a result of movements along a static ceteris paribus schedule. Preoccupation with price elasticities has in some cases led economists to ignore more critical variables.

Alongside the preoccupation with price elasticities, the assumption of fixed coefficients stands equally as an obstacle to economic estimation and forecasting of key policy and outlook variables. With the increased economic and political interelationships among the various sectors of the national and international economies, the magnitude of structural parameters are less likely to remain constant through time. This has been true of agriculture (Fox, 1962; Schuh, 1976; and Gardner, 1981).

Tomek and Robinson (1977, p. 388) cite the large underestimation of beef prices during the early 1970s using models based on pre-1969 data, suggesting that a change in the structure of the demand for beef in the U.S. may have been responsible. More recently, the observed decrease in demand for red meats has been attributed to changing tastes, changing attitudes toward health, the rapid growth in new processed poultry

products and the associated increasing shift of consumer preferences towards chicken and away from red meats. These and other changes all point to an evolving and at times an abruptly changing structure in the demand for meats in the U.S. If account is not taken of these changes, future economic forecasts may well be inaccurate. Furthermore, if economic models are estimated with a constant parameter formulation and the parameters change over time, especially for those markets where significant market adjustments have taken place, then economic policies based on these estimates are at best questionable and may be misleading. It is towards this matter that the present research is directed.

1.2 Research Objectives

The broad objectives of this study are (a) to test the assumption, underlying the classical model of consumer demand, of constancy of structural coefficients in the retail demand for major meats in the U.S.; (b) to investigate parameter variation in terms of systematic behavior over time; (c) to relate systematic variation of estimated slope coefficients and estimated measures of responsiveness of demand to observed structural changes in retail meat demand; and (d) to incorporate estimated models of retail demand into a model of U.S. agriculture and to simulate the long-term impacts of recent structural changes on U.S. agriculture and international feedgrain markets, and particularly on U.S. imports of beef.

1.3 Orientation of Research

In the U.S., the beef subsector has had and continues to have a dominating effect on the retail market for meats. To be sure, poultry meat and certain non-meat foods have in recent years claimed an increasing share in consumers' diets. Beef still, however, commands the major portion of the consumers' budget and of the consumers' purchased quantities of retail meats. It is also the major source of protein.

The presence of the U.S. beef market is also felt internationally. Besides being the largest producer of beef, the U.S. is the world's largest importer of beef, mainly processing-quality beef and an important exporter of table cuts of beef. The U.S. market is of prime importance to Australia, the world's major exporter of beef and largest supplier of beef to the U.S. U.S. beef imports, however, represent less than 10 percent of total U.S. beef consumption. In a world in which total beef trade is a small proportion of total world production and in which trade patterns and price formation in world markets are influenced considerably by institutional factors, changes in domestic markets of importers can have a pronounced effect on the returns to exporting nations. This is certainly the case in the U.S., where developments in the markets for meats can significantly influence the level of beef imports and consequently affect the returns to exporters who supply the U.S. market, chiefly Australia and New Zealand. Compounding the uncertainty of gaining entry into the U.S. beef market is the regulation of U.S. beef imports by a complex 'countercyclical' meat import law. Access for those exporters is further complicated by the fact that this law does not impose a binding constraint in all years.

One source of uncertainty and a major determinant of the level of beef imports permitted entry in the U.S. is the U.S. retail demand for meats. Changes in the structure of demand for table beef, hamburger beef, pork and chicken are investigated in this research. Analyses of the impact of these and other structural changes on imports of beef into the U.S. are reported.

1.4 Organization of Proposed Research

In the following chapter, the U.S. beef market is discussed in the context of world trade patterns. The structure of the U.S. market and key changes in consumption and marketing are also discussed. In Chapter 3 the theoretical underpinnings of traditional consumer demand are critically reviewed with respect to the measurement of structural changes in demand parameters. Given this theory and its noted limitations, an extensive array of methods for identifying and estimating structural changes in demand are reviewed. Chapter 4 reports the results of empirical analysis of retail meat demand models. Emphasis is given to relating observed changes in retail meat markets to estimates of time-varying structural coefficients of demand for table beef, hamburger beef, pork and chicken. In Chapter 5 preferred models of retail demand for each of these four major meat categories are incorporated into a larger econometric model of U.S. agriculture and world grain trade. Simulations of this model over the longer term provide scenarios of impacts of structural changes on U.S. retail meat demand and in particular, on the level of beef imports permitted entry under the countercyclical meat import law. The final Chapter 6 contains concluding comments and the policy implications from the previous analyses.

CHAPTER 2

STRUCTURE, INSTITUTIONAL SETTING AND THE CHANGING ENVIRONMENT OF THE BEEF MARKET

2.1 The World Beef Market: An Overview

The world beef market can be viewed in terms of the following broad dimensions: cattle population, aggregate production, consumption per person, and imports and exports. World beef cattle numbered over 1.2 billion in 1982.[1] Two-thirds were located in developing countries with the greatest concentrations being in Asia (30 percent) and South America (18 percent). The majority of beef cattle in developed countries are found in Europe (11 percent) and the U.S. (9 percent). Centrally planned economies which include parts of the developed and developing worlds accounted for 17 percent of all beef cattle in 1981; USSR contained 8 percent of the total. Over the past two decades (1960-1981), growth in cattle numbers has been greatest in the USSR, Oceania and Africa; in these countries growth has been 50 percent or more. Slower growth has been experienced in the U.S. and Europe, at less than 20 percent.

Developed countries carried 35 percent of the cattle but accounted for 67 percent of total beef production. This disparity may be explained by the subsistence livestock practices and low productivity in

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[1] Data are cited from various issues of FAO, Production Yearbook, and from Simpson and Farris (1982). A proportion of the animals reported as beef cattle are dual purpose breeds.

developing countries. The U.S. produced 22 percent of the world's beef from only 12 percent of the world's cattle. Europe had 11 percent of the world's cattle and 22 percent of production. Growth in production has been relatively slow over the 1960-1981 period: 43 percent in the U.S., 44 percent in the USSR and 53 percent in North and Central America. By contrast production growth, though from a smaller base, has been much faster in Asia and Oceania.

About 24 percent of world beef was consumed in the U.S., 22 percent in the whole of Europe, 15 percent in the USSR and 12 percent in South America between 1961 and 1981. Growth in consumption has been fastest in the USSR.

The international market for beef is characterized by a few major exporting and importing countries. The beef trade has represented between 8 percent and 10 percent of world production (OECD, 1980). Currently, four major regions dominate beef imports, namely, the U.S., the EEC, and to a lesser extent Canada and Japan. These key developed country markets jointly account for over two-thirds of total beef imports. The U.S. and the EEC are also leading producing regions in which imports comprise only a small proportion of total beef consumption. Oceania (mainly Australia and New Zealand) and South America (mainly Argentina, Brazil and Uruguay) provide the bulk of the world's beef exports, although these countries account for a relatively small proportion of total world production. Details are presented in Table 2.1.

There exists a large number of other countries which trade in beef. Collectively, they represent a significant proportion of total trade

Table 2.1

Beef Production, Consumption and Trade: Averages 1971-73, 1976-78 and 1977-81 (Carcass Weight Equivalent)

		Production		Consumption		Imports (Exports)[a]		
		'000 Tonnes	% of World Total	'000 Tonnes	Pounds Per Person	'000 Tonnes	% of World Total	As a % of Consumption/ Production
A. Major Importing Countries								
USA	1971-73	10,115	29.5	10,741	117	873	39.4	8.1
	1976-78	11,735	27.7	12,619	130	958	45.7	7.6
	1979-81	10,092	24.8	10,979	106	949	40.6	8.6
EEC (9)	1971-73	5,387	15.7	6,399	55	672[b,c]	30.4	10.5
	1976-78	6,428	15.2	6,529	62	205[b]	10.0	3.1
	1979-81	6,864	16.9	6,667	57	324[b]	13.9	4.9
Japan	1971-73	279	0.8	393	9	111	5.0	28.2
	1976-78	348	0.8	467	9	128	6.1	27.4
	1979-81	430	1.1	594	25	175	7.5	29.5
Canada	1971-73	890	2.6	933	95	94	4.2	10.1
	1976-78	1,148	2.7	1,209	115	115	5.5	9.5
	1979-81	979	2.4	997	93	82	3.5	8.2
Total	1971-73	16,671	48.6	18,466	..	1,750[a]	79.1	..
	1976-78	19,659	46.4	20,824	..	1,406[a]	67.2	..
	1979-81	18,365	45.1	19,237	..	1,530[a]	65.4	..
B. Major Exporting Countries								
Australia	1971-73	1,306	3.8	566	97	716	26.2	54.8
	1976-78	1,954	4.6	955	139	982	34.5	50.3
	1979-81	1,573	3.9	730	110	873	27.5	55.5
Argentina	1971-73	2,117	6.2	1,540	101	562	20.6	26.5
	1976-78	3,892	6.8	2,302	121	591	20.7	15.2
	1979-81	2,989	7.3	2,436	132	551	17.4	18.4
New Zealand	1971-73	407	1.2	134	143	274	10.0	67.3
	1976-78	544	1.3	178	194	380	13.3	70.0
	1979-81	502	1.2	187	198	341	10.7	67.9
Brazil	1971-73	2,100	6.1	1,883	42	185	6.8	8.8
	1976-78	2,333	5.5	2,187	42	171	6.0	7.3
	1979-81	2,167	5.3	2,017	35	188	5.9	8.7
Total	1971-73	5,930	17.3	4,123	..	1,737[b]	63.6	..
	1976-78	7,723	18.2	5,622	..	2,124[b]	71.7	..
	1979-81	7,231	17.8	5,370	..	1,953[b]	61.5	..

Source: USDA, Foreign Agriculture Circular: Livestock and Meat (various issues).

[a] For importers these data relate to gross imports; for exporters data relate to gross exports.

[b] Excludes intro-EEC trade.

[c] Excludes live cattle trade.

volume. Individually, however, they exert very little influence on the market and account for a very small proportion of world beef production and consumption.

The present structure of world trade in beef has arisen partly because of comparative advantages in beef exporting and partly due to institutional factors in response to, for example, the existence of foot and mouth disease in certain regions. Exporting regions such as South America and Oceania have a comparative advantage in beef production because of natural conditions, such as their large pasture bases which favors cattle raising and their low human population pressures arising from a comparative endowment of land. Areas such as the U.K. and Japan have a comparative disadvantage in beef production and, hence, are importers of beef. The U.S. and Canada have a relatively small area of permanent pasture and are major importors of grass-fed beef. However, these countries are also major exporters of livestock products, supported by their extensive feedgrain systems.

Also impacting on the overall pattern of trade and effectively segmenting the market into an Atlantic market and a Pacific market has been the regulations relating to foot and mouth disease. The beef trade consists predominantly of fresh, chilled and frozen beef, with frozen boxed manufacturing quality beef[2] being the main type. The flow of trade is predominantly between Oceania and North America on the one hand and between South America and the EEC on the other. This pattern emerged

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[2]Manufacturing beef, processing beef, ground beef and hamburger beef are used interchangeable in the literature. This practice is adopted in this research. At various points in this research some differences among these terms will be highlighted.

following prohibition by Japan and the U.S. of meat imports from foot and mouth infected regions such as South America. Because these regions cannot ship their fresh, frozen or chilled beef to the U.S. they now depend almost exclusively on Europe and the USSR.[3] Hence, Australia and New Zealand, countries free of foot and mouth disease, are the only major suppliers to the North American and Japanese markets. Australia accounts for around 50 percent and New Zealand for some 20 percent of U.S. beef imports.

An additional factor which led to the current structure of the market was the entry of the U.K. into the EEC-9 in 1973. Up to the 1960's the U.K. dominated international trade in beef and was the major market for Oceania beef. During this time North American and Japanese imports were negligible. The U.K. had no prohibitive restrictions on trade in meat except for health and sanitation and Australian beef trade flourished under the Fifteen Year Meat Agreement with the U.K. By the early 1960's this agreement expired, fortuitously for Australia, just when the U.S. emerged as a significant importer in the world beef market. The U.S. was experiencing rapidly rising income per person, a growing 'fast food' industry and had few trade restrictions. These developments consolidated the trade pattern illustrated in Figure 2.1, i.e., the establishment of separate Pacific and Atlantic trading markets which were only weakly linked by Oceania's European trade, now greatly diminished by U.K. entrenchment within the EEC.

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[3] Argentina is permitted to export cooked canned beef to the U.S., although these exports represent less than 10 percent of total beef imports.

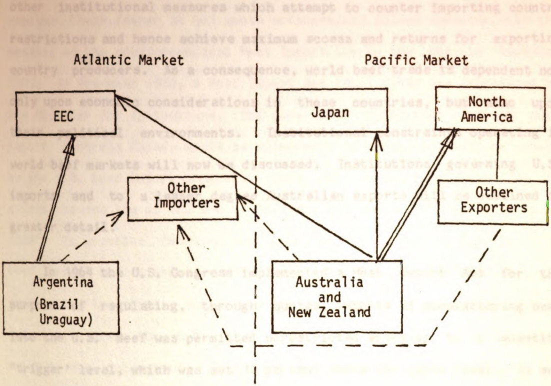

Figure 2.1 Pattern of World Trade in Beef

2.2 Institutional Constraints in World Beef Trade

Various policies restricting trade have been adopted by all major beef importing countries, the objective being to maintain prices and/or incomes to domestic producers. Major beef exporters have responded with other institutional measures which attempt to counter importing country restrictions and hence achieve maximum access and returns for exporting country producers. As a consequence, world beef trade is dependent not only upon economic considerations in these countries, but also upon their political environments. Institutional constraints operating in world beef markets will now be discussed. Institutions governing U.S. imports and to a lesser degree Australian exports will be outlined in greater detail.

In 1964 the U.S. Congress implemented a Meat Import Act for the purpose of regulating, through quotas, imports of manufacturing beef into the U.S. Beef was permitted unrestricted entry up to a quantity 'trigger' level, which was set 10 percent above the quota level. In any given year, if imports were expected to exceed this trigger level of 110 percent of the base meat quota then the quota was invoked. The President had the power to relax or suspend the quota in the national interest, e.g., when internal beef prices have been high as in 1973. However, because of certain destabilizing effects of this law, the 1979 Meat Import Law was enacted. The latter law has a countercyclical component which, in effect, permits increased imports when domestic beef supplies are low without involving quotas but limits imports when supplies are high. Further details of this quota will be discussed in Chapter 5.

Access to the Canadian beef market has been subject to a quota restraint since 1976. Previously, restrictions on imports were less formally imposed, often being negotiated with major supplying countries. The level of the restraint has been determined by the Minister for Agriculture in response to general market conditions. However, moves to replace these rather ad hoc quota arrangements gained momentum with the passing of the countercyclical Meat Import Law in the USA in December 1979. In November 1980, a Meat Import Act (Bill C-46) was introduced by the Minister for Agriculture. The government felt that without such import controls Canada would be vulnerable to market distortions caused by the U.S. beef import controls. This Act, also countercyclical in effect, became law at the end of 1981 and was applied to beef imports in 1982[4]. In practice, Canadian beef trade policy is very similar to U.S. beef trade policy and its meat import laws. This is because the Canadian cattle industry is similar in many respects to the U.S. cattle industry. Like the U.S., a fed-beef production system predominates which is also subject to a pronounced and regular cattle cycle that closely follows the U.S. cycle.

Internal stabilization objectives of domestic livestock industries largely determine Japanese beef trade policy. These objectives are to maintain prices to producers at stable and high levels by world standards. The Livestock Industry Promotion Corporation (LIPC) is the controlling agency, responsible for establishing global quotas on beef

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[4] Weeks and Turner (1981) provide a detailed review of the potential effects of this law.

imports, stockpiling beef, and various other activities[5]. The LIPC administers the quota system by issuing licenses to Japanese importing firms which then negotiate with overseas suppliers. Levies are charged on all imports and effectively raise world prices up to internal wholesale prices. Proceeds from these levies are used to promote Japan's livestock industries.

A commitment to greater self-sufficiency in livestock products underlies Japan's policies. As a result, consumer beef prices are maintained at very high levels relative to other countries, and imports are virtually unrelated to world trade prices. Japanese beef imports are influenced by the domestic market, in particular by the level of domestic beef production. For instance, since 1979, the Japanese government has been subsidizing Japanese dairy farmers to slaughter low-yielding milk cattle. The aim is not to increase milk production, but to increase dairy industry productivity. These subsidies have led to higher dairy cattle slaughterings and a consequent increase in domestic meat production. In most years, Australia has captured 80-90 percent of this market. However, future global beef quotas continue to depend upon both economic and political considerations (Bureau of Agricultural Economics, 1981). For example, the currently depressed dairy-beef market induced the LIPC to reduce the chilled beef quota, since these chilled beef imports compete directly with Japanese dairy-steer beef. Furthermore, Japan's current trade surplus with the U.S. has resulted in pressure from the U.S. on Japan to relax restrictions on imports,

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[5]Details of Japanese beef import policies are contained in Bureau of Agricultural Economics (1975) and Longworth (1978).

including U.S. table quality beef. For this reason Japan can be expected to give preferential treatment to U.S. beef imports.

Intervention in the beef market of the EEC comes under the Common Agricultural Policy (CAP) and its extensive and seemingly plethoric array of rules and regulations. Since 1980, the EEC has been a net exporter of beef and veal. A system of variable levies and duties provide the mechanism for controlling imports and supporting internal prices. This mechanism comes into effect when internal prices fall below 'guide' prices. The market is supported also by intervention buying, stockpiling of beef, and 'restitution' payments (subsidies) to EEC exporters in times of surplus production or stocks. On occasions when their measures have been ineffective in maintaining internal prices at guide price levels, virtually all imports have been prohibited as occurred in the mid-1970's. During 1981, imports by the EEC operated under three quota schemes: first, the GATT levy-free quota including boneless frozen beef and veal and high-quality cuts plus an Australian quota of buffalo meat; second, the ACP imports from African, Caribbean, and Pacific nations; and third, the balance sheet arrangements quota (Bureau of Agricultural Economics, 1981, pp. 25-26).

This turnabout of the EEC in 1980 from net importer to a net exporter of beef and veal reflects to a very large degree the extensive policy mechanisms of internal support and associated barriers to cheaper world imports which have protected beef producers in the EEC. EEC beef 'surpluses' which are finding their way increasingly into world trade and third country markets are directly related to the high internal price supports given to the perennially surplusing production of the EEC

dairy industry. EEC dairy cattle are predominantly dual purpose. As dairy cow numbers grow, so does beef production.

With a mere 8-10 percent of total world beef production entering world trade, the use of government measures has allowed major importing regions to transfer much of their potential price instability to external markets. As a consequence, the instability in major exporting countries is greatly magnified and their access to world markets is substantially reduced.

In view of the above policies, major exporting countries have implemented their own institutions and policy measures to maximize access to world markets. Among these, price discrimination is often administered by way of a state monopoly marketing board. In 1968, the year U.S. quotas first became binding, Australia implemented an Export Diversification Scheme to regulate shipments of beef to the U.S.[6] This Scheme is operated by the Australian Meat and Livestock Corporation (AMLC) which issues licenses or 'entitlements' to exporting firms who must first earn the right to export to the U.S. by making sales to non-U.S. markets. This price discrimination has the effect of directing some Australian beef to lower priced export markets (sometimes at a loss to Australian exporters) and of raising domestic consumer and producer prices.

New Zealand also operates a national beef marketing board which, like the AMLC, allows private firms to handle exports. Also like the

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[6] An analysis of this scheme is given by Freebairn and Gruen (1977).

AMLC, the New Zealand Meat Board has considerable market power. Since 1955 the Board has used its intervention powers to maintain a price stabilization scheme for producers and maintain minimum prices for meat in New Zealand under the Export Meat Prices Act[7]. The majority of cattle slaughtered are destined for the export market.

Argentina's once dominant position as a beef exporter weakened, partly because of foot and mouth disease in that country. Australia and New Zealand, both free of the disease, prospered as a result. Ensuing sanitary restrictions limited Argentina's access to the 'Pacific' market of North America and Japan to canned beef. Argentina exacts substantial, though variable, taxes on exports of beef primarily to generate government revenue. To some extent these taxes militate against national goals to augment foreign exchange earnings. Other policies attempt to restrain the high level of domestic meat consumption, which is the highest in the world.

Overall, trade patterns and price formation in the world beef market are influenced in a pronounced way by institutional factors. U.S. and Canadian beef imports are mostly unresponsive to prices except during tight domestic supply conditions. That is, normal fluctuations in domestic prices will not affect import volumes. Similarly, Japan's imports, which are strictly controlled by quotas, are determined primarily by domestic needs and not by changes in the world market. Hence, in these three major Pacific markets which annually accept around 60-70 percent of Australia's beef exports, exporters face a demand which is

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[7] The Scheme is described by Johnson (1978).

virtually unresponsive to price. However, trade with the Atlantic segment is highly price responsive. In this market Oceania competes directly with South America.

From the foregoing, therefore, it is clear that although the U.S. is an important market for beef exporters, exports to the U.S. have represented a relatively small proportion of total U.S. consumption of beef; less than 10 percent. However, beef imports represent around 20 percent of U.S. consumption of processing quality beef. Exports of beef from the U.S. are even less significant. Various studies conducted over the last decade or so have concluded to a greater or lesser degree that U.S. beef imports have had a small impact on domestic prices of beef and, consequently, on the profitability of domestic beef production[8]. Therefore, from the U.S. standpoint, the aggregate U.S. beef market, especially for high quality table beef cuts, may reasonably be considered predominantly as a domestic system.

2.3 Characteristics of the U.S. Beef Subsector

Except for quotas on imports, the beef market unlike several other U.S. agricultural industries, is relatively unfettered by government intervention policies. Nevertheless, the beef subsector is an integral part of the rural economy, and has important linkages with, in particular, the feedgrains subsector and the pork and chicken subsectors. Direct government intervention policies affect the price of grain. And

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[8] The magnitude of this impact was the subject of a major investigation by the U.S. International Trade Commission (1977). The Commission concurred with the results of earlier analyses.

since feed costs comprise two-thirds of total production costs in feedlot operations, these grains policies, significantly, though indirectly influence the beef market.

The study of the beef subsector[9] or the beef market is the study of a political economy. Consistent with this notion is the subsector representation in Figure 2.2. Albeit simplistic, the principle participants in the system, the subsector, are identified. Figure 2.2 goes beyond the traditional industrial organization framework of structure, conduct and performance, and includes the structure of a broader environment. The political-economic environment of the beef 'market' includes the many overlapping opportunity sets of participants in the system.

> The political-economic system structures relationships among participants, thus structuring the opportunity sets for individuals and groups by defining rules for access to resources and pay-offs from the aggregate opportunity set. (Shaffer, 1979, p. 2)

This is but one possible configuration of the interactions among participants and clearly, no attempt is made to detail every component of this system. Nevertheless the important linkages between participants and the commodities produced are emphasized. In this way the operating environment, i.e., the underlying structure of the beef system may be visualized.

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[9] For treatments of the beef subsector from slightly different perspectives see Campbell and Hayenga, ed (1978); McCoy (1979); Shepherd and Futrell (1982); or Simpson and Farris (1982). Material in this section also draws from U.S. International Trade Commission (1977) and Harris (1980 and 1981).

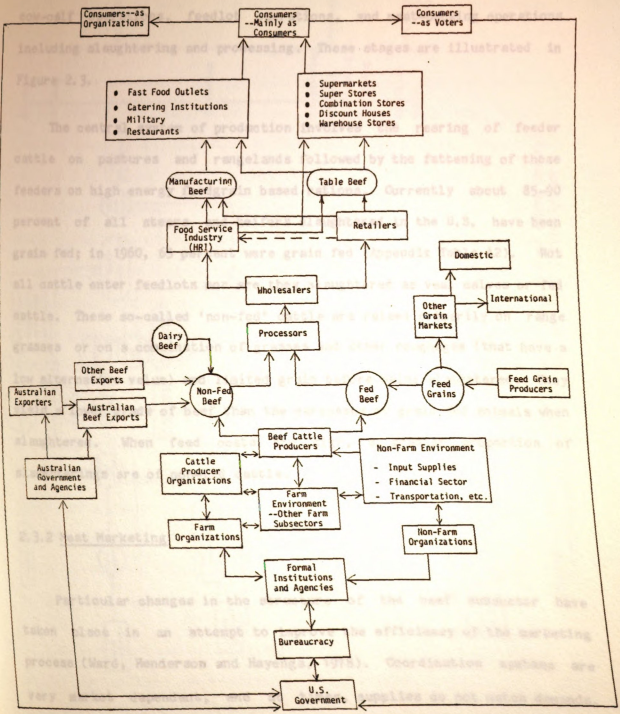


Figure 2.2 The Political-Economic Structure of the U.S. Beef Subsector

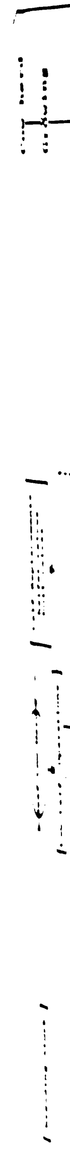
2.3.1 Beef Cattle Industry

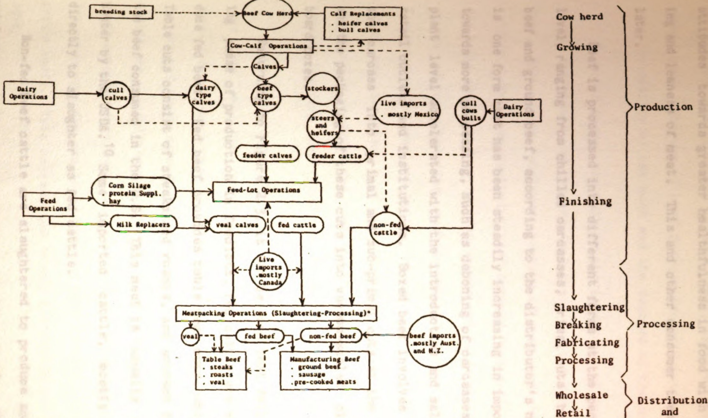
The production of beef may be segmented into three major stages: cow-calf operations, feedlot operations, and meat-packing operations including slaughtering and processing. These stages are illustrated in Figure 2.3.

The central system of production involves the rearing of feeder cattle on pastures and rangelands followed by the fattening of these feeders on high energy feedgrain based rations. Currently about 85-90 percent of all steers and heifers slaughtered in the U.S. have been grain fed; in 1960, 65 percent were grain fed (Appendix Table A2). Not all cattle enter feedlots nor are they slaughtered as veal calves or fed cattle. These so-called 'non-fed' cattle are raised primarily on range grasses or on a combination of grasses and other roughages (that have a low alternative value) and limited grain before being slaughtered. They yield a lower grade of beef than the carcasses of grain fed animals when slaughtered. When feed costs are high, a greater proportion of slaughterings are of non-fed cattle.

2.3.2 Meat Marketing

Particular changes in the structure of the beef subsector have taken place in an attempt to improve the efficiency of the marketing process (Ward, Henderson and Hayenga, 1978). Coordination systems are very market dependent, and at times, supplies do not match demands. Contracts between major feedlot operators and major meat packers facilitate dependable supplies with rigid specifications. The importance of





* The carcass may be partially or fully processed at the meatpacking plant or it may be shipped for processing to another meat plant or to a retail outlet.

Figure 2.3

Structure of Major Flows of Live Cattle and Beef Among Central Participants in the U.S. Beef and Beef Cattle System

meeting more exact specifications lies in the emerging trend in consumer attitudes towards greater healthfulness in food with respect to packaging and leaness of meat. This and other consumer trends are discussed later.

Beef is processed into different forms at the packer and processor level, ranging from chilled carcasses, primal cuts, boxed beef, boneless beef and ground beef, according to the distributor's needs. Ground beef is one form that has been steadily increasing in importance. The trend towards more processing, such as deboning of carcasses at the packing plant level accelerated with the introduction and sale of boxed beef to retail outlets and institutions. Boxed beef involves the division of the carcass into primal and sub-primal cuts at the meat packing plant and the packaging of these cuts into vacuum-sealed plastic-lined cardboard boxes.

Returning to Figure 2.3, it can be seen that following the finishing phase of production in feedlots, fed cattle are slaughtered to produce fed beef. Fed beef provides table meat cuts, which include veal. Table cuts consist of steaks and roasts, and account for a large part of the beef consumed in the U.S. This meat is usually graded choice or better by the USDA.[10] Some imported cattle, mostly from Canada, go directly to slaughter as fed cattle.

Non-fed beef cattle are slaughtered to produce some table beef but mainly to produce manufacturing quality beef. Manufacturing beef

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[10]The role of beef grades and the implications beef grades have had for U.S. beef consumption will be discussed later.

includes all beef requiring further processing (ground, chopped, cooked or canned) and includes ground beef, sausages, and various types of cooked beef. The use of beef for manufactured products depends largely upon the quality of the meat and the demands of the market.

As noted above, the bulk of the commercial slaughter is made up of grain fed steers and heifers, and these are the primary source of table beef. Most of the remainder consists of cows and non-fed steers and heifers. Most manufacturing beef derives from cull dairy and beef cows and bulls and meat from non-fed steers and heifers. A further and major source of manufacturing quality beef is imports of Australian and New Zealand non-fed boneless beef. Because of its leaness, U.S. processors often mix imported beef with otherwise 'waste' fat and trimmings from domestically produced fed beef, in their production of hamburger beef, thereby lowering their plant operating costs per unit of production.

The average proportion of processing beef obtained from each carcass type and the respective amounts of processing and table beef derived from each source is presented in Table 2.2 (Agnew, 1979). A feature of these data which is quite often overlooked is that grain fed cattle are a significant source of processing beef. The average fed beef carcass provided 20 percent of its weight as trimmings and other low value cuts for use in processing beef production (including fresh ground beef). This represented absent a third of all processing beef in 1978.

Almost 90 percent of imports which enter the U.S. primarily as frozen boneless beef, are ground for use in processed and ground beef products. Imports accounted for approximately 9 percent of all beef

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U.S. Distribution of Processing and Table Beef in 1978

Processing Beef	Table Beef	Total Beef Proportion

Table 2.2
U.S. Distribution of Processing and Table Beef in 1978[a]

Source	Average Yield of Beef for Processing[b]	Processing Beef[c]		Table Beef		Total Beef	
		Quantity Produced	Proportion of Total Production	Quantity Produced	Proportion of Total Production	Quantity Produced	Proportion of Total Production
	%	Billion Lbs.	%	Billion Lbs.	%	Billion Lbs.	%
Fed Steers and Heifers	20	3.5	34	13.8	87	17.3	66
Non-Fed Steers and Heifers	33	.6	6	1.2	8	1.8	7
Non-Fed Cows	86	3.7	36	.6	4	4.3	16
Non-Fed Bulls	100	.6	6	-	-	.6	2
Total Domestic:	35	8.3	80	15.7	99	24.0	91
Imported Beef	87	2.0	19	.3	2	2.3	9
Total:	40	10.4[d]	100	15.9	100	26.3	100

Source: Agnew (1979).

[a]Errors due to rounding.

[b]The average yield is the estimated percentage of each source that is processing beef, on a carcass weight basis.

[c]Includes fresh ground beef.

[d]Ground beef comprised 5.87 billion pounds and processed products comprised 4.50 billion pounds. These quantities are 57 percent and 43 percent of total processing beef, respectively.

consumed in the U.S. Australian beef exports have commonly been around 50-55 percent of total U.S. beef imports. If it is assumed that all U.S. beef imports from Australia were lean beef of manufacturing quality, then these imports account generally for around 10 percent of all processing beef consumed in the U.S. The proportions presented in Table 2.2 will vary somewhat over the cattle cycle as the composition of slaughterings of fed and non-fed cattle varies in response to relative price levels. During herd liquidation, non-fed cattle slaughterings (especially of cows) increases markedly. The supply of processing beef increases subsequently relative to table beef production, which tends to vary less over the cattle cycle. During the herd build-up phase supplies of processing beef is greatly reduced.

Some 98 percent of total U.S. meat production is consumed domestically; the remaining 2 percent is exported. The majority of domestically consumed meat is channelled through retail outlets, particularly retail food stores.[11] However, one of the most visable structural changes that has occurred in meat distribution has been the rapid growth in the food service industry (HRI). HRI trade handles an estimated 40 percent of final meat sales and this share has been increasing (McCoy, 1979). One-quarter of HRI purchases are supplied by retail stores. To the retailer, meat is a very important item, generating on average some 25 percent of total gross retail food store sales (McCoy, 1979). The

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[11] For a discussion of wholesale pricing in the livestock industry see, for example, Hayenga (ed.) (1978) and McCoy (1979, pp. 220-221).

impact of family eating patterns and the growth of the fast food industry on consumer demand are discussed in more detail towards the end of this chapter.

Although food retailing has been subject to substantial change and development many of these changes and developments have not been recent ones. The development of the system of retail chains gained its greatest momentum in the 1930's and 1940's. Their initial raison detre was in attaining some management control over supplies. With chain growth and mass purchasing economies, came gains in bargaining power. The second major development was the supermarket, also a product of the 1930's and 1940's. The emphasis was on economies of size in terms of volume. By the late 1950's and early 1960's, food retailing was highly concentrated, dominated by a few national and several regional chains.

The growth in fast food outlets has been a most prominent development in meat retailing in the U.S. over the last two decades (Schmelzer, 1981). Hamburger restaurant growth has been evident but so has growth in fast food steakhouses. Much of the growth in these franchised, chain operated, ready-to-eat food establishments has been associated with an increasing preference of consumers to eat more meals away from home. Away-from-home eating has increased both in terms of the proportion of the food budget spent on such meals and the proportion of meals eaten away from home. Beef, especially ground beef used in hamburger patties, forms a major component of fast food meals and forms a sizeable proportion of total sales value.

Vertical integration by retailers is not a major factor in the structure of meat marketing. A possible innovation for backward integratio

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integration by retailing firms is to establish a brand name and hence to achieve some product differentiation. While such differentiation is possible with processed meats (mainly sausages) the applications appear limited for fresh meat. For instance, distinctive packaging has not been a major factor in differentiating fresh meats[12].

Pricing of meat at the retail level is a relatively simple matter for processed products (similar to non-food items), since the product bought at wholesale is identifiable with the product sold at retail. This is not so in the case of fresh meat where wholesale cuts must be broken down to retail cuts. Shrinkage costs (losses due, for example, to trimming, spoilage or moisture losses) must be accounted for in the pricing of each cut. Perhaps even more critical is how the wholesale cut will be divided into saleable retail cuts. This will vary among carcasses depending upon conformation of the animal, degree of finish, carcass weight, degree of trim, sex and method of cutting (McCoy, 1979, p. 237). The total value of the carcass to the retailer is dependent, not only upon the retail price per pound but also upon the cut-out (i.e., saleable retail meat obtained). The characteristic that two carcasses of identical weight and grade can yield significantly different quantities of saleable meat, prompted the adoption of USDA yield grades in 1965. If a retailer can purchase beef according to rigid specifications then he is able to achieve a consistent cut-out range and hence he can more accurately match those supplies to the effective demand for various retail cuts in the store. This level of market coordination,

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[12] Some success in product differentiation seems to have achieved in retailing chicken.

though desirable, is difficult to achieve in a cyclical production environment. Not only are product specifications variable, but variable product supplies cause inefficiences at the retail level. The persistence of these inefficiencies undoubtedly encouraged such contractual arrangements as exist among Cargill, Keystone, MBPXL and McDonald's which coordinate feedlot operations with fast food distributions.

To the meat retailer, the optimal cut-out of a carcass or wholesale cuts, given the prevailing consumer demand for retail cuts, is the basis of a profitable business. However, with no detailed information on the consumer demand for individual cuts, retailers have to use considerable judgment on the prices they set for the various retail cuts. The prices of cuts which move slowly may need to be reduced before spoilage occurs. If table cuts are not moving and some deterioration occurs then they may be converted into ground beef and sold at a discounted price. Prices may be raised on cuts which are moving rapidly.

2.3.3 Consumption of Beef, Pork, Poultry, and Other Meats

A concern widely held by many participants in the U.S. beef subsector has been the strong downturn, since 1976 record levels, in beef consumption per person. This downturn stands sharply against a long-term upward trend in consumption per person for most of the post-war period. Many attempts by economists and industry analysts have been made to identify and quantify those factors determining the demand for beef and in particular, causing the recent decline in beef demand. Factors usually considered in traditional demand analyses are (a) the unit price of beef, (b) unit prices of competing meat products, namely, chicken, pork

and to a lesser extent turkey, lamb, mutton and fish, and (c) some measure of income available for purchasing these products, usually disposable income per person. Supply factors are also important since, with the exception of relatively small amounts of net imports and beef stocks, production will usually approximate consumption. More will be said later on how supply factors effect quantities of beef demanded.

However, some would argue that other factors, less easy to identify and even harder to quantify, are the key to explaining the apparent decline in the demand for beef. These other factors include longer term influences such as changing consumer tastes and preferences, changing eating habits and life-styles, and changes in the demographic composition of the U.S. population. The intention in this section is to review briefly the main characteristics of and trends in the consumption of beef, other red meats, poultry and fish, and then to analyze some of the underlying forces which are currently shaping consumer demand for beef.

2.3.3.1 Trends in Consumption

Beef and veal have accounted for between 50 and 65 percent of all red meat consumed in the U.S. As a proportion of all meat (red, poultry, and fish meats) beef usually accounted for less than 40 percent (Table 2.3). For many years, until 1976, beef consumption per person generally followed an upward path, increasing from 64 pounds per person in 1960 to a record peak of 94 pounds in 1976. The exceptional decline in beef consumption in 1973 followed a 28 percent increase in livestock prices received by farmers, the subsequent decision by cattlemen to withhold cattle for herd expansion, and the associated boycott of beef

Table 2.1
Consumption Per Person and Annual Percentage Changes in Consumption Per Person
of Red Meats, Poultry and Fish, 1960-82

Table 2.3
Consumption Per Person and Annual Percentage Changes in Consumption Per Person of Red Meats, Poultry and Fish: 1960-82

Year	Beef	Veal	Pork	Lamb and Mutton	Total Red Meat	Edible Offals	Poultry	Fish	All Meat	Percentage Annual Change: Beef	Pork	Red Meat	Poultry	All Meat
	Pounds Per Person, Retail Weight													
1960	64.2	5.2	60.3	4.3	134.0	10.2	34.0	10.3	188.5					
1961	65.8	4.7	57.7	4.5	132.7	10.1	37.3	10.7	190.8	2.5	-4.3	-0.1	9.7	1.2
1962	66.2	4.6	59.1	4.6	134.5	10.1	36.8	10.6	192.0	0.1	2.4	1.4	-1.3	0.1
1963	69.9	4.1	61.0	4.4	139.4	10.3	37.6	10.7	198.0	5.6	3.2	3.6	2.2	3.1
1964	73.9	4.3	61.0	3.7	142.9	10.5	38.5	10.5	202.4	5.7	0.0	2.5	2.4	2.2
1965	73.6	4.3	54.7	3.3	135.9	10.0	40.7	10.8	197.4	-0.0	-10.3	-4.9	5.7	-2.5
1966	77.0	3.8	54.4	3.6	138.8	10.3	43.4	10.9	203.4	4.6	-0.1	2.1	6.6	3.0
1967	78.0	3.2	60.0	3.5	145.5	10.7	44.9	10.6	211.7	1.3	10.3	4.8	3.5	4.1
1968	81.2	3.0	61.4	3.3	148.9	10.9	44.6	11.0	215.4	4.1	2.3	2.3	-0.1	1.7
1969	82.0	2.7	60.5	3.1	148.3	10.7	46.6	11.2	216.8	0.1	-1.5	-0.0	4.5	0.6
1970	84.1	2.4	61.9	2.9	151.3	10.9	48.4	11.8	222.4	2.6	2.3	2.0	3.9	2.6
1971	83.4	2.2	68.0	2.8	156.4	11.0	48.6	11.5	227.5	-0.1	9.9	3.4	0.0	2.3
1972	85.5	1.8	62.6	2.9	152.8	10.6	50.7	12.5	226.6	2.5	-4.7	-2.3	4.3	-0.0
1973	80.5	1.5	57.1	2.4	141.5	9.8	48.9	12.8	213.0	-5.8	-8.8	-7.4	-3.6	-6.0
1974	85.6	1.9	61.7	2.0	151.2	10.6	49.5	12.1	223.4	6.3	8.1	6.9	1.2	4.9
1975	87.9	3.4	50.6	1.8	143.7	10.2	48.6	12.2	214.7	2.7	-18.0	-5.0	-1.8	-3.9
1976	94.4	3.3	53.7	1.6	153.0	10.7	51.8	12.9	228.4	7.4	6.1	6.5	6.6	6.4
1977	91.8	3.2	55.8	1.5	152.3	10.6	53.2	12.7	228.8	-2.8	3.9	-0.0	2.7	0.0
1978	87.2	2.4	55.9	1.4	146.9	10.1	55.8	13.4	226.2	-5.0	0.0	-3.5	4.9	-1.1
1979	78.1	1.7	63.8	1.3	144.9	9.7	60.5	13.0	228.1	-10.4	14.1	-1.4	8.4	0.8
1980	76.5	1.5	68.3	1.3	147.6	9.6	60.4	12.8	230.4	-2.0	7.1	1.9	-0.0	1.0
1981	77.2	1.6	65.0	1.4	145.2	9.6	62.4	13.0	230.5	0.1	-4.8	-1.4	3.3	0.0
1982	77.2	1.7	59.0	1.5	139.4	9.6	63.9	13.0	225.9	0.0	-9.2	4.0	2.4	-2.0

Source: USDA data published in American Meat Institute (1982); and USDA (1983), Livestock and Poultry, LPS-4, May 1983.

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by consumers; retail beef prices rose about 20 percent that year. Surprisingly, consumption per person of the major meats, pork and chicken also declined in that year. Consumption of beef then fell by more than 18 percent to 77 pounds per person in 1982.[13]

By comparison, pork has shown considerably greater yearly variability in consumption per person. During the recent years of decline in beef consumption (1976-80), consumption of pork tended to increase, but since beef consumption has stabilized, pork consumption has begun to decline. Veal consumption has trended downward over the long term, except during 1974-77 when cattlemen marketed young calves for slaughter in response to sluggish cattle prices. Generally, it has been more profitable to mature calves for slaughter as steers or heifers than to slaughter calves. Lamb and mutton consumption has steadily fallen over the period. Red meat consumption and total meat consumption per person reflected much of the annual variation in individual meat consumption. Notably, red meat consumption has varied since 1967 within a relatively small range of 140-155 pounds per person. This, to a large extent, reflects the relatively high degree of substitutability between beef and pork over much of this period. In some respects it would seem that pork has played largely a residual role for consumers of red meat.

By contrast, there has been a pronounced upward trend since 1960 in total meat consumption reflecting the steady rise in poultry consumption, and to a lesser extent, fish consumption per person. Between 1960 and 1982 poultry consumption per person rose by 88 percent from 34

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pounds to 64 pounds; and fish consumption per person rose by 26 percent from 10 pounds to 13 pounds. Total meat (including red meat) rose 22 percent between 1960 and 1981 from 189 pounds to 231 pounds, but in 1982 it fell 2 percent to 126 lbs.

Despite the recent decline in beef consumption per person, this commodity remains for consumers the major source of animal protein. The shares of beef, pork and poultry meat in total meat consumed have varied over the past 20 years or so, however beef still commands the largest share (Table 2.4). For the first time, in 1982, the share of poultry meat exceeded the share of pork. Increases during the 1960's and 1970's in the share of poultry meat in total meat consumption were largely in response to reductions in its relative prices. Variations in the shares of beef and pork consumption in total meat consumption per person over the 20 years, also reflect changes in their respective production cycles. For example, because the production of beef closely approximates beef consumption each year, beef consumption patterns will follow changes in the beef production cycle, with prices the adjusting mechanism. Thus, the production cycle itself is a reflection of supply and demand conditions in previous years.[14]

Despite the high degree of substitutability between beef and pork, the total share of red meat in total meat consumption per person has

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[14] The 'demand-shifting force' of livestock supplies was discussed by Uvacek (1968) and will be considered later.

tended steadily downward. Apart from a small increase in fish consumption over the period since 1960, the decline in importance of red meat is largely due to inroads made by chicken into meat consumption in the U.S.

Another way of viewing changes in meat consumption is in terms of animal protein consumption. Since 1970 there has been relatively little change in total meat consumption per person (i.e., beef, pork, veal, lamb, and poultry) (Table 2.4). Despite the considerable variation among consumption levels for individual meats, total meat consumption per person since 1975 has been around 226-230 pounds. Protein from fluid milk and eggs has fallen steadily while fish and particularly cheese consumption per person has steadily risen over the past 20 years (National Cattlemen's Association, 1981). The total consumption per person of all these protein foods trended upward to 1970 but since the mid-1970's it has stabilized somewhat around 435 pounds equivalent per person. The significant point to be made from these data is that future growth in overall meat consumption may be limited, with the levels of consumption of individual meats being determined largely by their relative prices.

2.3.3.2 Price Competition from Pork, Poultry and Other Meats

The previous discussion on relative shares of meats suggested that there exists competitive interrelationships among the price of beef and the consumption of other meats, especially pork and poultry. Figure 2.4 illustrate such substitutability between beef and pork and between beef and poultry meat. Simply, in periods of relatively high beef price

Table 2.4
Shares of Beef, Pork and Poultry Meat, and Red Meat Consumption in Total Meat Consumption Per Person: 1960-82

Product[a]	1960	1965	1970	1975	1980	1981	1982
				Percentages			
Beef	34.1	37.3	37.8	40.9	33.2	33.5	34.2
Pork	32.0	27.7	27.8	22.6	29.6	28.2	26.1
Poultry Meat	18.0	20.6	21.8	21.8	26.2	27.1	28.3
Other[b]	15.9	14.4	12.6	14.7	11.0	11.2	11.4
Total:	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Red Meat[c]	71.1	68.8	68.0	64.3	64.1	63.1	60.3
Other Meat	28.9	31.2	32.0	35.7	35.9	36.9	39.7
Total:	100.0	100.0	100.0	100.0	100.0	100.0	100.0
				Pounds Per Person			
Total:	188.5	197.4	222.4	214.7	230.4	230.5	225.9

Source: Derived from Table 2.3

[a]Retail weight.

[b]Includes veal, lamb and mutton, edible offals, and fish.

[c]Includes beef, veal, pork and lamb and mutton.

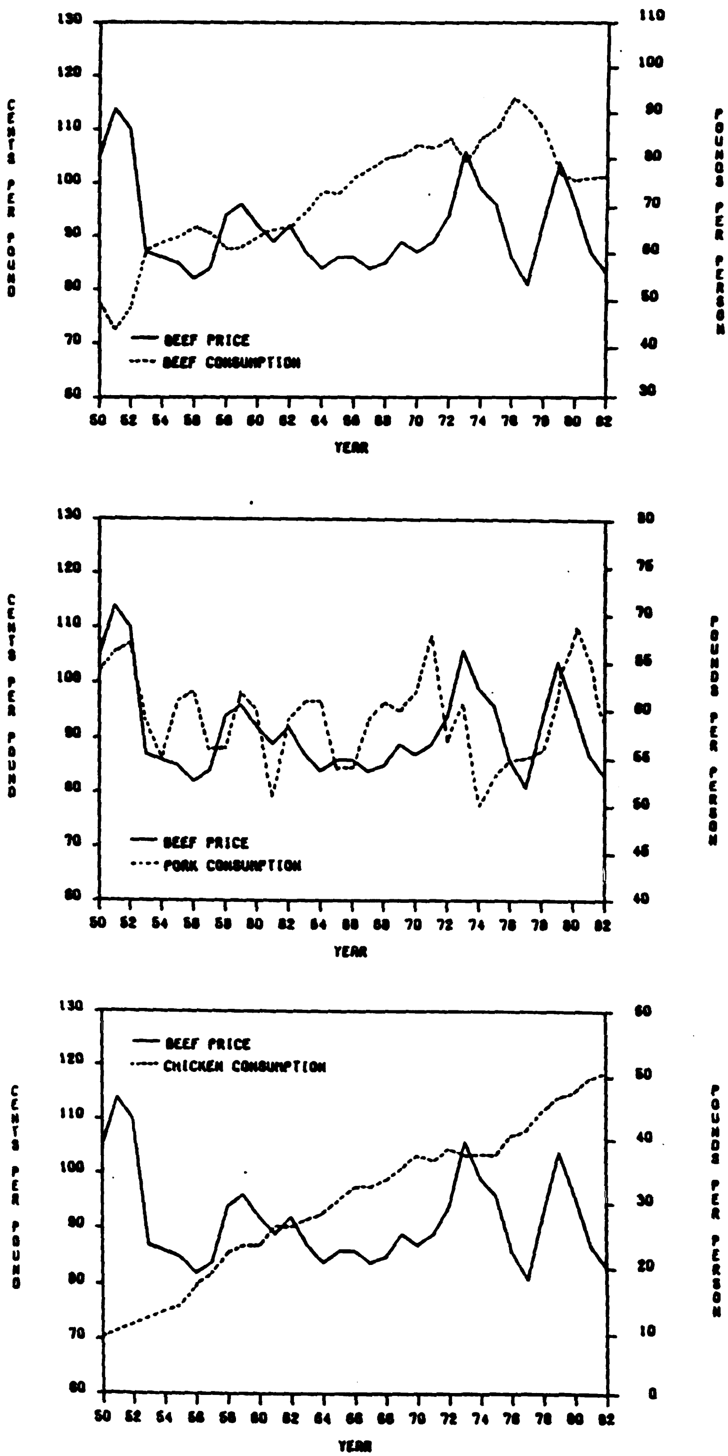

Figure 2.4

Relationship Between Beef Consumption Per Person and Beef, Pork and Chicken Prices rises, cons

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rises, consumption of beef will decline and demand for pork and poultry will rise.

In terms of quantities consumed per person beef has been preferred over other meats by U.S. consumers. Pork is the next most important meat consumed, followed closely by chicken. However, it is expected that consumers of beef are more responsive to competing meat prices during periods of tight budgetary constraints. This would seem to explain a large part of the reduced consumer demand for beef over the past few years. Real disposable incomes per person declined and rises in retail prices of beef made beef less competitive with the relatively lower priced pork and poultry meats.

Over the last 10 years to 1982 the undeflated retail price for beef (choice) increased by 70 percent compared with 117 percent for the CPI (all items), 99 percent for the CPI (all foods only), and 61 percent and 20 percent for pork and poultry (broilers), respectively. However, the real damage to beef's competitiveness occurred over the last three to four years. Between 1977 and 1981 retail beef prices rose by 63 percent compared with 59 percent for the CPI (all items) and 49 percent for the CPI (all foods only). Over these years retail pork prices rose by 40 percent, and retail poultry prices rose by only 19 percent. As a consequence, meat price relativities have moved sharply against beef. These trends can be seen from Figure 2.5. In the early 1950's the retail price of chicken was around 80 percent of the beef price compared to 30 percent in recent years. Large supplies of relatively cheap pork and poultry meat substantially eroded the demand for beef at the retail level. Another factor which has contributed until recent years to the

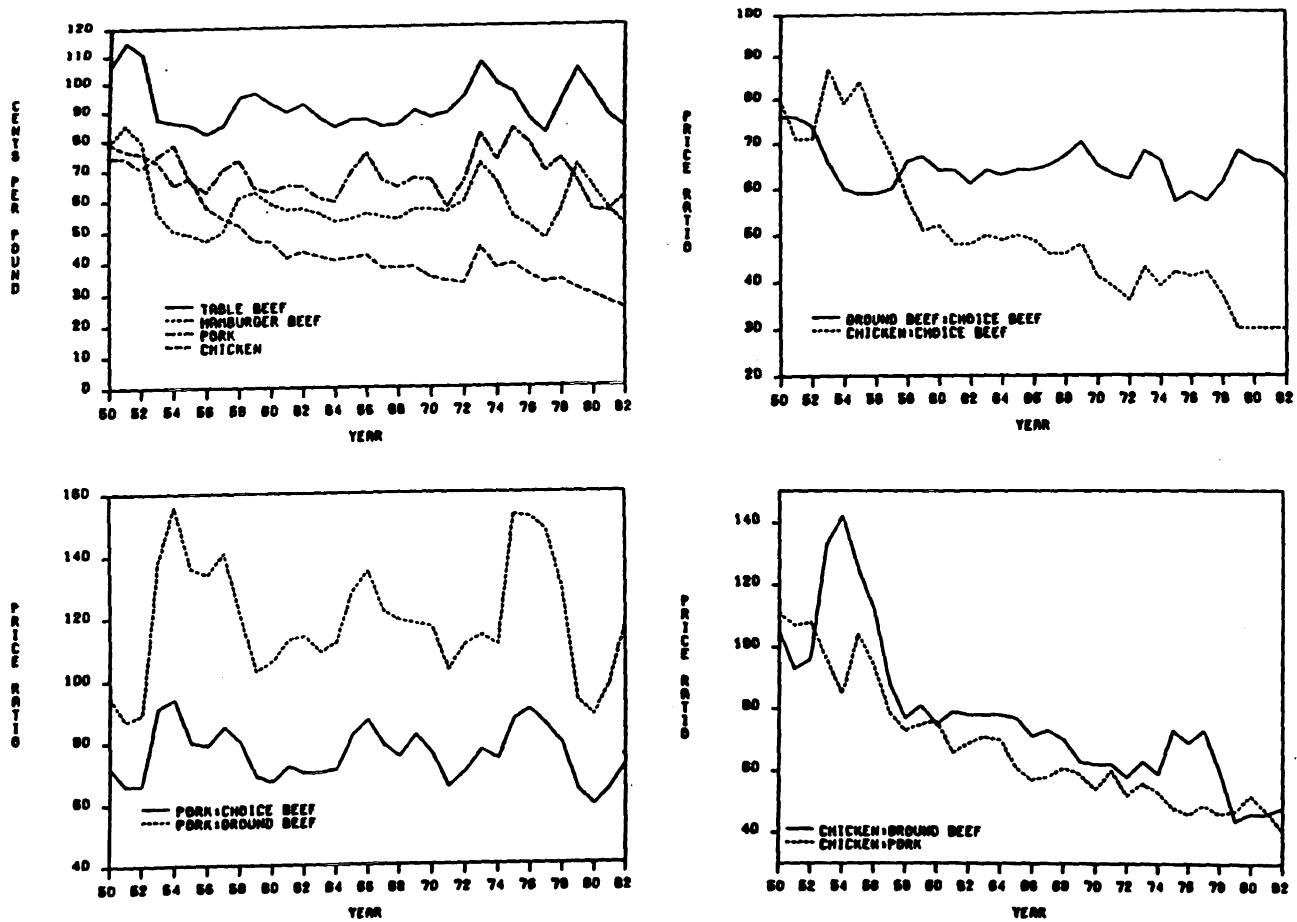

Figure 2.5

Retail Price Relativities of Table Beef, Hamburger Beef, Pork and Chicken widening S

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widening spread between beef prices and particularly chicken prices has been that production and distribution efficiency have increased more rapidly in the poultry industry (and, to a lesser extent in the pork industry). This has made possible a steady decrease in real chicken prices. Notably, for chicken this price spread with beef has levelled off more recently at 30 percent, possibly suggesting that these production and distribution efficiency gains achieved in a highly industrialized chicken industry have begun to diminish. The potential of the comparatively traditional beef industry to achieve such gains for itself seems quite limited, at least over the short term. However, the beef industry can be expected not to lose further ground it terms of its price competitiveness with chicken (and pork, whose position in this regard lies somewhere between that of beef and chicken).

Later in Chapter 4 an attempt is made to estimate the responsiveness of demand for beef to changes in the prices of competing individual meats. Much of the past research on the U.S. demand for beef provides estimates only for the combined effect of competing prices on the demand of beef. A recent exception by Haidacher et al. (1982) indicate that on average the U.S. consumer decreases consumption of red meat by almost 7 percent for every 10 percent increase in the price of red meat, ceteris paribus. Also, consumption of red meat per person increases by one percent per every 10 percent increase in the price of poultry meat, ceteris paribus. More specifically, the results of this study indicated that beef and veal consumption per person in the U.S. decreases on average by 6.5 percent in response to a 10 percent increase in the retail price of beef and veal, ceteris paribus. Moreover, beef and veal consumption per person is estimated to increase by one percent and 0.4 percent for every percent

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10 percent rise in the retail price of pork and chicken, respectively, ceteris paribus.

The cross-effects of the broader meat categories are substantially greater. For example, a 10 percent increase in the price of red meats will result in a 5.6 percent increase in the consumption of poultry meat, ceteris paribus. Similarly, the price effect of poultry meat on red meat consumption is greater than the price effect of the individual product effect of chicken on beef and veal or of chicken on pork. This would suggest that for consumers, the major meat purchasing decision is between red meat and poultry meat. Thereafter the decision is which red meat to purchase. This purchasing behavior by consumers would tend to explain the relatively higher cross-price elasticities between beef and pork and between pork and beef than exists between these products and chicken.

2.3.3.3 Disposable Income and Consumer Expenditures on Meat

Retail prices, of course, are not the only determinants of consumers' decisions to buy. Changes in the level of disposable incomes also have a significant impact on the demand for beef and, indeed, on the demand for all other items within a consumer's preference set. Consumer purchases are subject to a budgetary constraint on a budget that must be allocated among durable and non-durable goods, services and food. Demand theorists suggest that this allocation process occurs in two stages: in the first stage the consumer allocates his budget among the broad categories of expenditure, for example, food versus non-food. In the second stage the consumer allocates the food sub-budget among say groceries, P

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groceries, produce, frozen foods, meats and beverages.[15] Arguably, a third stage might involve the allocation of the meat budget among beef, pork, chicken, and other meats. A related decision is also made to consume at home versus away from home.

The level of real disposable income per person is influenced by developments in the U.S. economy. Factors include the rate of growth in the economy (GNP growth), the inflation rate (the effect on consumer purchasing power), the level and rate of unemployment, interest rates, the level of government disbursements, taxation rates, and changes in the distribution of disposable incomes. There is often a direct relationship between the level of real disposable income per person and many of these factors. The impact of these factors on food expenditures and in particular, on beef consumption, can be substantial.

Interest rate levels, for example, appear to have an influence on consumer purchasing patterns, although their impact is difficult to measure. The effect of high interest rates on consumers will be favorable when consumers act as lenders; conversely, the impact will be unfavorable when consumers act as borrowers or as purchases of products in which interest charges are a substantial component of costs. Either way, it may be argued, that the high interest rates between 1979 and 1982 are likely to have had a negative effect on consumer demand for beef. On the one hand, high interest rates will tend to attract consumer's disposable funds into saving and investment schemes and draw funds away from consumption expenditures. This will result in at least

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[15] Details of the theory of consumer demand are[20] provided in Chapter 3.

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some trading-down (i.e., purchasing of cheaper versions of a food item, e.g., moving from choice beef to hamburger or eating more at home) and in some cases in trading-out (i.e., no purchases of the item, e.g., moving from beef to chicken or meat to non-meat foods). On the other hand, higher direct costs such as home mortgage charges, and higher induced costs of food due to higher interest charges to producers, wholesalers, distributors and retailers, may result in a similar reduction in consumer demand for beef and other food products.

Real personal consumption expenditures per person on beef and other meats increased strongly during the early 1970's to a large extent in response to increases in real disposable incomes per person. The recent declines in beef and pork expenditures have been due to rising retail prices of beef and pork and a strong downturn in disposable incomes. The overall result of these recent movements in real disposable incomes and meat expenditures has been a large reduction in the proportion of consumer income allocated to beef expenditure (Harris, 1982, p. 88). From its peak level of nearly 2.7 percent in 1975, the proportion of U.S. disposable income per person spent on beef has fallen to two percent. The proportion spent on pork declined to slightly over one percent. Interestingly, the proportion spent on poultry meat has also declined, though slightly, and is at about .5 percent of real disposable income per person.

During periods of declining real disposable incomes, therefore, consumers can be expected to reduce real personal consumption expenditures, which includes expenditures on food items, especially 'luxury' food items. Most table cuts of beef (steaks and roasts) are generally considered

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considered to be of higher quality than the relatively cheaper pork and poultry meats. Therefore, demand for beef is probably more responsive to changes in real incomes than is demand for either pork or poultry meat. Similarly, demand for the higher quality and more expensive cuts of beef such as fillet steak, is more responsive to changes in real income than is demand for the lower quality beef products such as ground beef. The responsiveness of demand for beef to changes in income is measured by the income elasticity of demand. Time-series estimates of income elasticities of demand will be discussed in Chapter 4.

One aspect of the retail demand for beef which warrants further analysis is the interrelationship between retail prices and income levels over time. That is, the relatively low consumption of beef over the past few years may have been influenced by the interaction of of income constraints and relative retail meat prices. It may be hypothesized that consumers were more responsive to changes in the price of competing meats during periods of relatively tight consumer spending, as occurred in 1980 through 1982, than during periods of steady income growth, as occurred during the 1960's and early 1970's.

2.3.3.4 Some Cross-Sectional Aspects of Meat Consumption

Certain insights into the nature of demand for beef, which may not be obtained from time-series analyses, may be gained by examining cross-sectional data. Many of these insights derive from being able to keep certain factors constant in the analysis which may vary in time series analyses. These factors include income distribution, family size, age and other socioeconomic and demographic characteristics of the consumer.

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consumer. Time-series data will be used in Chapter 4 to examine the consumer demand for beef and other meats in the U.S. The purpose of examining cross-sectional data is to highlight the substantial variation that exists among consumers of meats; a variation that is masked when aggregate market data used in time series analyses.[16]

Cross-sectional data, used primarily to investigate income-consumption relationships, have been collected during various household food consumption surveys conducted in 1955, 1965-66 and 1977-78 and published by the USDA (1956, 1972, and 1982).[17] The analyzed results of these surveys have been presented elsewhere.[18] In each of these studies, estimates of 'income' elasticities were obtained. These estimates may differ depending on the form of the income measure used.

The most recent analysis of household food consumption surveys is by Haidacher, et al. (1982) who examined data from the 1977-78 survey. These data covered 32 categories of meat which included fresh and processed. Meat categories were analyzed by income quintiles, household size, consumer age group, race, region, seasonality of consumption and type of urbanization. Each of these items were in turn analyzed by

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[16] Certainly, time-series analysis would be more revealing if cross-sectional data were available continuously through time. Such data, unfortunately is not available in the U.S.

[17] The USDA has also conducted food consumption surveys on a national scale in 1936, 1942, and 1948 (urban only). Only the 1965-66 and 1977-78 surveys included all four seasons of the year.

[18] For an analysis of the 1955 and the 1965-66 surveys, see Rockwell (1959) and Rizek and Rockwell (1970), respectively. For a comparison of the 1955 and the 1965-66 surveys see George and King (1971). For a comparison of the 1965-66 and the 1977-78 surveys, see Haidacher, et al. (1982).

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quantity and value of meat consumed. These researchers then compared the results of the spring quarter of this survey with the spring quarter of a similar 1965 survey.

Relationships among selected meat categories only will be reviewed here. For instance, consumption patterns of the major meat categories, viz., beef, pork and chicken will be analyzed. Also important to this research are the patterns of consumption of table cuts of beef (steaks and roasts) vis-a-vis manufacturing quality beef products (especially ground beef). Ground beef[19] was the largest category of beef consumed per person in the 1977-78 survey, accounting for an average 37 percent of all beef eaten at home.

The level of household income, as discussed earlier, is a major determinant of meat consumption patterns in the U.S. However, there are many diverse aspects of this determinant which are simply averaged out in aggregated annual income data. For instance, consumer households in the South had after-tax incomes more than 20 percent lower than other regions in the U.S. Black households had incomes nearly 60 percent lower than non-black households. Low income households consumed at home, more meat in total, although they paid less for it per person than

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[19]Substantial confusion and misunderstanding surrounds the labelling of ground beef. The term hamburger may be misleading. Although fresh ground beef is mostly sold as ground round, hamburger, or ground chuck, it is all ground beef with different percentages of fat. The lean-to-fat ratio of the meat is the most important classificatory standard of ground beef and not from where it comes on the overall carcass. Ground round with 10-15 percent fat is the leanest category and ground sirloin is usually the fattest category. Additional fat may be added to the beef up to a legal maximum of 30 percent fat (or 70 percent lean) (Bloch, 1977).

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consumers in high income households.[20] However, these low income households consumed less red meat, less beef, and fewer table cuts of beef per person. Higher income consumers, consumed more of the high priced meats such as lamb, veal, and rib and loin cuts of beef and consumed less pork, poultry (especially whole chickens) and chuck, round, ground and other beef. In terms of quantities, low income households consumed only slightly more than high income households. However, the proportion of ground beef consumed in total beef consumed ranged from 40 percent for low income households to 34 percent for high income households.

Regional differences were found to be significant for most meat items. Most of the variation was in the type of cut of meat and, hence, in its price rather than in the quantity consumed.

The type of urbanization of the household residence also influences the choice and amount of meat consumed. Central city residents consumed and spent more in nearly every meat category than did suburban or non-metropolitan residents. City residents consumed over 90 percent more chicken parts per person than did non-metropolitan residents. This result would seem to reflect (a) the greater amount of home production in non-metropolitan areas and, hence, fewer store purchases, and (b) the greater demand for convenience in at-home food preparation by the larger number of two-wage earning households in central city areas.

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[20] All consumption data are on a per person basis unless otherwise stated. Also, consumption data in this section refers to food consumed at home. Measures of meat consumed from non-household supplied, such as schools, cafeterias and restaurants were not available and, therefore, were not included in this analysis.

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Household size was a factor which influenced meat consumption in the U.S. Small size households consumed more and spent more per person on meats than larger households in virtually every meat category.[21] Reasons for this characteristic may be that (a) small size households are usually of adults only who consume and spend more per person than households with children, which are more common in large households, and (b) two-person households are more likely to have two income earners (except for retirees), with a higher income elasticity for food and a propensity to eat more expensive foods. Age of household occupants is therefore important. In fact, differences in the consumption levels among the various age groups were significant in nearly every meat category both in terms of expenditures and quantity consumed. The heaviest meat eaters in the majority of meat categories came from the 40-64 age group. A notable exception was the 13-19 age group wherein 44 percent of total beef was eaten in the form of ground beef, compared to 40 percent in the 20-39 age group and 31 percent in the 40-64 age group. Smaller quantities, but similarly high proportions of ground beef were consumed by the youngest age groups (0 $<$ 5, 5-12). Possibly the heavy promotion and advertising associated with the rapid growth in ground beef-based fast food outlets (e.g., hamburgers, tacos) have influenced at-home consumption patterns among the younger meat consumers, in particular, the teenage group. Certainly the more expensive table cuts of beef are consumed largely by the older age groups. Other notable exceptions, consistent with the consumption pattern of ground meat are chicken parts,

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[21] Some of these differences, however, were not statistically significant, for example, as was the case for ground beef consumption differences.

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processed chicken and franks, which are eaten at home mainly by those under 20 years.

A further factor providing a considerable influence on meat consumption patterns in the U.S. is seasonality. The seasonal variation tends to be associated with weather conditions and holidays. For example, meats such as ground beef, steaks, chicken parts, franks, and fish, which are frequently cooked on outdoor grills, are consumed more heavily during the spring and summer. Conversely, meats such as whole turkeys and chickens and beef and pork roasts are more heavily consumed in the fall and winter, reflecting in particular the Thanksgiving and Christmas holiday periods. Overall, however, these seasonal variations tend to counter each other such that total meat consumption, red meat consumption and also beef consumption remained relatively stable throughout the year.

Comparison of 1965 and 1977-78 Surveys: Again drawing from the Haidacher et al. (1982) study, a snapshot of household meat consumption and expenditure patterns in 1977-78 is compared with a similar snapshot in 1965. As before, this review will focus on the major meat categories and on the within-beef categories, especially between table beef cuts and ground beef.

Data on changes in at-home and away-from-home eating patterns reveal substantial between-survey increases in the percentages of meals eaten away from home for every meal occasion, regardless of sub-grouping considered. In both surveys, meals eaten away from home increased with increasing income levels, although between 1965 and 1977 an increased percentage of meals were eaten away by lower income groups. It is likely tha

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likely that the relative cheapness and convenience of fast food restaurants may have contributed to this increase in away-from-home eating by lower income groups. Changes in consumer lifestyles and the increased proportion of young adults may also have been factors.

Comparative details of consumption of individual meat items are available only for at-home consumption. Perhaps the strongest 'trend' between survey periods was towards the more convenience-type foods such as ground beef and chicken parts, and away from the heavier table beef cuts, roasts and steaks, and away from whole chickens and turkeys (except during specific holidays) (Table 5). A further tendency was towards increased fresh pork consumption per person and away from consumption of processed pork products. Ground beef and chicken parts consumption per person rose by 51 percent and 75 percent, respectively, while consumption of table beef cuts showed a tendency towards no change or a decrease between survey periods. The proportion of the total meat budget allocated to red meat declined from 70 percent to 66 percent.

As would be expected consumption of total meats, red meats, and beef increased with increases in income level per person. Consumers in low income households increased their consumption levels of total red meats between the two surveys. There were substantial increases in ground beef consumption per person in each income group, with the largest gains occurring in the lowest and highest income groups. A similar phenomenon occurred for chicken parts, except that the largest growth was in low income groups. The negative relationship between income and pork consumption per person in 1965 was more pronounced in 1977-78.

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Table 2.5
At-Home Meat Consumption and Expenditure in the U.S., Spring 1965 and Spring 1977

	1965	1975	1965	1975
	Allocation of Meat Budget		Weekly At-Home Consumption Per Person	
	$	$	lbs.	lbs.
Total Meats:				
Nominal	124.28	252.77	4.42	4.39
Real (1967 = 100)	131.51	139.27		
	%	%	%	%
Total Meats	100.0	100.0	100.0	100.0
Red Meats	70.1	66.4	62.0	61.5
Beef	42.1	41.0	36.0	39.4
Steaks & Roasts	31.5	26.6	23.5	22.8
Ground	7.7	11.7	9.3	14.1
Other	3.0	2.5	2.9	2.5
Pork	25.1	23.1	24.0	20.5
Fresh	8.1	8.5	7.7	8.0
Processed	8.9	7.4	7.9	5.9
Bacon & Sausage	8.1	7.0	8.4	6.6
Veal	1.5	1.2	.9	.7
Lamb, Mutton, Goat	1.5	1.2	.9	.9
Poultry	11.4	12.4	18.6	19.4
Chicken	10.3	10.9	17.4	17.3
Whole	8.1	6.2	14.3	11.8
Parts	1.8	3.7	2.7	4.8
Processed	.4	1.0	.4	.9
Turkey	.7	1.6	1.0	1.8
Whole	.3	.6	.9	.9
Parts	.4	1.0	.2	.9
Fish & Shellfish	7.7	10.5	8.1	8.4
Fish	6.3	8.5	7.2	7.5
Shellfish	1.5	1.9	.9	.9
Miscellaneous	11.1	10.9	11.5	10.7
Franks	3.3	3.1	3.6	3.4
Luncheon Meats	6.3	6.4	5.7	5.5
Variety Meats	1.5	1.4	2.3	1.8

Source: Derived from Haidacher, et al. (1982, pp. 56-57)

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Most notably, for every major meat category, except chicken, the expenditure and quantity elasticities were smaller in absolute value in 1977-78 than in 1965. As concluded by Haidacher et.al. (1982), this may indicate a declining preference in the demand for meat and meat items consumed at home.

Some important problems and inconsistencies in these results and in the elasticities estimated in the Haidacher et al. study were evident. This may be in part due to the omission of away-from-home data in much of the study. For instance, away-from-home consumption of meat is thought to be considerably more income responsive than is at-home meat consumption. Nevertheless, it appears from the study that consumers are switching increasingly to the more processed, convenience-type meat items, in particular, ground beef and processed poultry items such as chicken parts, processed poultry and turkey parts. Also, most of the various socioeconomic and demographic variables analyzed were found to have had a significant influence on meat consumption, especially on an individual meat item basis.

2.4 Current Forces for Change in Consumer Demand for Meats

In the previous section it was concluded that a distinct shift seems to have taken place in the consumption per person of the major meats in the U.S. A major shift has been away from red meats, particularly beef, and toward white meats. More particularly, the transition seems to have been away from the traditional table cuts of beef, i.e., steaks and roasts, and from whole chicken and whole turkey, toward processed ground beef, chicken parts and to a lesser extent fresh pork.

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Clearly, changes in relative meat prices and income levels are major determinants of the market demand for meats at the retail level. When viewed in aggregate, these two factors explain a substantial part of the recent decline in beef consumption in the U.S. This conclusion has been reached by a number of researchers.[22] Notwithstanding this observation, some analysts of the U.S. meat markets argue that prices and incomes are not the only factors explaining this downturn in total beef consumption per person since the mid-1970's. Certain non-price influences are also considered to have had a significant impact on the retail demand for beef and other meats. For instance, changes in the demographic character of the U.S. population, changes in the distribution of incomes, changing consumer habits and tastes, shifting attitudes to health, changing preferences for convenience foods, increased frequency of eating away from home and changes in the overall beef marketing system have been credited with some of the changes in beef consumption. Indeed, some of these developments in food retailing and consumer responses may have been price and income induced. Therefore, it is within the context of changing meat prices and changing income levels that some of these other factors influencing beef demand are now considered.

2.4.1 Impact of Age Structure and Size and Composition of Consumer Households

Changes in the structure of the U.S. population appears to have had a profound influence on the consumption patterns of particular food items. There exists considerable evidence that differences in economic

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[22] For example, see Haidacher, et al. (1982) who concluded that 95 percent of the variation in quantity demanded of meat products is explained by changes in prices and income.

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behavior are systematically associated with differences in age.[23] The post-war baby boom has had and will have a continuing impact on the size and structure of age cohorts as the babies in that boom grow up and move through those cohorts. That boom began in 1946 and lasted until 1965. Thereafter a substantial drop-off in births occurred, which in time will have its own impact on consumer behavior. Therefore, people born during the baby boom years are now aged between 18 and 36 years. During the mid-1960's through the 1970's the bulk of this group would have impacted primarily on teenage-oriented markets. The group's impact on the labor force began when the group's first members reached working age in the mid-1960's. As this group swelled, the number of teenagers and young adults available for work increased and rapid growth in the labor force followed, causing unemployment rates to climb (Russell, 1979).[24] Over the next five years as the baby boom group grows older and the smaller cohorts of people born since 1965 begin to enter the work force, the character of unemployment will change further.

This will not, however, be the end of the baby boom group. Its impact will manifest itself in different ways in older age cohorts. Changes in the age structure may have important effects on both the amount and composition of consumer spending in the future. For example, it may be inferred from the previous section that an increase in the 40-64 age group relative to the 20-39 age group will cause a 20-30 per-cent increase in the consumption per person of all meats, red meats,

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[23]For a discussion of this literature, see Russell (1979).

[24]Under normal circumstances this particular group has higher unemployment rates than older workers.

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beef, chicken and fish. Similarly, greater percentage increases would occur for pork, turkey and high priced veal and lamb. Consumption of ground beef and chicken parts, highest among the 13-19 and 20-39 age group, would tend to fall as the baby boom group grows older and moves beyond their cohorts.[25] However, the logic of these conclusions rests heavily upon the assumption that as the younger consumers age and move into older age cohorts, they change from being, for example, heavy ground beef consumers to being heavy table beef consumers. This would depend greatly upon the degree to which they carry tastes and preferences into older age.

The composition and size of households also change over time. These changes affect people's spending and food consumption patterns. The decline in birth rates since 1965, the tendency towards postponement of marriage, and the rising number of divorces all point to proportionally more single people and childless couples among the young households of the 1970's and 1980's than were among those of the 1950's and 1960's. Three major demographic trends have developed concomitantly. First, there has been an increase in the number of single people, especially in the 20-40 age group and an increased number of single person households, some of which would have been occupied by old people and/or widows. Mitchell et al. (1980) estimated that on average single person households have higher per person annual incomes. Spending of food by single person households has been higher on a per person basis than multiple person households (Sexauer and Mann, 1979). They also spent nearly 100

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[25] A similar conclusion was reached by Mitchell, et al. (1980, p. 6).

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percent more on meals away from home. Second, there is an increasing number of two-income households. Third, perhaps the most significant trend of the 1970's and obviously related to the above two points, is the increasing number of working women. Between 1960 and 1980 the percentage of women who were working rose from 33 percent to 48 percent (Beef Industry Council, 1982). The last of these three development has been due to a number of factors. The baby boom contributed to a natural increase in the percentage of women eligible to participate in the work force. The recessionary economy, high unemployment and the inflationary squeeze on incomes during the 1970's and early 1980's made it necessary for many women to supplement the household income. Also, the changing lifestyles of and attitudes toward working women encouraged or at least made it possible for women to develop careers.

The effect of this trend is not straightforward since there exist many types of working women, i.e., with or without a family, professional or non-professional, or single partner and no family. The age group 45-54 traditionally has supplied the largest labor force participation rates among women. However, relative increases in numbers of working women have been greatest among those under 35 years of age (Russell, 1979). A result of these changes is that men are now doing more of the shopping (Mitchell, et al., 1980; BIC, 1982). To some extent there have been changes in the traditional roles played by men and women. This may in turn change the overall complexion of consumer behavior as it was once known. There may now be a need to know more about the shopping demands of men. For example, it is alleged that, in general, men shop faster than women.

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2.4.2 Changing Lifestyles and Consumer Health and Nutrition Attitudes Toward Meats

An overall effect of the above demographic changes has been a change in consumers' lifestyles. With more two-income earners per household, free time has become scarce and leisure time has become more valuable. With less time available for shopping purposes, eating out becomes more common or, if eating at home, convenience in shopping and food preparation becomes more important (Stafford and Wills, 1979). In turn, a derived demand has developed for time and labor saving equipment such as microwave ovens, slow cookers, hot-dog and hamburger cookers and food processors. The demand for convenience in shopping has resulted in the growth of supermarkets, superstores, and hypermarkets, which emphasize one-stop shopping.

Convenience in food preparation is usually achieved by a greater degree of food processing, as reflected in the increased demand for chicken parts, processed chicken, and ground beef in contrast to whole chickens and beef roasts. A 1978-79 survey of 166 convenience foods showed that 59 percent of these foods cost more per serving than the ingredients for their fresh or home prepared counterparts; 13 percent cost the same and 28 percent cost less (Traub and Odland, 1980).[26] On average beef convenience foods were 45 percent more expensive than their home prepared counterparts; all-beef patties were 81 percent more expensive. Pork foods were 35 percent more expensive, chicken foods were 64 percent more expensive, and chicken meat was 154 percent more expensive than when prepared at home. Although many of these processed

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[26] It was not clear from this article how labor and energy costs were allocated.

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convenience foods are, in general, more expensive, any premium paid for such processing would usually be of little concern to a two-income household. That is, for many, the convenience outweighs any shortfall in quality or additional cost.

A typical response of consumers to stagflationary pressures[27] and deteriorating real incomes such as have existed in varying degrees during the latter part of the 1970's and early 1980's, is to 'trade down' to a cheaper form of the product, to buy less of the same product, or to 'trade-out' of that particular product and buy a different, though substitutable product. Consumers (except perhaps for the very wealthy) have made this response in various ways over the past several years. As noted earlier, high beef prices or reduced consumer budgets caused consumers to buy less or trade-down from expensive steaks and roasts to cheaper table beef cuts or to ground beef. Some consumers traded out towards chicken and even towards non-meat products. For slightly different reasons, for many consumers enduring a recessionary squeeze on their incomes, the greater consumption of convenience and/or processed foods, and the increased patronizing of fast food eating places was an obligatory trading-down. For others, many of whom were up-scale shoppers, such behavior was in response to a desire for greater shopping value. The rapid growth in generic foods was manifest evidence of this desire (Anon, 1981a). Upward spiralling beef prices imposed substantial

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[27]Stagflation, a term coined in the 1970's, describes the situation when an economy is experiencing inflation during an economic recession, i.e., when economic activity is said to be stagnant but inflationary.

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cost pressures on restaurants specializing in beef menus. As a consequence, many restaurants, especially fast food places, introduced non-beef meals and sandwiches, namely chicken and fish, as a protection against the rising cost of their beef inputs (Anon, 1981b, Anon, 1981c).

Yet, clearly, no one lifestyle has been adopted by all consumers[28]. For some, priority is given to more holistic preferences and a concern with freshness, nutritional value and healthfulness. This holistic concern, itself a result of a more educated consumer, has resulted in, for example, a greater demand for product labelling. Health and nutritional concerns have become much more important to American consumers. A recent USDA survey indicated that nearly two-thirds of those surveyed said they had adjusted household diets in the past several years for health or nutritional reasons (Jones and Weimer, 1980). Weight control was stated as the main factor influencing food choice, and reducing fat intake was the major reason cited. The move away from red meats and toward white meats, some people have contended, has been in response to this concern. Recommendations by various health organizations and government agencies that meals should contain more fish and poultry (which have less saturated fat than red meats) and more lean or trimmed meat cuts, may have furthered this move away from red meats (LeBovit and Boehm, 1979; Longen and Stucker, 1980; Jones and Weimer, 1980)[29].

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[28]For a discussion of various consumer lifestyles which have helped shape food retailing in the U.S., see Mitchell, et al. (1980) and Hamm (1983).

[29]In 1977 a U.S. Senate Select Subcommittee issued 'dietary goals' which specifically recommended that consumers eat less fat, especially animal fat, to prevent cholesterol related health problems, among others. The American Medical Association has made similar recommendations.

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Nevertheless, there exists considerable controversy surrounding these recommendations. The tenor of these recommendations is probably not in question, but rather the appropriateness of these very general recommendations for healthy people. For instance, the Food and Nutrition Board of the National Academy of Sciences recommended in a recent report, Towards Healthful Diets (1980) that only sedentary people attempting to achieve weight control should be advised to reduce fat intake. The Board made no specific recommendations about dietary cholesterol for healthy persons.

Another institutional concern held in some quarters is the feeding of antibiotics to farm animals, especially to beef cattle (Burbee, 1980). Almost one-half of all antibiotics produced in the U.S. in 1978 were administered through farm animal feeds. They are used to control animal diseases and ostensibly to promote growth. Opponents of their use state that the offending organisms develop resistance to the antibiotics, raising the possibility of organisms, now safe to humans, transferring their resistance to harmful organisms that could infect humans and/or farm or wild animals (Roberts, 1979).

A ban on antibiotics would reduce meat supplies and raise prices to consumers (Burbee, 1978). Meat consumption would fall, albeit slightly, although with relative price inelasticity of meat demand, gross revenue to farmers would rise. Higher farm income from the ban may increase meat supplies but it may take some time before supplies reached their original

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original levels[30]. On the other hand, current adverse attitudes towards the healthfulness of meat may already be reducing meat demand. Such drugs are the most frequently detected chemical contaminant in meat (Roberts, 1979). However, to conclude that drugs (antibiotics and sulfur drugs) administered to beef cattle account, at least in part, for the recent decline in beef consumption may be premature. These drugs are as frequently detected in poultry meat, and poultry meat consumption has risen markedly.

2.4.3 Consumer Preferences and Beef Grades

Despite reservations about certain attributes of meat, in particular beef, consumers have indicated a strong preference for beef. A study conducted in 1975 on consumers' perceptions of benefits of meat items scored beef highest in nutrition, ease of preparation (convenience factor) and family taste (Sun, 1979). On price, beef scored worse than poultry and fish but fared better than pork and shellfish. On nutrition, poultry also ranked behind fish, second in ease of preparation and

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[30] A proposal is presently before the Food Safety and Inspection Service, USDA to require that countries exporting meat to the U.S. submit their product to a residue testing program. The proposal requires that the standards applied to imported meat and meat products be at least equal to those applied to the domestic U.S. product. However, the potential for this proposal to be essentially a non-tariff barrier to meat imports is reflected in the catch-all sentence that 'testing would be required only for those substances known to be in use in the production of meat and meat food products in the particular exporting country or otherwise known to be present in the environment of such country' (Office of the Federal Register (1982)). The arbitrariness of the interpretation and hence the impact of this proposal is obvious. For instance, since most antibiotics are used in feedlot cattle and most beef imports are range fed, antibiotic levels are not in question, but of course, any other substance may be questioned.

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in taste, but best in price. These attitudes may have changed since 1975, a year of high beef prices.

Some researchers have argued that this change may have in fact occurred as reflected by the change required in the role of the meat department in supermarket stores (Allen and Pierson, 1980). There has been a substantial change in the format of stores retailing food in the U.S. The move has been away from the traditional supermarket which has relied on the meat department to generate store profits. A proliferation of new products, new packaging concepts and marketing formats has caused fresh meat sales to lag behind other food product sales. Today's consumer is oriented toward improved value, greater convenience, a desire for more information and change. This change demands a rethinking of product development, packaging and merchandising of meat. There is a need for consistency of trim, thickness and eating quality, and for better information on preparation. There also exists a need to develop new packaging systems. Boxed beef marketing has been a major development in this direction. Other trends which have not yet run their course include the growth in boneless cuts, the expanded variety of meat cuts, family packs, 'chub' packs for ground meats, and microwave-ready meats. UPC (Universal Product Code) scanning has not yet made a major impact on beef retailing but can be expected in the future to provide detailed information of demand for individual meat cuts and to facilitate a closer matching of supply and demand for meat at the retail level (Walsh, 1977). Given this information, retailers will be able to more accurately determine the most profitable carcass cut-out, and provide consumers with a product which more closely meets their particular demands.

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Another, perhaps more direct way of meeting the specific demands of consumers for meat products is to market a product more closely tailored to consumer requirements. For a number of years evidence has emerged in various forums by various participants in the beef marketing system that consumers want leaner and less expensive beef. Literature supporting this observation has already been cited. Allen and Pierson (1982) quote the experience of Safeway, the nation's largest retailer. Safeway feels it successfully shifted from the USDA choice grade of beef, which for decades was the focus of its merchandising program, and now sell mainly leaner, no-roll beef products. The means of providing this differentiated beef product is to develop meaningful beef grades.

The issue of beef grades in the U.S. has had a relatively long and tempestuous history which will not be entered into here[31]. The central aim of grading is to improve pricing efficiency, the accuracy of identification of product value, and overall production efficiency. Not all beef is graded. In 1980, 56 percent of the commercial beef supply was graded; 75 percent of beef cattle were federally graded (Burbee, 1982, p. 17). Of that beef graded, 5.9 percent was graded Prime (the top beef grade), 89 percent was graded Choice, and 4.3 percent was graded Good. Most beef that might have been graded U.S. Good or Standard was not graded. Grades designate differences in color, tenderness, juiciness and flavor. Therefore, grading would seem to be closely tied to consumer preferences. Grade standards must be adjusted from time to time to accommodate new technologies for raising cattle, new techniques for

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[31]For some of this background see Nelson (1977), McCoy (1979) and references contained therein.

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evaluating beef quality, changes in economic conditions, and shifting consumer tastes and preferences. Changes in grades have implications throughout the entire beef marketing system from producers to consumers.

If grade changes achieve their objectives and truly reflect consumer preferences with respect to palatability (eating quality) and value, then a structural change in the demand for beef will occur. Theoretically, the increased utility from the consumption of beef will shift the demand curve for beef to the right, ceteris paribus; otherwise no significant change will occur. Researchers have attempted to test for this response following the 1976 Federal grade changes (Purcell and Nelson, 1976; Nelson, 1977). Virtually every study on consumer preferences for beef has shown a clear preference for leaness in meat appearance. Partly in response to this preference, the 1976 grade changes were designed to decrease the degree of marbling to qualify a carcass for Prime and Choice grades and hence, increase the proportion of carcasses grading Choice and Prime. Nelson (1977) examined monthly data on beef consumption by grade covering a period before and after the introduction of grade changes. Using a zero-one dummy variable for before and after grade changes, no significant response was found; that is, no shift in the demand for beef resulted from the grade changes. The study's results indicate that the grade changes achieved the objective of widen

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of widening price differentials between quality-yield grade combinations, suggesting that between grade price spreads had increased[32]. Nevertheless, there was little evidence found in that study that time spent by cattle in feedlots had been reduced and hence reducing production costs or that today's beef cattle are leaner than those graded under the previous standards (Burbee, 1982)[33].

The dilemma which faces those charged with designing the optimal system of beef grades is, as many studies have shown, the large amount of confusion and unfamiliarity which consumers generally have with USDA beef grades (Smith and Weimer, 1980)[34]. The main confusion or contradiction exists between preferences as revealed in sensory tests (eating tests) and preferences as revealed in visual tests. Visual tests indicate a preference for leaner grades at equal prices or even with price differentials against beef[35]. On the other hand, eating preferences were very rarely revealed for the leaner grades. Despite the apparent inconsistency, this result does show some identifiable characteristics,

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[32]With more beef of grade Good being graded as Choice beef, consumers became concerned at the time of the grade changes, that they would be paying the same Choice prices for beef formerly graded lower. It was a question of whether producers' savings in producing less costly beef would be passed on to consumers. Price differentials widened, i.e., implying product differentiation, but beef demand did not increase.

[33]More beef has been graded Choice since 1976, however, since grading is voluntary, a simple comparison of the grade distribution of the officially graded carcasses grossly misrepresent the grade distribution of all beef carcasses.

[34]See also for example, McCoy (1979), Reidy (1980), and Purcell and Nelson (1976).

[35]This result was obtained almost 30 years ago by Kiehl and Rhodes (1956). The same conclusion was found in survey results published in 1980 (Smith and Weimer, 1980).

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such as preference for leaner cuts and a positive relationship between marbling and palatability. Certainly, some of the misconceptions and confusion could be alleviated by improved consumer knowledge and marketing information, as well as further refinements in the beef grading system[36]. Part of the problem may be that consumers have begun to lose confidence in the grading system (Burbee, 1982). Although consumers have been informed for years that Prime is superior to Choice which is superior to Good, many consumers, concerned with their nutrition and health, want tender, juicy meat which is nearer in leaness to the 'lower' grades of Good and Standard. Essentially, this means that producers, packers and retailers have yet to market a product which satisfies the demands of the final consumer in the marketplace[37].

2.4.4 Changes in Family Eating Patterns and Growth in the Fast Food Industry

In analyzing the U.S. meat market, it is worth remembering that there is no such person as an average consumer. Part of the failure of beef marketing has been the absence of any targeting of promotion and advertising to specific consumer segments which will provide the greatest return for the marketing effort expended[38]. The diversity

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[36] See Veblen (1977) for an overview of these and other problems existent in the U.S. beef system.

[37] Currently, alternative beef grading standards are being examined by the Agricultural Marketing Service of the USDA. Proposals have been submitted by, among others, the National Cattlemen's Association and by the Community Nutrition Institute. For details of the main alternatives see Burbee (1982).

[38] This specific issue was addressed in 1981 by the Beef Industry Council of the National Livestock and Meat Board. The Council assigned a marketing consultant the task of developing a marketing strategy, including national advertising and promotion for the purpose of 'returning the beef industry to profitability.' This strategy is contained in Beef Industry Council (1982).

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among consumers of beef and other meats is evident from consumer attitudes towards fresh versus processed foods. For instance, for many consumers fresh foods are more attractive from a nutritional and health standpoint. However, for the most part, the trend toward convenience is essentially a trend toward processed and/or frozen foods. Hence, one can expect demand by consumers to move toward a variety in foods which is tailored more towards a range of diets and lifestyles. Many of the demographic and socioeconomic changes among U.S. consumers reflect this tendency. In particular, developments in family eating patterns are a consequence of the collective impact of many of these changes. This impact on the demand for beef and other meats is likely to be of a longer term nature. For example, in many dual income households, breakfasts as a weekday meal have all but disappeared -- hence, the consumption of breakfast meats like bacon and sausages has declined. Moreover, with a family of four or more, it is usually cheaper to prepare meals at home than it is to eat out at a restaurant. However, with the trend toward smaller families and working parents, eating out becomes more attractive. A parallel development of these trends is a decline in the traditional family (i.e., housewife, employed husband, and children) and the traditional sit-down family meal. This particular trend explains much of the decline in per person consumption of beef and pork roasts, and whole chickens.

A major characteristic of the change in eating patterns in the U.S. has been the increasing proportion of the consumers dollar spent on meals away from the home (Figure 2.6). Over the period 1970-80, with


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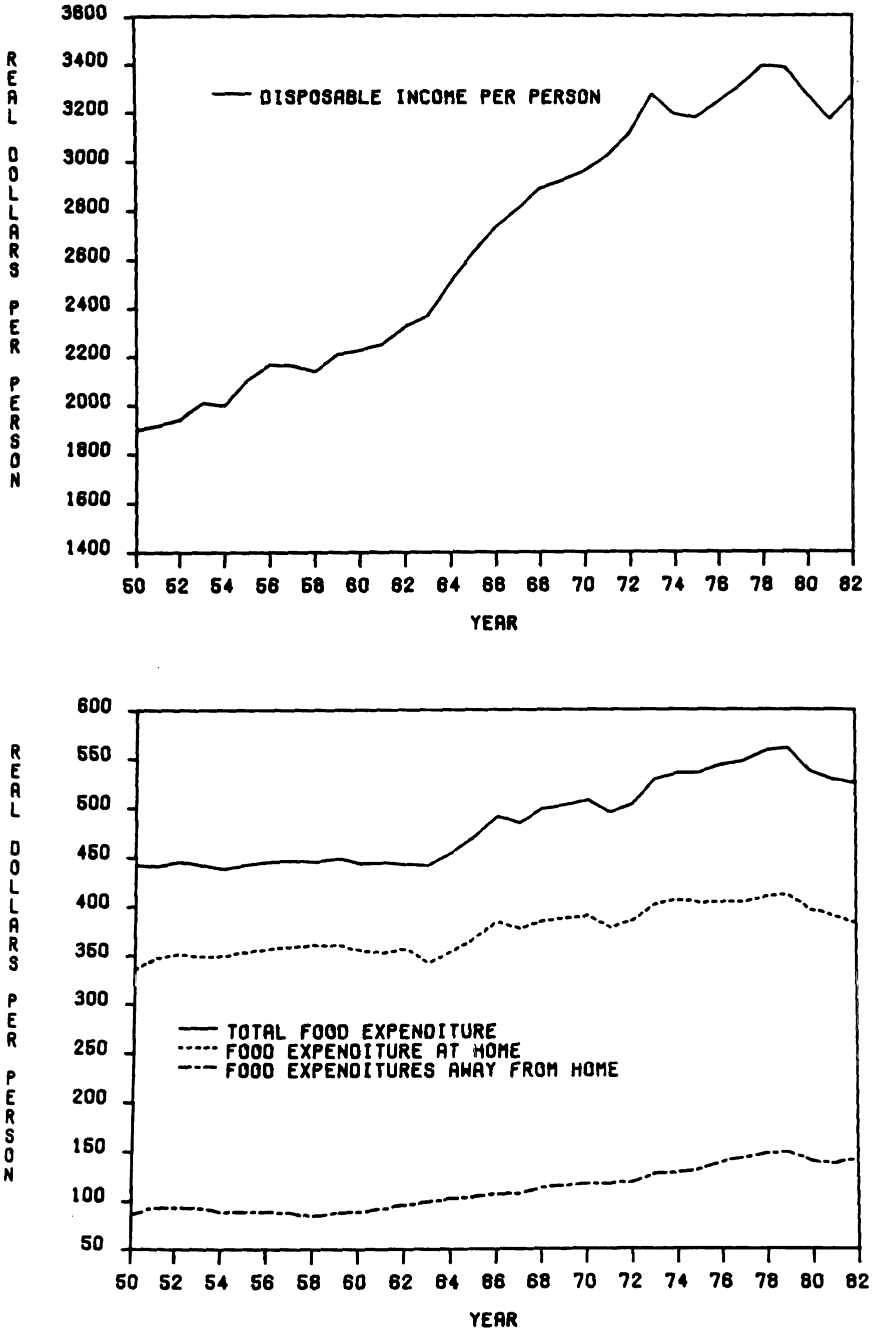

Figure 2.6

Income and Expenditures for Food at Home and Away From Home the excep

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the exceptions of 1974 and 1980, expenditures per person on food consumed away from home increased at a rate faster than expenditure on food for consumption at home (Gallo, 1981). As a result, expenditures per person on food consumed away from home increased its share of total food expenditures per person from 23.2 percent in 1970 to 26.5 percent in 1980. Some of the reasons for this result have already been mentioned; i.e., increased purchasing power in dual income households, greater value placed on leisure time and relative cheapness in feeding a smaller sized family.

With an increasing number of consumers eating away from home the food service industry experienced, especially since the early 1960s, a rapid growth in sales (Schmelzer, 1981). Much of this expansion was due to the rapid growth of firms in the fast food industry (i.e., McDonald's, Burger King, Wendy's, Kentucky Fried Chicken). Business census data show that between 1958 and 1978 real sales in food stores and eating places[39] increased 44 percent and 83 percent, respectively (VanDress, 1980). Real sales in fast food places increased by 305 percent over this period. Moreover, fast food restaurants currently account for around 45 percent of the total number of eating places.

The growth of the fast food industry in the late 1960's and 1970's brought about a rapid rise in consumption of ground beef and has been largely responsible for the generally strong demand for imported beef over the past 20 years. Most of the lean beef imported from Australia

[39]Eating places include restaurants, cafeterias and fast food places which together account for about three-fifths of expenditures for food consumed away from home. Fast food outlets are the fastest growing segment of the away-from-home market.

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is consumed through the fast food industry. Commonly, 30 to 40 percent of all beef consumed in the U.S. is in the form of manufacturing quality beef (American Meat Institute, 1982, p. 17). Ground beef is the major component of manufacturing quality beef and has comprised regularly around 64 percent of all manufacturing quality beef. Ground beef is used to manufacture hamburger patties and is sold primarily through fast food outlets, although ground beef is sold also at retail food stores for meals prepared at home.

A factor having a major influence on the share of ground beef and other processed beef products in total beef consumption is the beef production cycle. In addition to a weakening of demand for beef during 1980 through 1982, the current relatively low level of beef consumption per person is a partial reflection of the cattle industry being near the low point of its production cycle. Moreover, the proportion of ground beef in total beef consumption is generally highest when ground beef prices are lowest relative to table beef prices, as occurred for example during 1975-77. These years coincided with peak beef cattle slaughter and beef production and a period of low producer prices. The combination of an excess supply of beef cattle (a peak in the cattle cycle) and low producer prices, resulted in the liquidation of many breeding cows, reduced grain feeding of cattle in feed lots, and the related diversion of large numbers of cattle as non-fed, lower quality beef. With this influx of manufacturing quality beef, ground beef prices tend to fall relative to choice beef prices, and hence, ground beef consumption rises.

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Satisfaction among consumers with ground beef has shown to be generally high (Smith, 1978). It does, however, face competition for the consumer's dollar. There appears to be two, though not unrelated, levels to this competition for the consumer. For away-from-home consumption, ground beef predominantly used in hamburger-type sandwiches, faces its strongest competition from fast foods like chicken and fish sandwiches. Sun (1979) argues that much of the growth in fish consumption has been due to growth in fast food places, which have recently accounted for some 60 percent of total fish consumption. It would seem, therefore, that a large part of the increased consumption of fish has been due to increased eating away from home plus an increased convenience in fish products purchased for home cooking. Hamburgers, per se, compete also with a number of products which contain, in varying degrees, ground beef, for example, tacos, pizzas. For home consumption, ground beef competes more directly with chicken (whole and parts), turkey and beef and pork cuts of meat. The increasing number of salad bars in many fast food places is likely to compete with hamburgers and other meat sandwiches. However, at home salad vegetables are more likely to have a complementary relationship.

A development in meat processing which may have contributed to the decline in hamburger meat and beef sausage/frankfurters consumption per person since the mid-1970's was the successful introduction of minced chicken and turkey in frankfurters. The inroads new processed chicken and turkey products have made into traditional domains of beef (and to a lesser extent pork) are reflected in the increased market share of poultry franks, from 5.2 percent to 10.1 percent of the frankfurter market between 1978 and 1980 (Sun, 1982). Beef's share declined over this period f

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period from 38.8 percent to 28.9 percent of that market. Price changes during this time contributed to much of the shift in market shares; the price of beef franks rose on average by 5.8 percent while chicken frank prices fell by 2.2 percent. In fact, it was high beef prices, falling consumer demand and an attempt to product differentiate which led to innovations such as the textured vegetable protein blended hamburger during the mid-1970's (Weimer, 1976). This product failed primarily because of adverse consumer perceptions about blended meat products.

Over the last few years the rate of growth in the food service industry and to a lesser extent in the fast food segment of that industry, has slowed appreciably (National Restaurant Association, 1980). This slower growth has been due mainly to the decline, in real terms, in expenditures per person on food for consumption away from home of 5.6 percent in 1980 compared to a 3.5 percent reduction in expenditures per person on food for home consumption. This is consistent with cross-sectional data that indicate that expenditures on meals away from home increase with increases in income per person. Therefore, reduced economic growth which reduces growth in real disposable incomes has had an adverse effect on sales in the food service industry. Interestingly, these periods of slower economic growth coincide with periods of reduced demand for imported beef. Hence, it would seem that sales of food for consumption away from home are affected before sales for home consumption are affected[40].

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[40]Apart from the lagged relationship implied here, expenditure elasticities of demand for food eaten away from home, are likely to be greater than those elasticities for food eaten at home.

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There are other reasons to believe that the trend toward eating away from home may steady or even decline in the future. In recent years growth in the fast food industry has tended to plateau despite attempts to vary the menu offered. The apparent maturing of this industry may reflect the aging of the baby boom group and its 'move' beyond the teenage years, years of greatest per person consumption of ground beef, chicken parts and processed chicken. Moreover, the present teenage cohort reflects the post-boom decline. Another factor slowing the growth in away-from-home meals is that the children of the baby boom are having families of their own. This, in many ways belated baby boom will tend to decrease the number of single and dual income earning households and can be expected to lead to more meals being eaten at home. Moreover, with the increased sale of food products with convenience in home preparation, there will be less incentive to eat meals away from home. Fast food and other restaurants have already begun to move against some of these adverse trends. They have expanded menu selection, increased promotion, changed services and redesigned their premises with an aim to attract families and the older customer (VanDress, 1980).

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CHAPTER 3

THEORETICAL FOUNDATIONS OF CONSUMER DEMAND AND APPROACHES TO THE ESTIMATION OF STRUCTURAL CHANGES

The study of consumer behavior generally is undertaken within the neo-classical paradigm, the foundation of which is the theory of the utility-maximizing behavior of individuals. In empirical work the static theory of consumer demand often forms the basis for specifying market demand. In this section this theory will be reviewed briefly for the purpose of providing a basis for subsequent discussions of the identification and measurement of structural changes in consumer demand. Also, since changes in consumer preferences, tastes and habits appear central to an understanding of the nature of structural changes, their role in demand theory will be discussed.

3.1 Traditional Theory [1]

The theory attempts to explain the problem of choices faced by an individual consumer with given prices, income, tastes, preferences and habits. The consumer will choose the most preferred combination of goods (and services) in such a manner that utility derived from their consumption or a combination of them is maximized. The behavior follows from the assumption of consumer rationality. Utility associated with the consumption of each good requires that the underlying preference

[1] Brown and Deaton (1972, p. 1148) consider that by 1939 most of the strengths and weakness of what we may call classical demand analysis had been probed and most of the techniques still in use had been discovered.

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relationships of the individual satisfies certain behavioral actions (George and King, 1971, pp. 4-5). More specifically, an individual consumer is assumed to possess a twice differentiable continuous quasi-concave utility function defined over a finite commodity space:

$$u = u(q_i) \qquad i = 1,2,\ldots,n \tag{3.1}$$

That is, a consumer makes a choice of quantities of various goods, q_1, q_2, . . . q_n, from a goods space with n elements. This utility function is assumed to be maximized subject to a fixed or known budget or income constraint in each time period. The consumer's budget constraint is:

$$\sum_{i=1}^{n} p_i q_i \leq y \qquad i = 1,2,\ldots,n \tag{3.2}$$

where unit prices of these goods are p_1, p_2, ...p_n, and y is the consumer's income or budget constraint.[2] This maximization process yields a set of demand functions of the form:

$$q_i = q_i(p_i, y) \qquad i = 1,2,\ldots,n \tag{3.3}$$

From these demand functions a number of important relationships or properties may be obtained on differentiation of the first order conditions (George and King, 1971, pp. 8-10). These properties which are in fact restrictions on the nature of the demand relationship, include the

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[2]The inequality sign is a more general notation, however, for the present purposes an equality sign will suffice.

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homogeneity condition, the symmetry restriction and Engel aggregation or adding-up restrictions.[3] The easiest way to impose these general restrictions simultaneously is to derive the system of demand equations from a specified utility function. This will provide demand equations for which all general restrictions are automatically satisfied (Phlips, 1974, p. 55). The cost of this approach, however, is a loss of generality implied by the choice of the particular utility function. The alternative is to begin with the desired specification of the demand equation and impose the restrictions as constraints in the regressions. However, the cost in this case is the large computational burden requiring very sophisticated econometric methods.

A particular advantage of imposing restrictions on consumer demand is that this reduces the number of parameters to be estimated. As George and King (1971, p. 21) pointed out, the number of parameters to be estimated independently still remains large when the system of equations involves a large number of goods. However, as one is often interested in only a small subset of the consumer's consumption possibility set or even a single demand equation, this degrees-of-freedom problem may be further mitigated by the notion of separability.

Separability provides a justification for imposing a restriction on the number of distinct commodities recognized. In essence, the aim is to include in the estimated demand functions price and quantity data and treat it as if it were price and quantity data of a single commodity

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[3]Derivation of these restrictions and their implications for demand analysis are concisely discussed in George and King (1971) and in many texts on consumer demand theory, viz., Green (1978) and Phlips (1974), in particular.

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(Green 1978, p. 150–152). Hence, the assumption that the consumer possesses a separable utility function makes estimation of demand functions manageable. In this research the concept of strong separability is defined as:

$$\frac{\delta u_i / u_j}{\delta q_k} = 0 \qquad (3.4)$$

where $i \in$ group g, $j \in$ group m, $k \in$ group $s \neq g$ or m. This means that the marginal rate of substitution between two goods i and j, belonging to different groups, g and m is independent of the consumption of goods in any other group, s.

Inherent in the separability assumption is that consumers set aside or commit sums of money to broad general purposes, e.g., meat, dairy products, fruit and vegetables, clothing, housing, private transportation, recreation, and so on. Then, it is assumed, that consumers decide at the appropriate time on the detailed disposition of these sums (Green, 1978, p. 153). In effect the consumer maximizes his utility in two stages. In the first stage of maximization, total expenditures are allocated between s separable groups and then in the second maximization stage, group expenditures are split into individual commodity expenditures (George and King, 1971, p. 27). In practice, it is not possible to look at marginal utilities to determine the nature of separability. Often arbitrary groupings are adopted. However, for the present purposes the research results of DeJanvry (1966, p. 112) are utilized, viz., that the meat category forms a separable group within the consumer's consumption possibility set.

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Thus far the discussion of demand theory and restrictions derived from it relate to an individual consumer. That is, the maximization of an individual's utility function is subject to a fixed budget constraint giving rise to a system of demand equations upon which various restrictions are imposed. As a practical matter, as statistical data almost inevitably relate to groups of consumers, it is usual to aggregate demands across individual consumers to derive market demand functions. This in effect assumes that the demands refer to a 'representative consumer' such that aggregate demand relations may be obtained directly from the representative consumer demands. However, the conditions for doing so are very stringent and unlikely to be met in practice. For instance, the most restrictive condition is that all consumers' Engel curves are parallel straight lines.[4] Nevertheless, in defense of this approach Houthakker and Taylor (1970, p. 200) argue that 'of all the errors likely to be made in demand analysis, the aggregation error is the least troublesome.' Further, Grunfeld and Griliches (1960, p. 1) conclude that aggregation may reduce the specification error and hence produce an aggregation gain. There is no departure from this standard assumption of the representative consumer in the present research.

A long standing problem in undertaking demand analysis lies in bridging the gap between the theory and empirical work. The gap exists primarily because of restrictive assumptions used in the theory and because of inadequacies in the data base. Some of these difficulties such as identifying separable groups and the aggregation of individual

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[4]For details of the implications of aggregation see Green (1978, p. 139ff) and Phlips (1974, pp. 98-100).

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demand relationships have been mentioned above. Others, which are not reiterated here are discussed by George and King (1971, p. 20ff). There is a need, however, for further coverage of certain aspects of consumer theory which relate closely to the nature and modelling of structural changes in demand. These include the common neo-classical assumption that consumer preferences are given, the theoretical treatment of commodities or goods as opposed to characteristics of goods, and extensions of the classical static theory into dynamic models of consumer behavior and habit formation.

3.1.1 Consumer Preferences and Goods Characteristics

In the above outline of traditional demand theory, underlying consumer preferences were assumed to be given for a particular period in time. Although this assumption greatly simplifies the classical treatment of consumer behavior, it is rather unrealistic to expect preferences of individual consumers or households to remain unchanged over time or unaffected by their environment. When preferences are allowed to change, the demand system also changes. This is because the individual preferences underlie the given utility function and its properties which in turn determine the form of the demand functions.

It is not the intention here to set forth a theory which considers changing preferences or which permits maximization of an intertemporal utility function. This has been attempted elsewhere.[5] The objective is simply to provide insights into how changes in preferences might effect

[5] A theory of intertemporal utility functions is presented by Phlips (1974, Ch. 10).

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demand and what might cause such changes. Moreover, in empirical analyses and estimation of individual or system demand parameters one should be aware of the implications of the assumption of an unchanging utility function over the observation period.

There is in fact no unique time period for which the utility function should be defined but these are restrictions on the possible length of the period. Since the consumer derives utility from variety in his diet and diversification among commodities he consumes, the utility function must not be defined for a period so short that the desire for variety cannot be satisfied or too long a period that tastes (and hence, the shape of the function) may change. The (static) theory would breakdown if it were impossible to define a period that is neither too short nor too long in the above view. In essence preferences are given. Were it practicable, it may be very important to incorporate into the analysis the fact that preference ordering may change over time (or from household to household)[6].

Green (1978, p. 26ff) outlines three possible reasons preferences change;[7] namely, the effect of advertising, the choices made by other consumers, and the longer term impact of changes in price.

Effect of advertising: Essentially, a consumer's choices are determined by his preferences and those preferences are influenced by the

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[6]These changes should not be confused with shifts in text book demand curves constructed under ceteris paribus conditions.

[7]For a discussion of the current state of modelling changes in consumer preferences see Pollak (1978), Pessemier (1978) and Marschak (1978).

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information which is available to him. Lancaster (1966) developed the notion that preferences among bundles of goods are not a fundamental determinant of choice, but are derived from preferences among the bundles of characteristics supplied by these goods. This notion may be at the heart of the perceived change in preferences for beef over other meats and foods. Normally advertising is concerned with persuading consumers to switch from one brand to another brand of a particular good.[8] In the case of meat demand, the concept may be more complex since recognized brands do not exist in the market. That is, meat is homogeneous with respect to brands, although there are many cuts and types of beef meats. Advertising in meats, where it has taken place, has concentrated on 'commodities' e.g., beef versus chicken versus pork. If consumers' preference orderings are based, not on commodities but on goods characteristics, then this advertising effort may have been misdirected. If it is possible to interpret each type of meat, e.g., beef, chicken, pork or cut of meat, as goods which supply broadly the same characteristics but in different proportions (i.e., vitamins, minerals, leaness, calories and taste), then a large part of advertising may be construed as an attempt to inform people of the bundle of individual characteristics of a given good. This begs the question regarding the cause of the recent decline in demand for meat, red meat and beef, in increasing order of magnitude of that decline. Does this reflect a change in

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[8] Galbraith (1979) stressed the ability of producers to manipulate consumers through advertising to the point where an individual surrenders her consumer sovereignty to the producer or producing organization. See also Galbraith (1973) and Gintis (1972) for discussions of the broader issue of produced influence of corporations and loss of consumer sovereignty.

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preferences or a change in information? That is, it may be quite consistent for a consumer, who has a particular preference ordering for particular characteristics of a good, to shift from beef to chicken because of new or changed information that chicken provides the bundle of characteristics which maximize his satisfaction in consumption. If the unit of observation were goods then this shift may be perceived as a change in preferences, namely of the good, beef. However, by looking at characteristics, preferences are unchanged, so then the determinant of choice in this case is information.

Take, for example, a consumer with a given preference ordering for the characteristic of 'health attributes' who is at that time consuming beef. Assume a report is released, stating that beef is high in cholesterol and dangerous to ones health, and that chicken, because of its low cholesterol level, should be consumed. In response, that consumer, assuming his rationality, will shift consumption to chicken, where his given preference ordering with respect to characteristics can be satisfied. No change in underlying preferences has occurred; simply the product, beef, in the eyes of this consumer, no longer contains the bundle of characteristics which reflects his preference ordering and which maximize his utility. Characteristics, therefore, would seem to be the focal point of advertising, namely, to inform people of the characteristics or the bundle of characteristics that a consumer will receive on purchasing a particular commodity (or brand).[9]

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[9] This is a point that until very recently has been overlooked in the promotion and advertising dollars spent by representatives of the U.S. beef cattle industry, in their attempts to turn around or at best halt the decline in per capita beef consumption (Beef Industry Council, 1982).

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This point is taken further by Lancaster (1966, pp. 132-133). He argues that despite the persistence of advocates of the pure theory, market researchers, advertisers and manufacturers act as though they believe that knowledge of the intrinsic properties of goods is relevant to the reaction and behavior of consumers. He notes that the classical theory does not allow for the introduction of a new good or for the quality of an existing good to change. The theoretical, and indeed the empirical problem arises when such structural changes occur within the last few years of the observation period. In this regard traditional theory would appear to have nothing to say and hence have no predictive value. If it were possible to measure the quantities of characteristics supplied by new or improved goods then a cost of living index could be defined in terms of a representative bundle of characteristics. Such a revision of demand theory may substantially overcome present weaknesses in the classical theory, such as the assumption of fixed preferences. Preferences relating to characteristics change less over time than preferences relating to goods which supply these characteristics in different proportions. The apparent difficulty of inventing or promoting a completely new characteristic would support this assumption. The point is that under the neo-classical paradigm the only characteristic of beef is 'beefiness' and the only source of 'beefiness' is beef.

Choices by other consumers: Besides advertising, preferences may also change through the choices made by other consumers. When the choices made by others result in an increase in a consumer's purchases it is called the 'bandwagon effect'. When the result is a decrease in a consumer's purchases it is a 'snob effect'. Green (1978, p. 28 and pp. 146-148) states that these effects should be incorporated into the theory c

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theory of individual behavior when applied to market behavior. It is unclear which effect would predominate in the market for meats. To some extent a bandwagon effect has resulted in the trend away from red meats, especially beef, due to alleged health considerations. Estimators of demand functions appear to recognize these factors as a source of preference change, but typically allow for this only in a very general way. Approaches to measure such structural shifts are detailed later. Green (1978, p. 147-148) presents a theoretical model of these effects on individual demand. He assumes all individuals have identical price dependent Marshallian demand curves of the form:

$$p_i = a + bq_i + cQ_i \tag{3.5}$$

where the demand price, p_i depends on the quantity purchased by the individual consumer, q_i, and on his expectation of the total amount, Q_i, purchased by that group of consumers. It is assumed that a > o, and b < o, giving a downward sloping demand curve in the case of consumer independence. Hence, the demand price may be increased in response to an increase in expected total purchases, where c > o for the bandwagon effect, or decreased, where c < o for the snob effect. When present the snob effect, c < o, will make the demand curve slope downwards more steeply, whereas a strong bandwagon effect, c>o may turn the slope to positive.

<u>Changes in price:</u> Price is a factor which may induce a change in preferences. Price changes clearly affect choices through their effect on the set of alternative goods that the consumer can afford within his given budget. The question is whether such a commodity price change

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affects a consumer's preferences among alternative bundles. Some would argue that the high retail beef prices of the late 1970's led to a change in preferences for beef in favor of chicken or pork or non-meat food. However, the logic of this argument seems unclear. When beef prices rose to levels unacceptable to consumers, there followed the expected contraction in purchases (a movement up the beef demand curve) causing the demand curve for chicken to shift to the right. This leads to an increased consumption of chicken at the same price, ceteris paribus. If consumers then developed new habits and tastes from the greater chicken consumption then overall preferences may have changed in favor of chicken. Nonetheless, the shift to chicken following the high beef prices should not suggest a change in underlying preferences for beef at that point. Simply, the consumer could satisfy with chicken his preferred ordering of his characteristic set (in terms of calories, vitamins, minerals and so on), more cheaply and within his budgetary limitations. Preferences only changed after new habits and tastes were formed through greater consumption of chicken, ceteris paribus. This is reflected in his reluctance to increase equivalently his consumption of beef when beef prices subsequently fell. This apparent asymmetry in demand response will be investigated below.

3.1.2 Dynamic Models and Habit Formation

As noted above, the static neo-classical theory of consumer demand is based on a number of restrictive assumptions. In particular, the theory implies that the representative consumer solves his maximization problem in each period regardless of any past behavior. There have been many attempts to relax this assumption and specify dynamic models of behavic

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behavior by accounting for habit formation and partial adjustment behavior.[10] The approaches usually adopted are either to date variables in the utility function, introduce dynamic aspects into the utility function or to introduce dynamic aspects directly into the demand function. Only the last approach is considered here.

Other than specifying a time trend, dynamic demand analysis usually involves lagged variables. Examples of direct inclusion of dynamic properties into demand are the cob-web model, the distributed lag model, a first differences model of changes rather than quantity demanded, and the habit formation or inertia model of consumer demand (Intriligator, 1978, pp. 235-242). The three main habit formation models are (1) the inclusion of an exogenously determined time trend to the static model to account for taste changes; (2) the partial adjustment model, an endogenous specification which assumes that adjustment of actual consumption to desired consumption is achieved only partially during any given time period because of habits; and (3) the state adjustment model. The first approach is relatively straightforward. The last two are discussed below. Of interest in this research, in addition to an accurate fitting of a model to observed data, is the development of a model that assists in identifying and measuring changes in the structure of those demand relationships.

The partial adjustment mechanism as formulated by Nerlove (1958) is an example of a distributed lag relationship. It assumed for prices and incomes, that consumers adjust consumption towards a desired or long-run

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[10] See, for example, Phlips (1974) and Green, Hassan and Johnson (1978, pp. 93-107).

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demand and in each period only partial adjustment to the desired demand level is achieved. Therefore, if

$$q^*_{jt} = q_{jt}(P_t, y_t) \tag{3.6}$$

represents the desired demand for commodity j in period t, a Nerlovian partial adjustment scheme would result in

$$q_t - q_{t-1} = \delta(q^*_t - q_{t-1}) \qquad o \leq \delta \leq 1 \tag{3.7}$$

where represents the 'coefficient of partial adjustment.' When ε=1 the adjustment is total and immediate and gives the original static case. Expressing (3.6) in a linear form with an additive error term and combining this with (3.7) gives the estimating equation in observable terms,

$$q_t = \delta a + \delta b p_t + \delta c y_t + (1-\delta)q_{t-1} + \delta u_t \tag{3.8}$$

or equivalently,

$$q_t = A + Bp_t + Cy_t + Dq_{t-1} + \delta u_t \tag{3.9}$$

When estimated in double logarithmic form, δ is the elasticity of adjustment, B and C represent the long-run price and income coefficients, respectively, and b and c represent the short-run effects. Conceptually this model reflects the impediment to immediate consumer responses due to imperfect knowledge. As price changes, some consumers will continue to respond to past prices because of habits or institutional constraints. Although widely used in empirical analyses, this partial adjustment model has no solid theoretical underpinning (Phlips

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1974, p. 154). In fact Griliches (1967) showed that essentially the same form of estimating equation, indistinguishable from the static demand model with autocorrelated errors, can be derived from quite different constructs.

An improvement on the partial adjustment model is provided by Houthakker and Taylor (1970). Their state (stock) adjustment model, in essence, is a habit formation model[11] typically applied to non-durable goods. The basic equation is

$$q_t = \alpha + \beta p_t + \gamma y_t + \phi s_t + u_t \tag{3.10}$$

where s_t represents a psychological stock of habits and ϕ is positive, i.e., the more of a good that is consumed the more will be purchased. This stock of habits is hypothesized to change over time according to the differential equation

$$\dot{s}_t = \frac{ds_t}{dt} = q_t - \delta s_t \tag{3.11}$$

where δ is a diagonal matrix of depreciation rates or the average 'using up' of stock. Since neither the depreciation rates nor the psychological stock are observable and therefore cannot be measured, it has to be eliminated from the equation.[12] From the above equations Houthakker and Taylor derive both a continuous and a discrete state adjustment model. As all statistical data are in discrete time, nor-

[11] See also Brown (1952) who examined habit persistence as the causal basis of lags in consumer demand.

[12] See Phlips (1974, pp. 165-166) for these manipulations.

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mally a year, the discrete version is more readily applied. Hence,

$$q_t = q_t(q_{t-1}, P_{t-1}, \Delta p_t, y_{t-1}, \Delta y_t, v_t) \tag{3.12}$$

where Δ represents the discrete first difference operator, e.g., $\Delta p_t \equiv p_t - p_{t-1}$, and all other variables are as previously defined.[13]

This model, as with the Nerlovian partial adjustment model has no theoretical base, being an ad hoc procedure for incorporating dynamics and habit formation into demand functions. In particular it suffers from integribility, the problem that these demand functions cannot be derived from maximizing a known utility function. Nevertheless, it does introduce three ideas, all noted by Marshall (1920 Appendix H, 3) some 50 years earlier. These were (a) that adoption to change in price is gradual, i.e., there exists a partial adjustment, (b) that the movement along a demand curve is irreversible, when habits have developed in the meantime, and (c) that the effect of habits is positive. Parts (a) and (c) have been essentially covered above. The notion of irreversibility of demand has particular relevance to the estimation of the demand for beef and so it is discussed below.

3.1.3 Irreversibility of Demand

Some 30 years after Marshall's observations Farrell (1952) attempted to explain by using irreversible demand functions why economic variables played such a minor role in certain demand analyses[14] and

[13]An alternative form that has been tested has prices and incomes in current rather than lagged form (Reeves 1980).

[14]See, for example, Prest (1949).

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certain time and 'trend' variables play such a major role. Simply, economic variables are considerably more important in the short run, whereas in the long run social variables are more important. In the longer run people's tastes may change especially due to habit formation. 'A man who has been induced by a rise in income or a fall in the price of tobacco to take up smoking or to smoke more heavily, will form a habit, and will not, when the price or income returns to its formal level, cut his consumption to the former level' (p. 174). This is the notion of an irreversible demand function.

Farrell's simple consumption-price-income model was of the form:

$$c_t = c_t(y_t, p_t, c_{t-1}, y_{t-1}, p_{t-1}) \qquad (3.13)$$

from which he developed a more specific model. That model distinguished between and provided coefficients for rising and falling stages in the income and price observations. Although his results were largely inconclusive some evidence was provided in support of the existence of demand irreversibility.

This idea of irreversibility of demand functions was applied by Goodwin, Andorn, and Martin (1968) to the consumption of beef. A key to irreversibility in beef demand was the existence of consumption habits and a cyclical pattern of prices and consumption. A related aspect is the important distinction between short-run and long-run responses in demand. The Marshallian demand curve defines the relationship between changes in quantity demanded to changes in price, ceteris paribus. This static concept implies a reversible relationship since a price-induced change in quantity demanded is completely reversed on the return of that price t

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price to its original position. In this case the concept of price elasticity of demand is a static one. However, given a dynamic model, demand is not necessarily reversible since changes in consumer habits formed over time are not necessarily reversible. Potential confusion may arise however, where 'static' and long-run concepts of demand.

Tomek and Cochrane (1962) identified the source of this confusion as the interchangeable use in the literature of the terms 'habit' and 'tastes and preferences'. They identified habits as being formed patterns of behavior which may impede quantity adjustments to a price change. Habits are subject to change or elimination. Therefore, they are not concerned with consumer like and dislike of a product. Likes and dislikes are reflected in consumer preferences. Tomek and Cochrane (1962, p. 719) further concluded that 'changes in tastes and preferences may be regarded as structural change--that is, a change in the consumer's preference map. This change can shift the demand curves and change the structural parameters (i.e., elasticities). A change in habit affects only the rate of quantity adjustments with a given set of determinants of demand.' These authors hypothesized that of the impediments to instantaneous adjustment of consumer reactions to price changes, consumer habit may be the most important in creating lagged quantity responses to price changes. Therefore, they conclude that the long-run price elasticity for a product represents a complete quantity adjustment to a given price change where the determinants of demand are constant.

However, Tomek and Cochrane's conclusion that changes in habits are not structural changes under their definition of causing parameter changes

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changes rests a little uneasily. In a dynamic model, standard operating procedures, i.e., habits or routines, would seem more pervasive in their influence than to simply affect the own-price. Certainly habit may impede price-quantity adjustments, but habits will also impact on other consumption behavior patterns causing parameter shifts in other explanatory variables.[15] In fact, this is what happens with the irreversible demand function to be discussed below.

The consumption response associated with demand irreversibility may be illustrated as in Figure 3.1. In essence changes in demand structure are occurring between each phase or cycle of production-consumption. More particularly, the responsiveness of consumers' quantities demanded to changes in

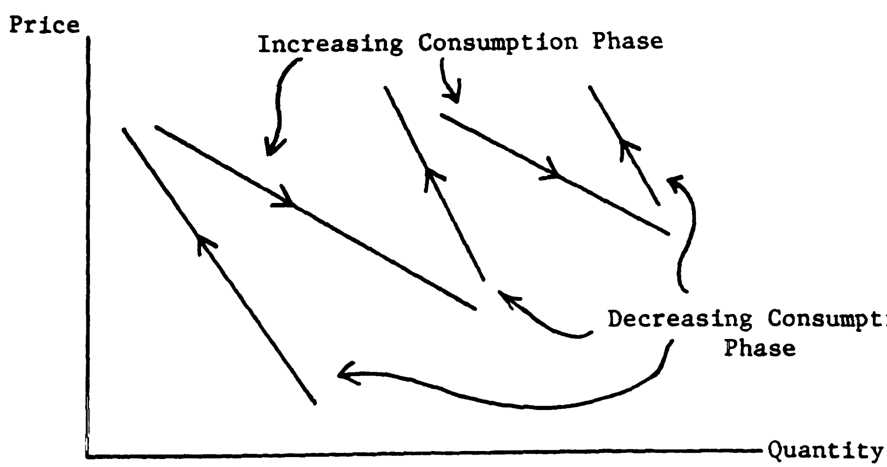

Figure 3.1
Irreversibility in Price-Quantity Relationships

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[15]Theoretical support that habits may change elasticities is presented in Pope, Green, and Eales (1980, p. 779).

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prices is hypothesized to differ on decreasing compared to increasing consumption phases. In effect this consumption response is a price induced change in tastes; similar to the situation described earlier for beef in the discussion on preferences. This dynamic response in contrast to the Marshallian static response is measured more appropriately by 'response' elasticities (Tomek and Cochrane, 1962, p. 730).

To model this phenomena, Goodwin et al. (1968) began with the equation for beef,

$$q_{Bt} = a_o + a_1 p_{bt} + a_2 p_{pt} + a_3 y_t + b_1 p'_{pt} + b_2 p'_{pt} + b_3 y'_t + u_t \quad (3.14)$$

where the quantity of beef, q_{Bt} is a function of the prices of beef and pork, p_{bt} and p_{pt}, and income, y_t. These prices and income represent decreasing quantity periods. The superscripts represent prices and income during the increasing quantity periods. Hence there is a close similarity with the specification of Farrell's (1952) model. Goodwin et al. than assume a Koyck distributed lag on all variables. The final estimating equation has current and lagged consumption, prices and income:

$$q_{bt} = q_{bt}(p_{bt-i}, p_{pt-i}, y_{t-i}, p'_{bt-i}, p'_{pt-i}, y'_{t-i}, q_{bt-i-1}) \quad (3.15)$$

for i = 0,1,2. Seasonal dummy variables were included to capture quarterly differences in beef demand. Short-run and long-run elasticities were computed for both decreasing and increasing consumption phase variables. The coefficient of adjustment suggested an immediate adjustment of consumption by consumers to a falling price but a lagged adjustment of consumption to a rising price. The latter indicated the persistence of habi

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of habits formed during the preceding phase of declining prices, implying the irreversible nature of beef demand at the retail level.

The time varying nature of structural coefficients in demand functions for beef is clearly indicated by the distinctly different short-run and long-run response elasticities in decreasing compared with increasing consumption phases. Although there is a merging of income and price effects in these response elasticities, in the short run, own-price elasticities are lower i.e., more inelastic, in periods of decreasing consumption phases (Goodwin et al. 1968, p. 25). This concurs with the hypothesis that consumers adjust consumption by less during the increasing price phase than during the decreasing price phase.

Income elasticities were higher in periods of decreasing price, indicating a stronger response to income changes in these periods. Also, price and income elasticities tended to decline over time. Goodwin et al. (1968, p. 25) explain the former as a result of a broader range of quantities being included in the relatively inelastic position of the demand curve over time, and the latter being due to a declining proportion of consumer income spent on beef given income was rising over the period.

Uvacek (1968) also noted the irreversible nature of demand curves, in particular for beef. He went further in recognizing a link between shifts in the beef demand curve and the cattle inventory phase.[16] During supply-reducing periods the demand curves are more inelastic. This timing link with consumption shifts is made possible by the high positive

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[16] See also reference to Goodwin (1965) on this point.

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correlation between the cattle cycle and slaughter levels. He hypothesized that, given the reduced role of income in explaining variations in the demand for beef,[17] the abrupt changes in demand that have persisted have had their origins in the beef production cycle.

> During the build-up phase of the cattle cycle, when larger quantities of beef are being consumed per capita, the higher incomes are utilized and the increased preferences for beef satisfied by making larger quantities of beef available to the consumer. This 'penned up' or 'accumulated' demand is utilized, not by a shift, but by a movement along the demand curve, and does not really evidence itself until beef supplies are withdrawn from the market. This situation occurs during the liquidation phase of the cattle numbers cycle, when beef supplies, in general, are decreasing. The result is a new and more inelastic demand curve during the reduced-supply periods, yielding substantially higher beef prices near the terminating years of this phase of the cycle. (Uvacek 1968, p. 1503).

The pattern of these shifting demand curves described here is identical to that illustrated earlier in Figure 3.1; namely the irreversible demand function over time. However, since Uvacek wrote these observations in 1968 the demand for beef has undergone considerable changes and has been subjected to important influences. Real disposable incomes in recent years have not moved upward at the rates of that time and perhaps, more significantly, there is evidence to suggest that preferences for beef have not continued to strengthen. On the contrary they appear to have weakened substantially. It is these changes in the structure of beef demand which are addressed in this research.

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[17] See, for example Meinken, Rojko and King (1956) and Tomek and Cochrane (1962).

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3.2 Structural Change in Demand Interrelationships

The classical theory of consumer behavior described in the previous section, provides a means of deriving demand curves, indirectly via utility maximization, in terms of relative prices and income. In practice, however, demand functions are estimated directly, for example, via econometrics, mainly because factors other than prices and income are important in explaining consumer behavior and the demand for a given commodity. Another problem with the classical derived demand functions, but also with many directly derived functions, has been typically that tastes and preferences are assumed as fixed and given. Many other important determinants of consumer behavior are also often ignored or treated cursorily, such as habit formation. In effect this treatment at times removes a major and common source of structural change in a demand relationship. Before dealing, however, with the means for identifying and quantifying structural changes in demand relationships, 'structural change' is first defined, and then placed into the problem-oriented context of this research.

3.2.1 Definition of Structural Change

In the context of demand estimation, the demand structure relates the underlying economic and behavioral relationship or model. Foote (1958. p. 213) described this structure as 'the process by which a set of economic variables is believed to be generated'. A structural change then is a change in this process. Poirier (1976, p. 1) was more specific: 'structural change will be said to occur whenever the parameters of an economic model change a "small" number of times in response to for

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to forces within or outside the model'. He draws a distinction between those time-varying parameter models in which parameters are required to continuously change over time or not at all. This distinction will be discussed further when time varying parameter models are reviewed. In this research both gradual and abrupt changes in economic structure are considered. Whether a structural change is perceived to have occurred gradually or abruptly clearly will depend upon the time interval chosen. Moreover, not all structural changes are necessarily time related. For example, on-off qualitative variables denoting the presence or absence of a population characteristic of the data such as education/no education or black/white consumers fall into this category. Although this study focuses on time series observations, these qualitative variables impact on the nature of economic relationships and therefore, are considered within the analysis of structural changes in consumer behavior and consumption patterns.

3.2.2 Nature of the Problem

As noted in the introduction to this research, much of the preoccupation with price and income elasticities of a particular commodity is founded in the classical approach to empirical work and the assumptions of the Marshallian demand curve (Brown and Deaton, 1972, p. 1149). The growth and development of electronic computing technology has made possible the estimation of complete systems of demand equations derived from theoretical considerations. Although there is much to commend this development, the attention towards the empirical testing of the models themselves has been somewhat at the expense of applied demand analysis. This does not condone the uncritical proliferation of models and paramet

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parameter estimates made possible by the computer. It does indicate the need for an improved balance in these two developments.

Directly related to the problem of estimating structural coefficients in many demand models is the assumption that the elasticities are constant for all values of the exogenous variables. Both single equation models and equation system models are subject to this criticism. Except for the shortest period in a time series this assumption would not be expected to hold. Brown and Deaton (1972, p. 1151) illustrate some conceptual difficulties with this assumption when using the double logarithm functional form for demand analysis. First, as a nation becomes richer, goods which were luxuries on average when the inhabitants were poorer, became more necessities as real incomes increase. Hence the elasticity coefficient on income would be expected to fall over time. A second more fundamental problem arises from the restriction that the elasticities are constant. If this were really so and those goods had elasticities greater than unity, then as real incomes increased, goods expenditures would eventually dominate the budget and reach the point where the sum of expenditures on each of the categories was greater than the total expenditure being allocated. Therefore, even though the model fits the data well when estimated, the results are implausible, greatly diminishing confidence in the model for forecasting.

A more fundamental indictment of the assumption of constant demand coefficients was provided by Lucas (1976). He argued that economic theory leads one to expect relationships to change over time and that the constant parameter formulation is inconsistent with this theory.

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For example, a change in policy will change the environment in which economic units operate and result in structural changes in the equations representing the behavior of those units.

3.3 Traditional Methods of Identifying and Estimating Structural Change

The objective in this section is to review the wide range of approaches now taken from both theoretical and empirical standpoints and to model structural change in demand relationships. Many of these approaches, which have appeared in the literature, have developed to a large degree, concomitantly with the sophistication of econometrics and electronic computer facilities. Simple methods may often be the most appropriate despite this computer and econometric sophistication. For this reason a broad sweep of investigatory techniques is presented from simplistic yet revealing graphical analysis to the considerably more complex continuous time varying parameter models and Legendre polynomial estimation.

3.3.1 Graphical Analysis

Some of the first indications that the underlying structure of demand for a certain commodity was changing was revealed by graphical analysis. This has long been an important tool in agricultural economics research, developed in the 1920's and 1930's, though much less used now (Waugh, 1964 and 1966). It is simply the plot of data, say, consumption versus price or income and the freehand fitting of a demand curve. Waugh emphasizes freehand fitting of a curve through the observation dots as this 'avoids the deadly routine of always fitting straigh

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straight lines (or straight lines in logarithms) whether they are appropriate or not' (p. 14). He claims that its neglect is due largely to 'fancy, super-refined mathematics and electronic computerization ...' and that '...the graphic tool is almost indispensable in preliminary analysis (p. 1).' Often a quick preliminary analysis will help determine the relevant variables and the form of the relationship among these variables. In particular it can identify changes in structure over time and provide valuable insights about the data which may otherwise be missed (Figure 3.2).[18]

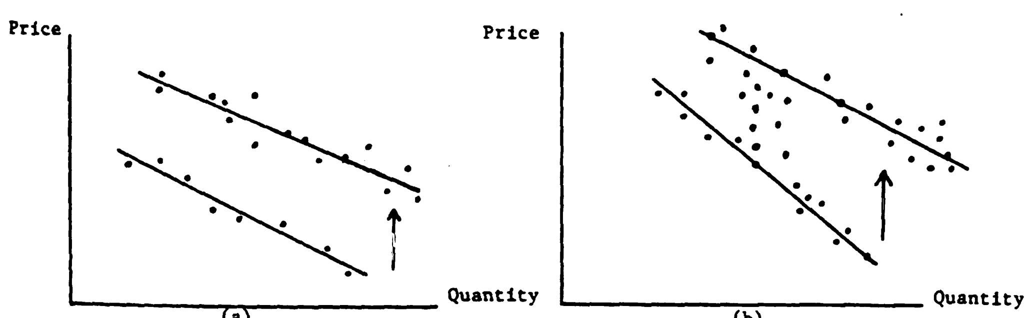

Figure 3.2
Shifts in the Structure of Demand

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[18]See for example (Rojko, 1961, pp. 47-48).

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There are earlier examples of this approach to show shifts in the structure of demand, however, Waugh (1964) illustrates for beef that it was necessary to draw two demand curves, one for the period 1948 through 1957, and another for 1958 through 1962. The upward shift in the latter period indicated reduced marketings of pork. Similar shifts over the period due to shifts in supplies of competing meats were identified for pork, veal and lamb but not for chicken. Waugh noted that he expected these shifts, which occurred at different points in the period to have occurred, logically, simultaneously. It has become apparent from later research that differential timing in commodity shifts are hardly surprising. The perfect operation of the Walrasian auctioneer in a multi-commodity system quickly breaks down with the introduction of institutional, psychological and habitual factors. These factors, manifested as lags in market relationships, may be characterized collectively as imperfect information flows.

Such shifts as described above may be abrupt as in Figure 3.2(a) or more gradual as in Figure 3.2(b). In the simple demand model, for example, consumption as a function of price and income, an abrupt shift, may typically be due to a change in government pricing policy. On the other hand, incomes have tended to increase gradually, perhaps cyclically with the economy, resulting in a gradual upward trend in the demand for meats as a whole. However, as will be the case with other means of quantifying structural shifts, graphical analysis shows when the shift occurred but not why it occurred.

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3.3.2 Time Trend Variables (Gradual Structural Shifts)

Where changes have taken place gradually over time and for which no specific explanatory variable is available a time variable has often been used. This formulation is also considered the most simple of dynamic specifications in demand analysis (Intriligator, 1978, p. 235). It has also been used to model habit formation (Pope, Green and Eales, 1980). It should be introduced as a measure of sources of continuous systematic variation only if such sources are believed to be important before the analysis is run, or if the time effect is believed to be linear or moderately curvilinear. A plot of the unexplained residuals versus time will determine this. If the plot does not indicate a trend relationship, but is non-random then an attempt should be made to discover the economic cause of the pattern. If the contribution of time in explaining variations in the dependent variable is large relative to that of other independent variables then it suggests that some major factor has not been identified and included (Foytik 1951, p. 419).

A time variable is often included in logarithmic equations either in a converted or unconverted form. It makes a difference whether time is in actuals, in logarithms or in some other form (Foote, 1958, pp. 40-43). Time, t, specified as an exponential function (unconverted data) is

$$q_{it} = a_i x_{it}^{bi} c^t \qquad (3.16)$$

or equivalently,

$$\log q_{it} = \log a_i + b_i \log x_{it} + t\log c \qquad (3.17)$$

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where $c \simeq 1$ and $t = 0,1,2\ldots,n$. and where q_t is consumption of good i and x_{it} represents all other explanatory variables. As a power function (converted data),

$$q_{it} = a_i x_{it}^{bi} t^c \tag{3.18}$$

or equivalently,

$$\log q_{it} = \log a_i + b_i x_{it} + c \log t \tag{3.19}$$

where $c \simeq 0$ and $t = 1,2,\ldots,n$

Typically, a time trend increases rapidly during initial growth and then tends to flatten out. Given the greater variety of possibilities including the above rapid initial growth scenario, Foote (1958) recommends the power function in most cases. He further notes that depending on the coefficient on time and whether time is in actuals or logarithms, extrapolation can give markedly different results. Caution is usually necessary when extrapolating, but more so when time is specified as a higher degree polynomial or when a exponential curve is used and the coefficient is greater than unity. Notwithstanding this warning, George and King (1971, p.44) suggest that for projection purposes, inclusion of a time variable may result in more reliable projections than if excluded.[19]

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[19] See Prest (1949, p. 39) and Foytik (1951, p. 421) who use t and t^2 terms in demand analyses. Prest found that after inserting t (as t log e) the residuals still appeared to show the influence of a trend factor and so he added the term t^2. Although the time variables were in exponential form the estimated coefficients on t and t^2 were very small and hence were not explosive. Also note that to allow for parallel shifts other than by a uniform amount or rate, second or higher degree terms of t would need to be specified.

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In the context of structural changes in consumer demand functions, a time trend is often introduced to represent the effects of continuous changes in tastes.[20] This is because at least for basic agricultural commodities tastes for the most part have not changed rapidly over time. In fact the time trend includes all variables which theory assumes constant under ceteris paribus conditions. This catch-all variable was specified in the classic demand studies of Schultz (1938) and Stone (1954).[21] In Schultz's specifications, time was included to explain systematic changes in all the variation in the dependent variable except the product's price. Stone improved considerably on this specification and upon its theoretical plausibility by including the prices of other goods and income per person.

Despite Foote's recommendation of the power function the exponential function is very common (Phlips 1974, p. 98) but in the form,[22]

$$q_{it} = \alpha x_{it}^{\beta} e^{\delta t + \varepsilon it} \qquad (3.20)$$

or equivalently,

$$\log q_{it} = \log a_i + b_i \log x_{it} + \delta t \log e + \varepsilon_{it} \log e \qquad (3.21)$$

One of the main reasons a time variable is included into the regression equation is to operate as a correcting factor for trend in each of the data series, i.e., to eliminate the growth factor (Foytik, 1951, p. 420).

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[20] A similar justification is used for specifying time in supply equations to represent changes in technology.

[21] See Phlips (1974, pp. 116-120) and Intriligator (1978).

[22] This equation in e is a special simplifying case of an exponential function generalized as c in equation (3.16) and (3.17).

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Alternatively, any linear trend in the dependent variable over time can be isolated and measured by using first differences of logarithms where the constant, a_i, in

$$\log\Delta q_i = a_i + b_i\Delta\log X_i \quad , \qquad (3.22)$$

is the measure of trend in q_i over time. Rojko (1961, p. 43) cautions that this specification only allows a trend that is increasing at an increasing rate. One way around this deficiency is to explicitly include time as an explanatory variable. Normally the constant term has little economic meaning. Therefore student-t values are rarely presented. However, the constant, a_i implies, if significantly different from zero, that some change in the dependent variable would occur from the preceding year even if there were no changes in the independent variable. Foote (1958, p. 43) suggests that if all variables in the first difference analysis are converted to logarithms and if the constant term differs significantly from zero, the percentage effect of time in each year can be obtained by taking the antilogarithm of the constant term plus 2. To take Foote's example, if a_i is equal to 0.015, and its antilogarithm, 2.015 is 103.5 than we can say that the time trend alone would increase consumption of q_i by 3.5 percent annually. If however, a_i is -0.015 and the antilogarithm of 1.985 is 96.6, then the trend above would tend to decrease annual consumption of q_i by 3.4 percent.

Notwithstanding the above inclusions of a time variable in demand specifications, there are further specific problems to be considered (George and King, 1971, p. 44). Variables such as prices and income are often

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often highly correlated with time creating difficulties of multicollinearity in the estimation of individual coefficients. The coefficient on the time variable may be overestimated and, as noted, the variable becomes a catch-all for unexplained variation in addition to the effect of time. A further difficulty, associated with its lack of theoretical standing, is that an interpretation of the coefficient of time is not provided readily. For these reasons researchers have been reluctant to include time into their demand formulations.

To reiterate, the rather heroic assumption made by the inclusion of a time variable is that all social and psychological and any economic factors not accounted for by the income and relative prices series, changed at a constant instantaneous percentage rate per unit of time and are captured by this variable. This assumption is clearly arbitrary and unsatisfactory in dealing with cyclical fluctuations or sudden changes or discontinuities in data. At best it is more a proxy reflecting miscellaneous changes than as representative of changes in tastes.

3.3.3 Dummy Variables (Abrupt Structural Shifts)

To account for structural changes in demand which are abrupt or discontinuous in nature shift variables can be introduced through dummy variables. These variables deal with qualitative information such as qualitative facts (e.g., male or female, black or white), qualitative shifts over time or space (e.g., war or peace, government subsidy or not, region one or region two), or conversion of quantitative facts into aggregate qualitative facts (e.g., rich or poor instead of quantitative income

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income level).[23] These dummy variables by convention take on a value of zero before the critical year (assuming annual observations) or zero for the presence of a characteristic, and take on the value of one after the event in time or in the absence of that characteristic. In effect the procedure permits a single displacement of the intercept for the period beginning in the year in which the change occurred. To obtain the effect of this change, the coefficient of the dummy variable is added to the intercept. This partitioning of the data set into intervals and defining a set of dummy variables over them has the desired result of providing unbiased regression coefficients in contrast to either estimating the whole period or, in the case of war years, dropping that data from the data series (Suits, 1957).

This once and for all structural change due to war, or policy or taste change, causes the demand coefficients to change. In past studies, in order to have a time series with sufficient data points, the pre- and post-World War II periods were utilized. From an efficiency viewpoint, the longer the time series the better the estimates of structural coefficients. However, unless the analyst explicitly considers the structural changes in the variables, the values of those estimated coefficients for policy in a future period may be diminished substantially.

Prior to the use of dummy variables, sudden upheavals in a series, say due to war years, was handled by simply omitting those years from the time series. It was assumed that conditions during the war were

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[23]See for example Suits (1957) and Intriligator (1978).

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somehow pathological and therefore observations in that period should be omitted when estimating the economic relationship. However, discarding observations involves a loss of information which should be used if possible. In this context, Brown (1952) had a somewhat different interpretation of the zero-one variable in a study of the effects of habits on the aggregate consumption function. He used this shift variable to describe the structural change which occurred after World War II. He interpreted the dummy variable as a measure of the aggregate impact of the non-measurable variables of consumer habit, the psychological impact of price controls, and the introduction of new products and new technology. Brown reasoned that the War not only caused changes in prices and incomes but also disturbed consumer habits, breaking existing habits and creating new ones.[24]

The procedure of combining data from periods that are believed to be non-homogeneous is appropriate if the effect of the structural change affects the level of the dependent variable only and occurs within a single year. The technique is not appropriate where the structural change affects the magnitude of the estimated coefficients, the general nature of the relationship, nor where the change is a gradual one over time as in the time variable specification. Dummy variables do permit some relaxation of the classical assumption of fixed parameters. That is, dummy variable parameters may vary over subsets of observations regarded as different. But within these subsets parameter shifts have

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[24]Measuring the impact of quarterly changes in the demand structure due to seasonal variation is also a common use of dummy variables. However, this application is not discussed here in any detail.

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zero variance, and between subsets, infinite variance. In reality the variance of parameter shifts is more likely to fall between the extremes of zero and infinity provided by the dummy variable formulation. Moreover, as observed by Waugh (1964, p. 41), abrupt shifts are of little use in forecasting if their cause is unknown. This is the case, particularly with episodic shifts such as wars, biological plagues, droughts, certain government policies which defy most rational forecasting.

3.3.4 Homogeneous Subperiods

Another way to handle structural changes is to estimate homogeneous subperiods in which no change in structure has occurred. This is analogous to the dummy variable approach, except that separate regressions are fitted to the data for each subperiod. The regression coefficients for each period are compared with each other as well as with the regression coefficients of the equation fitted over the whole period. Again, typically when the data series traverses years of war those war years are omitted from the analysis of the subperiods and usually from the whole period.[25] If the respective coefficients of each line fitted to the data are not significantly different from each other then a regression curve fitting data for the whole period will provide the most efficient estimator since it contains more observations and minimizes the residual sum of squares.

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[25] Foote (1958, p. 20) recommends that any abnormal year be omitted from the analysis. However, this may involve an important loss of information. See also Meinken (1955, pp. 49-50, 89-93) for algebraic modifications of a model to account for structural changes, e.g., in government policies.

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A technique is provided by Chow (1960) for testing two individual regression equations based on an F-test. Nevertheless, care should be taken in using this test and for that matter any F-test for identifying when structural change has occurred. Unless the subpopulations over which individual regressions are fitted, are distinct (for example, in the case of different regions), this test may indicate significant differences in subgroups even when observations in the subgroups are added or subtracted, i.e., redistributed, at least at the margin. In particular, a Chow test indicating a significant difference between two subperiods of a time series, implying a mid-period structural change may mislead since equally significant results may be obtained by alternative splits of the data. The implication is that any arbitrary data split may give statistically significant results for numerous subperiods.

Variations in the approach of specifying separate equations have been adopted in analyzing structural changes.[26] Instead of assigning dummy variables, Stanton (1961) in a study of seasonal demand for beef, pork and broilers, estimated separate equations for each season. Using annual data and comparing linear and logarithmic functional forms, Schultz (1938),[27] divided the observation period into subperiods on the basis of structural shifts in the data. Yet despite its practical appeal the arbitrary division of the data into subperiods often has very little economic basis.

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[26]See Rojko (1961, p. 44), Foytik (1951) and Waugh (1964, pp. 40-41).

[27]See Phlips (1974, pp. 116-118).

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3.3.5 Interaction Variables

It may be clear by now that gradual shifts (time variables) and abrupt shifts (dummy variables) may be included individually in the one regression equation. A shortcoming with dummy variables is that the structural change is hypothesized to be once-and-for-all. A further shortcoming is the assumption that the change affects the level (i.e., the intercept) of the dependent variable only and has no impact on the slope and shift coefficients. By contrast a time variable assumes the shift is parallel and at a uniform rate.

Through the use of interaction terms or multiplicative dummies these difficulties can be overcome at least partially.[28] This variable is usually multiplicative in terms of a slope or shift variable and a dummy or time variable depending on whether the interaction involving the slope or shift variable is abrupt or gradual, respectively. Of course, separate equations could be estimated, for example, to represent the distinct seasons, regions, characteristics or populations. The demand structure for teenage consumers of hamburger meat may be different, not only in intercept but also in slope coefficients, from adult hamburger consumers. In this case the own price of hamburgers, may interact with a dummy variable for age, i.e., an age dummy takes a value of one for observations relating to teenagers and a value of zero for adults. An ex ante check on this interaction is to plot the residuals against the dependent variable. Systematic departures in this plot may reveal that the slope of the regression changes as the type of consumer

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[28]See for example Pindyck and Rubenfeld (1976, pp. 77-87) and Intriligator (1978, pp. 60-62).

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varies. Following Foytik (1951) such systematic shifts in the regression coefficients over time have been approached alternatively by estimating the equation

$$p_i = a + (b+b^{'}W)q_i + (c+c^{'}W)y_i + (d+d^{'}W)q_{i-1} + (e+e^{'}W)W \qquad (3.23)$$

where $i = W$ = week of season p_i = price, q_i = quantity sold, and y_i = consumer income.

This approach considers all weekly observations together. The demand equation changes systematically over time (as the season progresses) if the coefficients $b^{'}$, $c^{'}$, $d^{'}$ and $e^{'}$ are significantly different from zero.

The interaction of quantitative variables, say own price and the linear time trend variables may be represented by

$$q_t = \alpha + \beta p_t + \gamma pT + \delta T \qquad (3.24)$$

or,

$$q_t = \alpha + (\beta + \gamma T)p + \delta T \qquad (3.25)$$

This is the simplest version of a continuous time varying parameter model which allows for continuous changes in the slope coefficient on price. Alternatively,

$$q_t = \alpha p_t^{\beta + \delta T} T^{\delta} \qquad (3.26)$$

or,

$$\log q_t = \log \alpha + (\beta + \gamma T)\log p_t + \delta \log T \qquad (3.27)$$

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which is linear in logarithms. Note, finally, that where a regression uses only dummy variables or explanatory variables, then that analysis is equivalent to an analysis of variance, and where it includes both dummy variables (qualitative) and quantitative variables as explanators it is equivalent to an analysis of covariance.

3.4 More Advanced Methods for Identifying and Estimating Structural Change

Models discussed above use dummy variables to operate as once-and-for-all intercept shifters or to operate with continuous variables as interaction terms to create slope changes. Nevertheless, separate regression equations are fitted to subsets of the data and in a discontinuous way. Structural change in economic relationships may take on another character: the change in structure may differentially effect the slope coefficient <u>during</u> the time period and possibly for specific segments of the time period under observation.[29] In the following sections, more advanced methods for dealing with these aspects and overcoming some of these problems are discussed.

3.4.1 Grafted Polynomials and Spline Functions

As illustrated in Figure 3.3, these are cases when the slope of the function changes at a point, say $\bar{X}$ over time. These curves may be approximated using 'grafted polynomials' (Fuller, 1969, pp. 35-46) or 'piecewise regressions' (Judge et al. 1980; Gujarati 1978, pp. 301-303).

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[29] Stinson and Lubor (1982) provide an example of this approach of segmenting the regression line using cross-sectional data.

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These functions may be categorized as spline functions[30] (Poirier, 1976). Spline functions are a special case of the more general group of switching regression models (Judge, et al. 1980, p. 382). Specifically they are models in which the regimes correspond to adjacent intervals along an independent variable axis and in which various continuity restrictions are imposed so that the 'switch' from one regime to the next is continuous and often often 'smooth'. Because of the important contribution of these functions to the econometric estimation of structural change their application in economic relationships will be reviewed here.[31] This discussion will be apropos, particularly to continuous time varying parameter models to be discussed later.

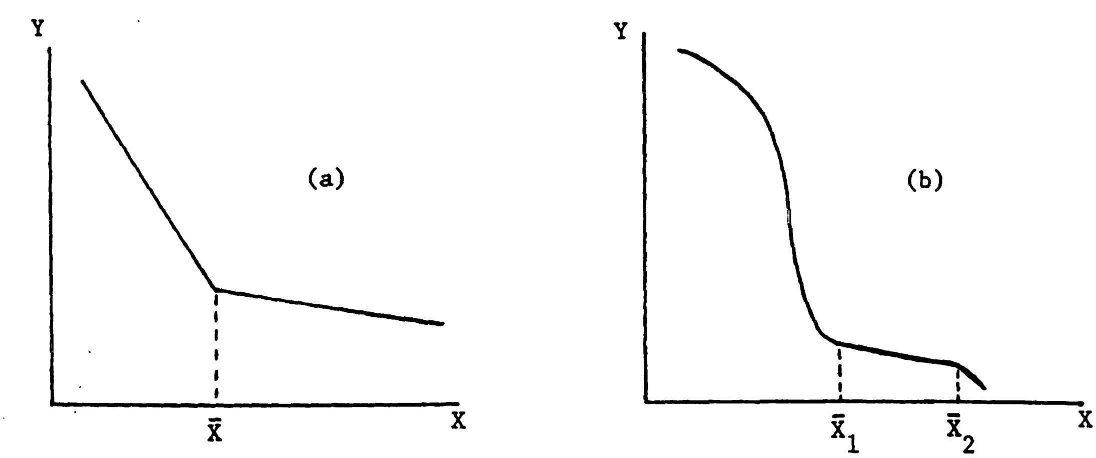

Figure 3.3
An Illustration of Joined Segments of Different Polynomials

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[30]More complex forms of these switching regressions are provided by Goldfeld and Quandt (1973).

[31]This review will draw extensively on the research of Poirier (1976) among others.

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Cases of the appropriate uses of the standard dummy variable, i.e., discontinuous changes in the dependent variable, have been discussed along with the various shortcomings in their use in econometric estimation. Poirier argues, however, that with the exception of inherently discontinuous models of structural change of a qualitative nature such as race, region or education, continuity in economic models is more consistent with reality. Where the explanatory variable causing the structural change is quantitative and continuous, then at the very least an interaction dummy should be used.

A point to note about spline functions is that while they are continuous at points of structural change they may not be smoothly continuous. Segments of the curve representing periods between significant points of structural change are connected by join points. These segments may represent splices of linear, quadratic, cubic, exponential or any other functional form. It is possible to represent these joined segments by a series of slope and intercept dummy variables subject to the constraint that segments join up continuously. However, spline functions satisfy this continuity without the need of such constraints. In the following, the discussion begins with the simplest form, the linear spline, moving to cubic splines, bilinear splines, splines in multiple regressions, and finally leading up to continuous time varying parameter models of structural change.

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Linear Splines:

The linear spline may be shown for k transformed variables as

$$q_t = \beta_o + \beta_1 W_1 + \beta_2 W_2 + \ldots + \beta_k W_k \tag{3.28}$$

where,

$W_1 = X_t$

$W_j = (X_t - \bar{X}_{j-1})$, for $X_t > \bar{X}_{j-1}$

$= 0$, for $X_t \leq \bar{X}_{j-1}$

and for j-i join points, j=2, 3,...,k and for time, t=1, 2, 3,...,n. The coefficient, β_1, represents the slope of the spline over the first line segment. The remaining coefficients, β_t, represent the change in the slope from interval j-1 to interval j, respectively. Therefore, for example, the slope of the second line segment is $\beta_1 + \beta_2$.

The attractions of this linear version are (a) its linearity in unknown regression parameters, β_o, $\beta_1 \ldots, \beta_k$; (b) the absence of parameter constraints; (c) the ease in constructing the transformed variables, W_1, $W_2, \ldots, W_k$ in standard regression programs; and (d) the ease of hypothesis testing of the presence of structural change, using standard student t-tests on each β. Statistical significance, different to zero, indicates a change in the slope between intervals j-1 and j and hence the notion of structural change at $\bar{X}_{j-1}$. Although omitted from the above formulation, it is a straightforward matter to include other explanatory variables within the context of multiple regression. Note, that end (join) points can be specified if it is believed that the data set is numerically bounded, for example, as in the case of income distribution segments which may have a lower bound of zero.

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<u>Cubic Splines:</u>

If the original relationship is non-linear and is a cubic polynomial then Poirier (1976, p. 21) shows that a structural change at the join points will yield a cubic spline. In this case the transition at the join point from one polynomial segment to another does not occur abruptly since the curve's first and second derivates are matched. This provides a very flexible approximation to the data. More generally, these are in essence higher order grafted polynomials in a single independent variable joined smoothly at known join points. Feasibly, the first line segment could be a cubic polynomial grafted to a linear segment (Fuller, 1969) as illustrated in Figure 3.3(b).

The case of a quadratic form over two line segments, i.e., one join point, and hence one structural change, may be shown as

$$q_t = {}_0 + \beta_1 W_1 + \beta_2 W_2 + \beta_3 W_3 \qquad (3.29)$$

where,

$$W_1 = X_t$$

$$W_2 = X_t^2$$

$$W_3 = (X_t - \bar{X}_1)^2, \text{ for } X_t > \bar{X}_1$$

$$= 0 \qquad , \text{ for } X_t \leq \bar{X}_1$$

In this case, a t-test on the coefficient, β_3 will indicate immediately the gain from adding this structural shift parameter to the model. Variations of these and other degree polynomials may be more appropriate in practice (Cornell, 1976).

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Judge et al. (1980, p. 388) suggest that a major shortcoming with the cubic spline, given its specification in a single independent variable, is the implied restriction of the form of structural change. Hence, there is limited scope for identifying the nature of the change. However, Poirier (1976) is clear in indicating that the addition of other explanatory variables is not only a simple matter but to be expected in any formulation of a spline function. Of course, a potentially limiting aspect of spline functions discussed so far is that the time of the structural change, i.e., the join points, must be known, ex ante.

Bilinear Splines:

A bilinear spline is obtained by creating an interaction variable with transformed spline variables. With subscripts omitted for simplicity of exposition, a relationship between q, the dependent variable and two independent variables X and Y gives the bilinear form

$$q = a + bX + cY + dXY \tag{3.30}$$

where the main effects are measured by bX and cY and the interaction effect is dXY. Application of this model to a piecewise formulation implies that the XY term operates only over portions or certain regimes of the XY space. Where these regimes are continuous then the resulting surface

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surface is a bilinear spline. In a notation consistent with linear and cubic splines, the bilinear spline may be represented as

$$q_t = \beta_0 + \beta_1 W_1 + \beta_2 W_2 + \beta_3 W_3 \tag{3.31}$$

where,

$$W_1 = X_t - \bar{X}_{i-1}, \text{ for } X_t > \bar{X}_{i-1}$$

$$= 0 \quad , \text{ for } X_t \leq \bar{X}_{i-1} \qquad i = 2, 3, \ldots, I$$

$$W_2 = Y_t - \bar{Y}_{j-1}, \text{ for } Y_t \leq Y_{j-1}$$

$$= 0 \quad , \text{ for } Y_t \leq \bar{Y}_{j-1} \qquad j = 2, 3, \ldots, J$$

$$W_3 = W_1 W_2$$

where, $\bar{X}$ has i-1 join points, $\bar{Y}$ has j-1 join points and time is t = 1, 2, ..., n.

An alternative formulation of the above equation is

$$q_t = a_{ij} + b_{ij}(X_t - \bar{X}_{i-1}) + c_{ij}(Y_t - \bar{Y}_{j-1}) + d_{ij}(X_t - \bar{X}_{i-1})(Y_t - \bar{Y}_{j-1}) \tag{3.32}$$

where $\bar{X}_0 < \bar{X}_1$, and $\bar{Y}_0 < \bar{Y}_1$ and a_{ij} is the value of q_t when X_t = $\bar{X}_{i-1}$ and $Y_t = \bar{Y}_{j-1}$, b_{ij} is the partial of q_t with respect to X_t, c_{ij} is the partial of q_t with respect to Y_t, and d_{ij} is the interaction coefficient between X_t and Y_t.

Because of the richness of the kinds of structural change which can be specified, the complexity of the hypothesis testing of these changes is increased though not prohibitive. However, since this spline is linear in its unknown parameters, classical testing procedures can be utilized (Poirier, 1976, pp. 62-64).

Bilinear splines have the advantages over dummy variables which continuity gives and they are less costly in degrees of freedom. However, higher order forms of this spline are increasingly more expensive in degrees of freedom and meaningful economic interpretation of the derived coefficients is more difficult. Nevertheless, combinations of linear and cubic splines are feasible. Two final points to note are that (a) spline functions may include other explanatory variables, splines with other variables in the equation and interactions with splines, and (b) in specifying those functions care must be taken to ensure multicollinearity is not introduced since each of these splines have intercepts implicitly or explicitly contained in them.

Unknown Join Points:

As noted above, a limitation of spline functions and indeed any switching regression whether it uses dummy variables or piecewise regression, is that the join point or exact time the structural change occurred is often unknown. Models where the join point(s) is unknown and hence needs to be estimated are contained in the literature, for example, Poirier (1978, Ch. 8); Judge et al. (1980), Silvestre (1969). Poirier argues that spline regressions have major advantages in practical implementation, especially when other explanatory variables are added, when more than two regimes or segments are involved, and when the disturbance term is not well behaved. Nevertheless, these models are computationally much more complex and may suffer from the requirement of large samples or large shifts in order to adequately test the model for stability of slope coefficients and of the estimated join points.

However, it is generally uncommon that some a priori information is not available concerning the location of the structural change. If the point in time when the change(s) took place is only approximately known then one approach is to choose several join points and/or construct several functions and then select the one or combination of join points and functions which give the smallest residual sum of squares.[32] The risk with this latter approach in finding join points is that as the function becomes complex, local minima instead of the global minimum may be located.[33] Also, unless the appropriate optimization techniques[34] are employed, iterative algorithms can be expensive to run when the number of iterations is large.

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[32]A rather different approach involving the criterion of minimizing residual sum of squares was utilized by Silvestre (1969). Although this method contained some novel aspects, it appears computationally prohibitive for all but the simplest models of structural change. Also, more efficient algorithms have been developed which largely supercede this approach.

[33]Mathematical algorithms which search for the global minimum tend to be iterative rather then analytical in nature. See Wold's four rules-of-thumb to find join points in cubic splines, quoted by Poirier (1978, pp. 151-152).

[34]See for example Kuester and Mize (1973).

3.4.2 Models of Quality Change

In the previous section a consumer theory which viewed a product as a collection of characteristics was discussed. This theory, due to Lancaster (1966), has been applied in various food consumption and demand studies. For example, Ladd and Suvannunt (1976) tested the hypotheses that (a) for each product consumed, the price paid by the consumer equalled the sum of the marginal monetary values of the product's characteristics and (b) consumer demand functions for goods are affected by characteristics of the goods. Products derive an inherent heterogeneity because of the array of various characteristics contained in them. Different qualities and quantities of characteristics provide this heterogeneity and hence models of consumer goods characteristics are useful in studies of product differentiation, quality, and grades and standards.

As noted earlier, traditional consumer demand theory has not viewed utility maximization in terms of product characteristics, nor does it have anything to say about the effect of quality changes and the introduction of new products in demand analyses. Wohlgenant (1982), however, is an example of one attempt to address this problem in the context of the demand for meats. He hypothesized that unexplained structural shifts in demand for meats can be attributed to quality changes in the composition of meats consumed. Rather than presume that negative shifts in the demand for red meat have been due to changing tastes and attitudes to health, he hypothesized that this shift is due to substitution of new processed poultry meats for processed red meats. The basis used for identifying structural shifts due to quality changes is that final consumption z_j, of each good, j, is formulated as a function of quantity, q_j, and quality, s_j, of the market good purchased. For example, quantity is in terms of pounds of meat consumed, while quality may be the number of grains of protein per pound of meat or some other quality characteristic such that

$$z_j = q_j \, s_j, \quad j = 1, 2, \ldots, n \tag{3.33}$$

Since it is not possible to characterize quality by a single attribute, s_j is viewed as an index of quality, depending upon a whole set of attributes,

$$s_j = s_j \, (a_{1j}, a_{2j}, \ldots, a_{mj}j) \tag{3.34}$$

for all j = 1,2,...,n and where a_{ij} is the amount of the ith characteristic yielded by one unit of the jth market good. These attributes might be protein, energy, carbohydrates, iron or any other nutritional, physical or if measurable, psychological attribute. Demand for each purchased good is derived as

$$q_j = q_j \, (p_1, p_2, \ldots, p_n, x_j; s_1, s_2, \ldots, s_n) \tag{3.35}$$

for j = 1,2...,n where the s_j's are given for each product, and p_j is the price of the jth good. These are constant-quality demand functions. An important restriction of this model specification is that quality changes are interpreted as movements along a stable demand curve through changes in the shadow prices, $\pi_j = p_j/s_j$ for the jth good. Hence, an increase in s_j decreases π_j causing z_j to increase.

Wohlgenant showed after netting out price effects between 1970 and 1980 that about one-half of the unexplained increase in poultry demand, and one-third of the unexplained decrease in demand for red meats (beef and pork) was due to quality changes. A significant shortcoming in this model relates to the invariant nature of the elasticity estimates. These results will be further referred to in later discussion of model estimation.

3.4.3 Time Varying Parameter Models

The notion of demand estimation that accommodates time varying coefficients or elasticities is not new in the literature. Apart from the early development of the intercept shift and slope dummy variables this broader concept of time varying parameters was discussed in the context of 'time-elasticity of demand' (Smith 1937; Prest 1949, p. 47). Waugh (1964, p. 8) observed an excessive concern with 'the' elasticity of demand for a commodity and felt that in reality demand elasticities commonly vary across markets, across uses, across grades and especially across time and from one part of the curve to another. Already noted is the absurdity of assuming a constant income elasticity of demand. It may be misleading to compute a single coefficient that purports to show the response of food consumption to income changes either across sections of time or through time. Foote (1958, p. 83) outlined some of the difficulties of interpretation and comparison of estimates of demand elasticities from time series data. In particular he pointed out the considerable variation in elasticity estimates obtained from regression equations run over different time periods and from data other than the average of the period; contrasting years of depression and prosperity. As pointed out by Foote, it seems clear that since an analysis of the cost of public programs depends largely upon the demand elasticity of the commodity, the accuracy and validity of estimated regression coefficients in terms of the time over which that coefficient is relevant bear upon the overall quality and effectiveness of government programs.

In the previous section, techniques were discussed which permitted the regression coefficients to change a small number of times and therefore allowed for a similar number of changes in structure over that time series. In this section models are reviewed which permit the coefficients to vary more continuously over time.

As evidenced by the plethora of approaches and techniques to identify and measure changes in the underlying structure of economic relationships the importance of modelling parameter variation is obvious. A major empirical question posed through this discussion is whether structural changes are inherently abrupt and instantaneous as portrayed by dummy variables, whether they are more gradual but nevertheless definitively identifiable over a small period of time after which a constant parameter prevails as might be modelled with spline functions, or whether in fact, structural changes occur more or less continuously over time. While economists using all three general approaches recognize the possibility of parameter instability, a required ingredient of the first two approaches is for most practical purposes, that of knowledge of when the change in structure occurred.

Notwithstanding this requirement, a necessary caveat in each case is that while structural changes may be identified from a statistical viewpoint, these techniques provide only limited economic interpretation of the change. Thus, the difficulty of pinpointing the nature of the parameter variation has resulted in the continued use of various constant parameter formulations. The merits of the simpler constant parameter models are well known. However, where there is evidence of instability in the parameters there would appear to be a trade-off between accuracy and complexity.

Mundlak and Raussar (1979, pp. 4-9) offer a number of justifications for the parameter variation formulation: (a) the 'true' coefficients are considered to be generated by a non-stationary or time-varying process; (b) even when the 'true' coefficients and the underlying structure are stable (since econometric models are simplified abstractions of reality), misspecification may cause inaccurate model forecasts, which may be countered by an appropriate parameter variation structure. An important misspecification is the omission of relevant explanatory variables particularly those that relate to structural changes resulting from taste and institutional changes or technological developments. Time series of these excluded variables exhibit nonstationary behavior and due to their correlation with included variables, the estimated effects of the latter can be expected to change with time. This time-varying interrelationship can be expected between proxy variables and the desired variable, for example, expectation formulations, which they proxy. That is, if the relationship between the proxy and its true counterpart is not constant across observations, then the coefficient of the proxy variable will not be constant; (c) an underlying assumption in the construction of aggregate data is that the relative weights of the constituent micro-units do not vary. As the relationship between micro-units is unlikely to remain constant in time series data, coefficients in the aggregate equation will vary; (d) an inappropriate specification of the functional form especially when a linear equation is fitted to an inherently non-linear relationship, can cause coefficients to vary across the sample. This is particularly so for time series displaying pronounced secularity; (e) perhaps the most intuitively appealing justification of a parameter variation structure is that economic relationships can be expected to change over time, at least because of changes in policy which affect the operating environment and hence the behavior of its participants; (f) the evidence that economic relationships are formed by dynamic processes fueled by expectations of future structural changes would indicate the presence of parameter instability over time. Certainly forecasts would be improved if account was taken of such parameter variation.

On the basis of the above observations it would appear unrealistic to assume that (a) the economic structure generating the sample observations remains constant, (b) there exists a single parameter vector relating the dependent and independent variables, (c) there exists a constant set of error process parameters, or (d) there exists a single functional form. However, as Mundlak and Raussar (1979) point out, the central issue is whether or not the explicit specification of a time-varying parameter structure will sufficiently improve accuracy and implementation to out weigh the increased complexities of such a specification.

In recent years a considerably large literature has developed along with numerous variants of the continuous time-varying parameter model. First, as a more obvious development of the classical linear model, the general model that combines time series and cross-sectional data is reviewed. Then, as a transitional link from previously discussed models to models to be discussed, Poirier's (1976) switching regression version of a time-varying parameter model is presented. Finally, for review purposes, a general version of the latter model and an important subset of more specific formulations will be presented.[35]

3.4.4 Cross-Sectional Time Series Model

In the context of the classical linear model of constant coefficients using time series observations, perhaps a logical development of this model is to estimate a relationship which combines time series and cross-sectional data. Typically, several years of data may be available for a number of households. This estimating approach is not used in this research because of the lack of

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[35] This review draws, inter alia, extensively upon Judge et al. (1980) and Mundlak and Raussar (1979).

consistent cross-sectional and time series data. However, for completeness and since this technique does allow structural changes in demand to be identified by permitting the assumption of fixed coefficients to be relaxed, the approach is discussed briefly.

In general, the model may be written

$$q_{it} = \beta_{1it} + \sum_{k=2}^{K} \beta_{kit}\, x_{kit} + e_{it} \tag{3.36}$$

where i = 1,2,...,N refers to the cross-sectional unit, household or individual, and t = 1,2,...,T refers to a given time period. The value of the dependent variable in q_{it} for individual i at time t and the value of the kth non-stochastic explanatory variable is x_{kit} for individual i at time t. The stochastic term is assumed to have the usual properties of mean zero and constant variance. The unknown parameters or response coefficients, β_{kit} may vary for different individuals and for different time periods. This general model may be classified, as the subscripts suggest, into various models ranging from the most restrictive case where all coefficients are constant, through to other combinations depending on whether the intercept or slope coefficients are constant or variable, whether the intercept and/or slope varies over individuals and/or over time. These and further sub-categories are detailed by Judge et al. (1980). In terms of time varying parameter models the general model where all coefficients vary over time and individuals is the most comprehensive. In practice, however, more restrictive assumptions are usually made.

To illustrate the type of structural information that can be obtained from such a model some of the results of a study by Douglas (1967) of the secular and cyclical changes in consumer demand for household laundry appliances is briefly reviewed. Time varying parameter models which rely wholly on time series data are presented in the following sections. It will then become clearer just how closely related are the time varying parameter and the pooling models.

Douglas examined changes in income elasticity over time. Elasticity coefficients were obtained for each household over the period 1932-61 (excluding 1942-45). She showed that the newer the product the greater the elasticity, which rose when the new product was introduced, reached a peak then declined secularly as the product experienced increased market maturity, and became negative for a declining product. Another important result with respect to the present study is that the price elasticity of demand changed over time in response to, first, the maturity of the market and, secondly, in response to competition. For instance, price elasticity was quite high during the years immediately following introduction of the electric and gas washing machines but showed a marked secular decline during subsequent years' (p. 73). She concluded that price elasticity declined as washing machines experienced increased market maturity and that the price elasticity for total washers, automatic washers, and dryers during the post-war years was probably quite low. From this evidence Douglas surmises that income and maybe price elasticity may be an effective basis for differentiating between luxuries and necessities. Two advantages given in having these elasticity measures through time are (a) as an aid 'in identifying where the position of a given product is at a given moment of time on the continuum between the possible extremes of luxury and necessity and particularly the particular products position relative to others' and (b) that 'changes in elasticity from year to year may be useful in tracking a product's movement through various levels of market maturity' (p. 74).

Since consistent time series and cross-sectional data are not available for the consumption of food, least of all meat, in the U.S., alternative approaches to obtaining intertemporal change in elasticity estimates must be sought. Also, it is recognized that the demand for a durable consumption good will have substantially different characteristics to the demand for meat. Nonetheless, the Douglas study is apropos to the discussion of time-varying parameter estimation and does motivate the search for such a technique in explaining such structural changes in meat demand.

3.4.5 Time Varying Switching Regression Model

Poirier (1976) has argued with considerable justification that the switching regression model more appropriately and realistically reflects structural changes in a model through the switch in parameter values from one regime to another. Certainly there is more structure built into the switching regression model in the way parameter values change than in the fixed coefficient or in the random coefficient regression model.

Spline functions which permit parameters to change over some time periods and remain constant over others have certain attractions. The model presented here is an extension of earlier spline functions except that all slope coefficients are allowed to exhibit continuous time varying behavior. Consider the simplified model, excluding other explanatory variables,

$$q_t = \alpha + \beta_t x_t + \varepsilon_t, \qquad t = 1, 2, \ldots, T \tag{3.37}$$

which is time varying in the slope coefficient β_t (but with a constant intercept α). Assume that β_t is a function of time such that

$$\beta_t = \gamma_0 + \gamma_1 t + \gamma_2 (t - \bar{t}_1) \quad . \tag{3.38}$$

Combining both equations, assuming the known join point t_1, gives

$$q_t = \alpha + \gamma_0 x_t + \gamma_1 (x_t t) + \gamma_2 [x_t (t - \bar{t}_1)] + \varepsilon_t, \tag{3.39}$$

or equivalently,

$$q_t = \alpha + [\gamma_0 + \gamma_1 t + \gamma_2 (t - \bar{t}_1)] x_t + \varepsilon_t \tag{3.40}$$

The following null hypothesis may be tested:

(i) H_0: $\gamma_0 = \gamma_1 = \gamma_2 = 0$

(ii) H_0: $\gamma_1 = \gamma_2 = 0$

(iii) H_0: $\gamma_2 = 0$

(iv) H_0: $\gamma_1 + \gamma_2 = 0$

where null hypothesis (i) tests for any effect of the regressor x_t on q_t; (ii) tests whether the slope is constant over time; (iii) tests whether the slope varies linearly over time; (iv) tests whether the slope is constant for $t \geq t_1$, but varies linearly for $t \leq t_1$.

Various extensions can be made to this simplified linear spline formulation. These are, among others (i) parameter variation according to a higher order spline, e.g., cubic spline; (ii) addition of join points to accommodate other points of structural change in the time paths of the coefficients; and (iii) time variation for more than one slope coefficient, i.e., the addition of other explanatory variables.

3.4.6 Continuous Time Varying Parameter Models

Consider, in its simplest form, the single equation, one explanatory variable model[36]

$$y_t = X_t \beta_t + u_t \tag{3.41}$$

where y_t is a vector of observations on n dependent variables; X_t is a matrix of n observations on k predetermined variables; β_t, which is allowed to vary over time, is a vector of parameters; and t denotes the time period. The error term, u_t is a random vector, serially uncorrelated and distributed with zero mean and covariance matrix, $E(u_t\ u_t 1) = \delta^2_u$, and $E(u_t\ X_t) = E(u_t\ \beta_t) = 0$.

[36]This time series model could be generalized to include both cross-section and time series observations. See, for example, Judge et al. (1980, p. 382)

Changes in β_t may be caused by structural variables, or by completely random effects as represented by the error term e_t in the equation

$$\beta_t = \beta_0 + H(X_t) + Z_t\alpha + e_t \tag{3.42}$$

where $H(X_t)$ denotes the general function of variables appearing in the system which may be associated with habit formation; Z_t represents completely exogenous variables and the error term has the usual properties of $E(e_t\ e_t^1) = \sigma_e^2$, and $E(e_t\ Z_t) = E(e_t\ H(X_t)) = 0$.

In demand equations it is not uncommon for β_t to depend on past consumption thus specifying habit formation, dependent upon past experience. Indeed, in the consumption of meat, it is hypothesized that social change and concomitant shifts in consumer tastes and preferences have induced structural change and, hence, variation into the parameter structure of meat demand. Mundlak and Raussar (1979, p. 12) instance forecasts of meat demand in the early 1970's, based on sample data up to 1970, which consistently underestimated actual levels of demand. They suggest that social changes in the traditional role of women resulting in greater numbers of working women and the associated demand for convenience foods, augmented actual consumption levels. In contrast, the recent observed shift away from red meats, especially the fattier table cuts of beef, due to health considerations, would reflect social change but in this case an overestimate with respect to actual consumption levels would be the result.

It is these sorts of changes and influences which can be represented in a parameter variation equation. Following Mundlak and Raussar (1979) equations (3.41) and (3.42) may be combined to produce

$$y_t = X_t\ \beta_0 + H(X_t)X_t + X_t Z_t\ \alpha + \varepsilon_t \qquad (3.43)$$

where $\varepsilon = X_t\ e_t + u_t$. The second and third terms in the equation are interactions of variables described above. To further explore the formulation in (3.43), let the general function, $H(X_t)$ be expressed as a function of past values or experience of the X_t's as determined by the geometric distributed lag,

$$\beta_t = \beta_0 + \delta X_{t-1} + \delta^2 X_{t-2} + \ldots + \alpha Z_t + e_t \qquad (3.44)$$

Multiplying equation (3.44) by δ and subtracting $\delta\beta_{t-1}$ from β_t, gives

$$\beta_t = \delta\beta_{t-1} + (1-\delta)\ \beta_0 + \delta X_{t-1} + \alpha(Z_t - \delta Z_{t-1})$$

$$+ (e_t - \delta e_{t-1}) \qquad (3.45)$$

where β_t is proportional to β_{t-1} and $0 < \delta < 1$.[37]

Both Judge et al. (1980) and Mundlak and Raussar (1979) provide excellent summaries of the various forms which the general time-varying model expressed in (3.41), (3.42) and (3.43) might

[37] Note that equation (3.43) is heteroscedastic where the variance of the error term ε_t has the following structure: $\sigma^2_{\varepsilon_t} = X_t^2\ \sigma_e^2 + \sigma_u^2$, assuming independence between u and e. See Judge et al. (1980, p. 384).

take. Some of these alternative specifications, developed in the literature, are presented with the purpose of illustrating the variety of assumptions that have appeared and the manner in which the classical model has been extended. For these purposes equation (3.45) is rewritten to provide the simplified base equation:

$$\beta_t = \delta_0\beta_0 + \delta_1\beta_{t-1} + \delta_2 X_{t-1} + \alpha\, z_t + \xi_t \tag{3.46}$$

Note that the coefficients on β_{t-1} and X_{t-1} differ. For equivalence between equations (3.45) and 3.46): $\delta_0 = 1-\delta$; $\delta_1 = \delta_2 = \delta$; $z_t = (Z_t - \delta Z_{t-1})$; and $\xi_t = (e_t - \delta e_t)$.

From (3.46) the following models are obtained:

(i) Classical linear model:

$$\delta_0 = 1,\ \delta_1 = \delta_2 = \alpha = \xi_t = 0 \quad \text{and, hence, } \beta_t = \beta_0, \text{ for all t.}$$

(ii) Random coefficient model (Swamy, 1970):

$$\delta_0 = \delta_1 = \delta_2 + \alpha = 0 \quad \text{and, hence, } \beta_t = \beta_0 + \xi_t.$$

(iii) Systematic parameter variation model (Belsey, 1973 a, b):

$$\delta_0 = \delta_1 = \delta_2 = 0 \quad \text{and, hence, } \beta_t = \alpha\, z_t + \xi_t.$$

(iv) Adaptive regression model (Cooley and Prescott, 1973 a, b):

$\delta_0 = \delta_2 = \alpha = u_t = 0$; $\delta_1 = X_t = 1$, for all t, and, hence,

$\beta_t = \beta_{t-1} + \xi_t$.

(v) Variable mean response model (Singh et al., 1976).

$\delta_0 = \delta_1 = \delta_2 = 0$; $z_t = 1$; $\alpha = \alpha\ f(t)$ and, hence,

$\beta_t = \beta_0 + \bar{\alpha} f(t) + \xi_t$, where

f(t) is some function of time.

(vi) Time varying parameter models

(a) Cooley-Prescott model (1973c):

$\delta_0 = \delta_2 = \alpha = u_t = 0$; $\delta_1 = 1$; $\xi_t = \eta_t - v_{t-1} + \phi_t$, and hence,

$\beta_t = \beta_t^p + \eta_t$

$\beta_t^p = \beta_{t-1}^p + \phi_t$, and

$\beta_t = \beta_{t-1} + \alpha_0\ w_t + \alpha_1\ w_{t-1}$, where

$w_t = [\phi_t, \eta_t]$; $\alpha_0 = [1, 1]$; and $\alpha_1 = [0, -1]$.

(b) Kalman filter models (1960, 1961):

$\delta_0 = \delta_2 = 0$ and, hence, $\beta_t + \delta_{1t}\ \beta_{t-1} + \alpha_t z_t + \xi_t$

Note that the coefficients δ_1, and α are also time varying in this formulation and are assumed to change in each period.

Each of those models is not without certain limiting characteristics. For instance, in the adaptive regression model, where the intercept varies sequentially, parameter variation follows a random walk with no allowance for turning points. In the widely used random coefficient model (Griffith, 1971) coefficients of the explanatory variables are specified as fluctuating randomly from one observation to the next (as opposed to being fixed) and the mean and variance of these unknown random parameters are estimated. Since economic phenomena are rarely random the economic content which this model provides, particularly for forecasting, provides very little insight into structural changes. The systematic variation models allow β_t to be explained in terms of economic variables, however, these structural influences are usually modelled qualitatively and suffer from measurement problems. The variable mean response model is justified in as far as calendar time explains continuous evolution of the parameter effects in β_t. This is a vast improvement from a dynamics viewpoint to simply including time trend variables in regression models. To the extent that variables in the mean response model proxy all unknown time-related dynamic forces within the economy, the β_t substitution is useful.

Although all of the above models are special cases derived from the generalized model of equation (3.46), only the last three are strictly time varying models. The former group have considerable structure built into the parameter shifts. By contrast the time varying models have much less restriction placed on parameter variation. The last three models allow parameters to vary from one time period to the next based upon a nonstationary probabilistic scheme (Judge, et al. 1980, p. 392).

The Cooley-Prescott model assumes that parameters are subject to both permanent changes, β_t^p, i.e., some persistent drift in the parameters values, and transitory changes. In a study by Ward and Myers (1979) this model was used to capture the dynamic effects of advertising on consumer demand.[37]

A time varying parameter model that has created considerable interest in economics is the Kalman filter model (Kalman, 1960; Kalman and Bucy, 1961)[38]. This model, long utilized by systems analysts, has arisen from the engineering literature (Manetsch and Park, 1980). Kalman filters have usually been applied to control problems within a predictive mode. The system model projects estimates forward in time which are continually updated and corrected by the incoming measurements. The current state of the model thus represents all the previous measurements which are not stored. The incoming measurements affect the estimate only when they disagree. This feedback mechanism implies that recent information is

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[37]See Judge et al. (1980. p. 394) for a discussion of the theoretical problems with this model. See also the convergent parameter model of Rosenburg (1973) for which equation (3.45) above is a generalization and extension of that Markovian formulation. This model is not applicable to the present research as it deals with cross-sectional variation of parameters over time.

[38]An exposition of this model is also contained in Judge et al. (1980, pp. 395-397).

important only so far as it differs from past measurements. In essence it is a one-step-ahead prediction process. Hence it seems a practical way to update econometric models which are subject to structural change.

Chavas (1982) uses Kalman filters in the context of a linear model to investigate structural change in the demand for meat in the U.S. Theoretically, this model deals with parameters varying over some periods but constant during others. Nevertheless, some major problems for estimation of economic relationships remain. First, in contrast to the experimental control available in engineering models, economists usually have little prior information on certain key parameters, namely δ_t and α_t and Ω_t, the covariance matrix $E(\xi_t \xi_t^1)$. Simplifying assumptions usually need to be made, for example, such as making these parameters time invariant. However, this simplification virtually collapses the model to the class of random coefficient models, although not necessarily stationary ones. Dixon and Martin (1982) discuss a random and systematic varying coefficient model using Kalman filters, but in the final analysis a random parameter model is used because of estimation difficulties.

This leads to the second limitation. The Kalman filter is primarily a forecasting model, although it can be used for econometric diagnostic purposes in the examination of variable and model misspecification. For instance, the model will indicate whether or not the included variable coefficient follows a random walk. If that variable exhibits such behavior than it arguably has very little economic value in the equation; from either a policy or predictive standpoint this would appear to be the case. Therefore, that variable as diagnosed should be excluded from the model. Certainly, for structural analysis its value is limited.

A third problem relates to available degrees of freedom. To set up the one-step-ahead forecasts, initial values for the estimated β_t and covariance matrix, Ω_t have to be obtained. This may be achieved by estimating an equation over a prior period of relatively stable observations, the parameters of which are then used to base the one-step-ahead projections.[39] A fourth more practical reason for the use of such models not being greater than it is, has been the relative complexity of these techniques and the lack of available computer software.

In this section a variety of statistical models have been reviewed. These models have been developed for situations where the coefficients of the general linear model are assumed to vary in a systematic and/or random way over time.[40] Problems exist, however, with each model presented. As with all economic inference based on statistical models, interpretation of results in still required by the analyst. Moreover, this interpretation can only be as sound as the theoretical and institutional knowledge of the economic structure on which it is based.

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[39] Chavas' results of price and income elasticities for meat using the Kalman filter will be discussed later.

[40] Many of these formulations can also incorporate cross-sectional observations.

3.4.7 COMPLEX: A Non-Linear Optimization Search Technique

COMPLEX is a non-linear programming algorithm. Like many search techniques, it starts from some base and moves towards the optimum, based on sequential movements in the value of the objective function. The step size may be fixed or varied subject to certain conditions. The purpose, method and desirable features of this algorithm are summarized below.[41]

COMPLEX finds the maximum (or minimum) of a multivariable, non-linear function, U, subject to non-linear inequality constraints:

maximize $\quad U\ (X_1,\ X_2,\ \ldots,\ X_N)$ (3.47)

subject to $\quad G_k \leq X_k \leq H_k$ (3.48)

For k = 1, 2, ..., M, where M is the total number of constraints. There are N independent variables and hence N explicit constraints

$$\begin{aligned} G_1 &\leq X_1 \leq H_1 \\ G_2 &\leq X_2 \leq H_2 \\ &\vdots \\ G_N &\leq X_N \leq H_N \end{aligned} \qquad (3.49)$$

There are (M-N) implicit constraints, imposed on implicit variables, $X_{N+1},\ldots,X_M$ which are dependent functions of the explicit variables, X_1, $X_2,\ldots,X_N$. The upper and lower constraints, H_k and G_k, may be constraints or functions of the independent variables.

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[41]This review draws largely on Kuester and Mize (1973), but also see Box (1965) in which the algorithm was first developed.

The implicit constraints may be linear, e.g.,

$$G_{N+1} \leq X_{N+1} = 3\ X_1 + 4\ X_2 \leq H_{N+1} \tag{3.50}$$

or inherently non-linear, e.g.,

$$\begin{array}{llll} G_{N+2} & \leq X_{N+2} & = 4\ X_1^{\ 2} - 3\ X_2^{\ 2} & \leq H_{N+2} \\ \vdots & \vdots & & \vdots \\ G_M & \leq X_M & = f(X_1, X_2, \ldots, X_N) & \leq H_N \end{array} \tag{3.51}$$

Minimization of this model is achieved by maximizing (-U).

The procedure for problem solving using this algorithm and for obtaining a global maximum instead of a local maxima derives from the fact that the initial set of points are randomly scattered throughout the feasible region. This region of points is called the 'complex'. The algorithm proceeds according to a number of rules.[42]

(a) Rule 1:

An initial 'complex' of $K \geq N + 1$ points or vertexes is generated consisting of a feasible starting point and K-1 additional points generated from random numbers and K-1 constraints for each of the independent variables:

$$X_{ij} + G_i + r_{ij}\ (H_i - G_i) \tag{3.52}$$

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[42]The details of each rule are only briefly covered here. See the previous two references for further explanation.

for $i = 1,2,\ldots,N$ and $j = 1,2,\ldots,K-1$ where r_{ij} are random numbers between 0 and 1. The starting feasible point is chosen as a best guess. The parameter, K, can be varied: the greater is K, the greater are the changes of obtaining the global maximum. In the illustrated example in Figure 3.4 over the X_1-X_2 feasible space, three points are chosen, point one being the initial point.

(b) Rule 2:

All selected 'complex' points must satisfy both explicit and implicit constraints. This rule deals with the necessary adjustments in the point location when any of the explicit or implicit constraints are violated. The adjustment moves the offending points to within the feasible space.

(c) Rule 3:

The objective value, U, is evaluated at each point of the 'complex'. For 'complex' maximizing, the point, 1, having the lowest function value is replaced by a point, 4, which is located a distance α times as far from the centroid, C, of the remaining points as the distance of the rejected point (point one in example) on a line joining the rejected point and the centroid. The value of 1.3 for α is suggested by Box (1965) to provide the appropriate acceleration towards the optimal solution.

(c) Rule 4:

The new point is compared, in terms of U(.), to the old point. If U(new point) > U(old point), the new point is accepted as an improved one. If a point repeats in giving the lowest function value in terms of U(.), then it is moved half the distance to the centroid of the remaining points. In Figure 3.5 point 2 is an inferior point with respect to 1 and 3. However, X, the new point is even worse. Therefore, 2 is moved half the distance to the centroid, C, to the new point 4. The procedure of 'complex' is to eventually straddle the optimal point, Z.

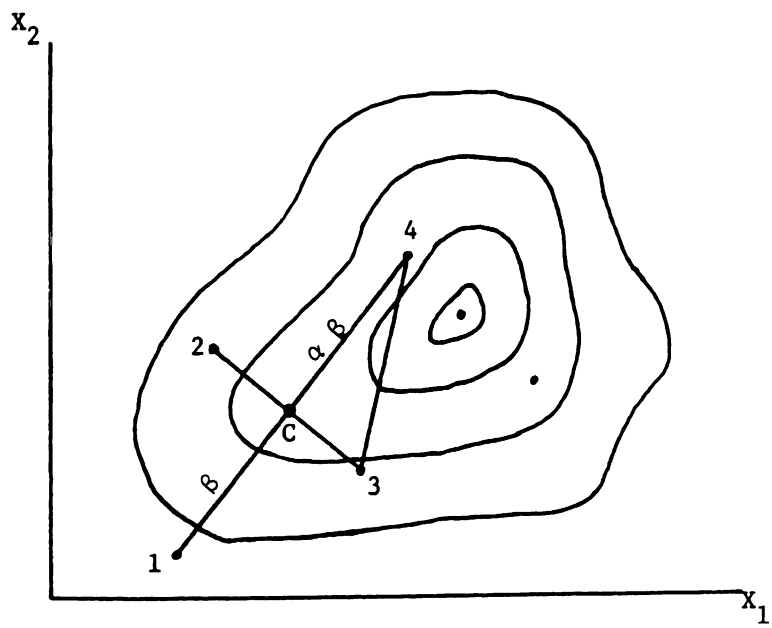


Figure 3.4

A 'Complex' of Three Points

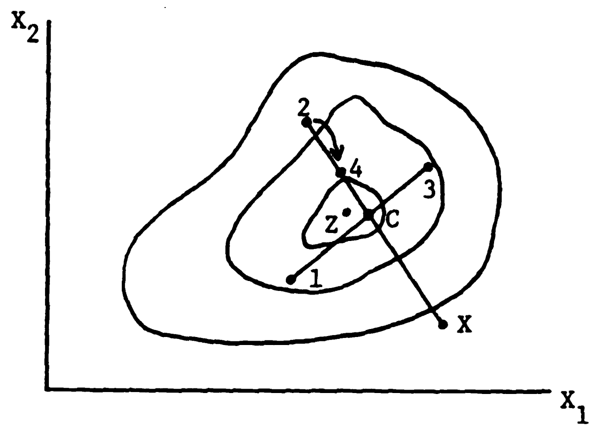


Figure 3.5

Movement from Inferior Points in 'Complex' Optimization Procedure

(e) Rule 5:

The new point is checked against the constraints and is adjusted as in rule 2, to satisfy all constraints.

(f) Rule 6:

Convergence is assumed when the values of U(.) at each point of the 'complex' are within β units[43] for α consecutive iterations (K , α , β , and γ are exogenously set in the program). An iteration is the set of steps

[43]The convergent parameter, β is in units of U('). Selecting an appropriate β is key to this complex technique.

necessary to achieve a new feasible point in the 'complex'. The larger is γ, the more rigorous is the solution process.[44]

The 'COMPLEX' algorithm requires starting values or best guesses for the X_N variables, plus values for K, α, β, γ and δ (explicit constraint violation correction). The algorithm will then provide values for U, the X's and the number of iterations taken to reach that objective function value, U.

Criterion for Identification of β Values

It is not always possible to identify every unknown parameter in the model. Nevertheless, identifiability implies obtaining estimates within the neighborhood of the real values. Hence, the following criteria are established: (a) each unknown parameter β_1, $\beta_2, \ldots, \beta_N$ must influence U, and (b) each member of the β set must have an independent effect on U. The effect of a change in one β cannot be offset by a change in another one, i.e.,

$$\Delta U \simeq \frac{\partial U}{\partial \beta_1} \Delta \beta_1 + \frac{\partial U}{\partial \beta_2} \Delta \beta_2 + \ldots + \frac{\partial U}{\partial \beta_N} \Delta \beta_N \qquad (3.53)$$

[44] A flow diagram illustrating this algorithm is contained in Kuester and Mize (1973, p. 371).

Criterion (b) requires that $\Delta U=0$, which implies implies $\Delta\beta_1 = \Delta\beta_2 = \ldots = \Delta\beta_N = 0$ in some neighborhood about the optimum. In essence this is a condition of linear independence.

There are many optimization techniques which feasibly could be applied to the present problem. The classical gradient method and the improved gradient method are two such search algorithms. However, the former is not selective in that it starts on one slope and stays on it. This risks obtaining a local optima and not a global optimum. Also, if the iterative steps are too large the solution fails to converge and may over shoot the optimum point. The improved gradient method utilizes the COGGINS algorithm, the optimizing subroutine (Box, Davies and Swann, 1969). This method overcomes the local optima problem by iterating along a ridge. However, the problem, with this method is that it is a single variable maximization, i.e., of U(X) and is not subject to constraints. It does have application as a building block within multivariable search methods. For both of these methods a minimum or maximum is reached when the gradient vanishes. By contrast, COMPLEX is (a) more efficient than gradient methods in terms of achieving a faster convergence; (b) tends to find the global optimum; and (c) has the added flexibility of introducing constraints.

Within the class of multivariable search methods the minimizing algorithm of POWELL may be considered (Powell, 1965). However, COMPLEX is to be preferred until iterations get within the neighborhood of the optimum (after which convergence is slow with COMPLEX) or when a high degree of accuracy is not required. POWELL, which makes use of a quadratic convergence, does not perform well when the interim solution is outside the neighborhood of the optimum. Another shortcoming of POWELL is that this minimization of a multivariable, non-linear function is unconstrained.

3.4.8 Legendre Polynomials

In optimal control problems the vector of controllable variables, $\bar{X}_c$, can be represented in discrete or continuous form. Diagrammatically, the representation of $\bar{X}_c$, optimized over the time path $0 \leq t \leq T$, is given in Figure 3.6 below.

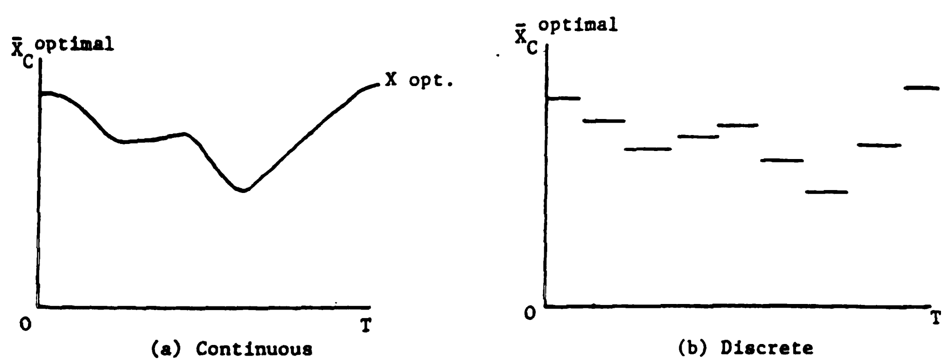


Figure 3.6

Representation of Continuous and Discrete Controllable Variables in an Optimal Control Problem

The problem in this research (where the controllable $\bar{X}_c$ are in fact the β's, i.e., $\bar{\beta}_c$), may be stated: find $\bar{a}$ such that $\bar{\beta}_c$ will optimize U(T) over the time path $0 \leq t \leq T$.

Legendre polynomials provide a means of representing any continuous function f(x) or f(t) over the interval (-1, 1). This set of polynomials, $\{P_n(x)\}$, which are orthogonal functions, have found application in representing continuous system controlable inputs in optimization studies. Hence, a function f(x) would be represented as:[45]

$$f(x) = a_0 P_0(x) + a_1 P_1(x) + \ldots + a_n P_n(x) \tag{3.54}$$

for x: $-1 \leq x \leq 1$.

These polynomial functions $P_n(X)$ are defined as:

$$\begin{aligned} P_0(x) &= 1 \\ P_1(x) &= x \\ P_2(x) &= \tfrac{1}{2}(3x^2 - 1) \\ &\vdots \\ P_{n+1}(x) &= \frac{1}{n+1}\left[(2n+1)\, x\, P_n(x) - nP_{n-1}(x)\right] \end{aligned} \tag{3.55}$$

The nth polynomial is obtained by recursion and is based upon $P_0(x)$ and $P_1(x)$.

[45] See Manetsch and Park (1981) for a more extensive background and development of this material.

The legendre polynomials are orthogonal over the interval (-1, 1) for x. That is,

$$\int_{-1}^{1} P_i(x)\ P_j\ (x)\ dx \qquad = 0 \qquad \text{for } i \neq j \quad (3.56)$$

$$\int_{-1}^{1} P_i(x)\ P_j\ (x)\ dx = \int_{-1}^{1} [P_i(x)]^2\ dx = \frac{2}{2\ n+1}\ , \text{ for } i=j$$

However, of particular interest here is the values which the a's will take in the function, f(x) in equation (3.54). An important property which allows the $\bar{a}$ vector to be obtained is called the finality of coefficients property. Essentially, this means that the a's are independent. This is a special property of orthogonal functions which is shown below.

Assume a function f(t) such that:

$$f(t) \simeq \sum_{n=0}^{N} a_n \phi_n(t) \qquad (3.57)$$

where t is time and ϕ_n is some basis function. A representation of f(t) is desired that improves as more terms are added as $N \rightarrow \infty$ in (3.57). It is also desired that as terms are added to this approximation of f(t), previously determined coefficients, $a_1, a_2, \ldots, a_N$ do not need recomputation. This finality of the coefficients, however, can only be obtained if the $\phi_n(.)$ functions are themselves orthogonal. The proof of this property is not presented here. It can be shown (Manetsch and Park, 1981), however, that for a set of orthogonal functions over the interval (t_1, t_2), an equation for determining the a's in equation (3.57) can be derived as

$$a_n = \frac{1}{\lambda} \int_{t_1}^{t_2} f(t)\phi_n (t)\, dt \ , \quad \text{for } n = 1, 2, \ldots \tag{3.58}$$

where λ is a constant. Each of the a's in equation (3.58) are independent of one another.

Therefore, given the orthogonal relationship expressed in equation (3.56) and given equation (3.58), an equation allowing determination of the $\bar{a}$ vector in equation (3.54) may be given as

$$a_n = \frac{2\ n+1}{2} \int_{t_1}^{1} f(x)\ P_n\ (x)\ dx \tag{3.59}$$

Applications of Legendre polynomials may be more usefully demonstrated in systems analysis by mapping $-1 \leq x \leq 1$ into $0 \leq t \leq T$, so that the polynomials are now orthogonal with respect to the time interval. By substitution of

$$t = \frac{T}{2}\ (x+1) \quad , \tag{3.60}$$

and therefore,

$$x = \frac{2t}{T} - 1 \tag{3.61}$$

equation (3.55) becomes

$$\begin{aligned} P_0'(t) &= 1 \\ P_1'(t) &= \frac{2t}{T} - 1 \\ P_2'(t) &= \frac{1}{2}\ [3(\frac{2t}{T} - 1)^2 - 1] \\ &\vdots \\ P_{n+1}^{1}(t) &= \frac{1}{n+1}\ [(2\ n+1)\ (\frac{2t}{T} - 1)\ P_n'(t) - nP_{n-1}'\ (\frac{2t}{T} - 1)] \end{aligned} \tag{3.62}$$

Note that $P_n'(t) = P_n(\frac{2n}{T} - 1)$. A continuous function, g(t) may be represented as

$$g(t) = a_0' \; P_0'(t) + a_1'P_1'(t) + a_2'P_2'(t) + \ldots \tag{3.63}$$

$$= f\;(\frac{2t}{T} - 1)$$

where

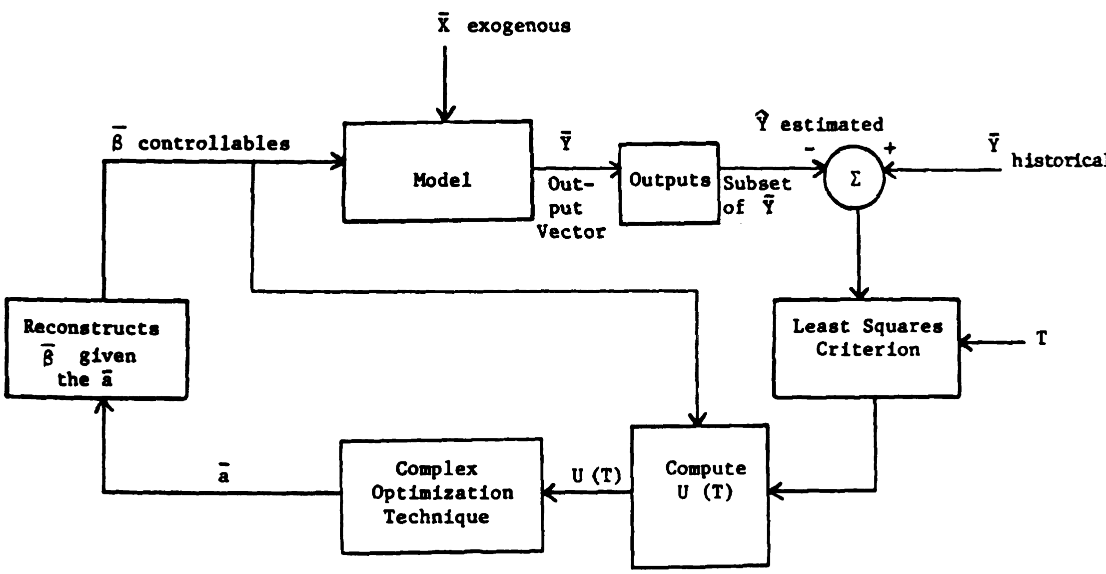
$$a_n' = \frac{2\;n+1}{T} \int_0^T g(t)P_n'(t)\;dt \tag{3.64}$$

3.5 A Time-Varying Model Using COMPLEX and Legendre Polynomials

The aim in this section is to combine the use of the COMPLEX optimization algorithm and Legendre polynomials in order to produce a continuous function with time varying parameters. The approach is analogous to conventional least squares techniques with some important exceptions. Figure 3.7 represents the overall process of integration of COMPLEX to find the optimal time-varying parameters in the economic model.

Using the weighted least squares criterion the problem may be stated:

$$\text{minimize} \quad U(T) = \sum_{t=1}^{T} \left[\frac{Y_t - \hat{Y}_t}{\bar{Y}}\right]^2 \tag{3.65}$$



where:

$$U\,(T) = \sum_{t=1}^{T} \left[\frac{Y_{jt} - \hat{Y}_{jt}}{\bar{Y}_j}\right]^2$$

Y_{jt} = observed value of the j^{th} good in time t;

$\hat{Y}_{jt}$ = estimated value;

$\bar{Y}_j$ = mean of observed value.

Figure 3.7
Block Diagram of Time-Varying Parameter Model

$$\text{subject to} \quad \hat{Y}_{jt} = \beta_{0t} + \beta_{1t} X_{2t} + \ldots + \beta_{kt} X_{kt} \tag{3.66}$$

$$\text{for} \quad t = 0, 1, \ldots, T; \; k = 0, 1, \ldots, n; \; \beta_k = \beta_0, \beta_1, \ldots,$$

$$\beta_n; \; X_k = X_1, X_2, \ldots, X_n.$$

The function, U(T), which is optimized by COMPLEX is the weighted least squares criterion, i.e., minimum weighted sum of the residuals squared where Y_{jt} represents the observed data; $\hat{Y}_{jt}$, the estimated value; and $\bar{Y}_j$, the mean of the observed values. Hence, U(T) is minimized subject to the estimated demand constraint, $\hat{Y}_{jt}$ for the consumption of the jth good in time, t.

The COMPLEX algorithm using Legendre polynomials provides a means of testing whether any or all of the β_{kt} coefficients on the X_{kt} exogenous or predetermined variables[46] are constant or in fact vary over time. The Legendre polynomials provide the means of introducing various degrees of polynomial into each β coefficient. The particular advantage of these polynomials over, say, directly specifying a given polynomial into the demand equation, by substitution, is the property of finality of coefficients. That is, the addition of a higher degree term in time does not change the 'a'

[46]Justification of a single equation estimation procedure is provided later.

coefficients previously estimated using the lower degree polynomial. Also, the same degree polynomial does not need to be set for each X_{kt}. Some β coefficients may be optimal over the time period as a constant value whilst others may more appropriately be specified in say, a linear or quadratic formulation. Hence, in general form U(T) is minimized subject to $\hat{Y}_t$ where

$$\begin{aligned}
\beta_{0t} &= a_{00}\, P_0(t) + a_{01}\, P_1(t) + \ldots + a_{0n}\, P_n(t) \qquad (3.67)\\
\beta_{1t} &= a_{10}\, P_0(t) + a_{11}\, P_1(t) + \ldots + a_{1n}\, P_n(t)\\
\beta_{2t} &= a_{20}\, P_0(t) + a_{21}\, P_1(t) + \ldots + a_{2n}\, P_n(t)\\
&\vdots\\
\beta_{nt} &= a_{n0}\, P_0(t) + a_{n1}\, P_1(t) + \ldots + a_{nn}\, P_n(t)
\end{aligned}$$

Now, the objective of COMPLEX within this optimal control specification is to find the values of the vector, $\bar{a}$ such that the $\bar{\beta}$ vector will optimize U(T) (i.e. minimize) over the time path $0 \leq t \leq T$. Within this optimal control algorithm, COMPLEX, the following procedure is: (a) fit a constant function, i.e. only one 'a' term on each slope and intercept term. This provides the base value for U(T); (b) then fit, say, a linear function, i.e. find a_{n0} and a_{n1} which minimizes U(T); (c) using these a's for comparison, add a further term, a_{n2} and so on finding all a's to optimize U(T); and (d) stop adding terms when the change in U(T) becomes negligible.

If the specification of the β coefficients in $\hat{Y}_{jt}$ are linear in coefficients then this approach is broadly equivalent to direct substitution of the β terms and estimation using ordinary least squares. However, the advantages of using the COMPLEX-Legendre polynomials method are: (a) when the degree of the polynomial is unknown, as will virtually always be the case, the property of finality of coefficients provides superior estimation to ordinary least squares; (b) Legendre polynomials provides a systematic search method with a definite criterion, i.e., minimizing the sum of the residuals squared, for the specification of the β coefficients compared with the more ad hoc search involved with OLS;[47] (c) COMPLEX allows for an inherently non-linear specification (in coefficients) of both the optimized function and the inequality constraints; and (d) COMPLEX will provide, given the above systematic search method, a global minimum sum of squared residuals.

The output from this model, in addition to $\hat{Y}_t$ and the size of the error of estimation, $(Y_t-\hat{Y}_t)$, includes the values of the a's and for β_t for each right-hand-side variable. When specified in logarithmic form the coefficient values are the values of elasticities over the total time period. Hence, this will provide a 'tracking' of elasticities over time which may be illustrated as in Figure 3.8. Changes in these β coefficients over time should provide insights in continuous structural changes which have occurred in the demand for red meats.

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[46]Legendre polynomials are optimal in the sense that there exists no better representation in a mean squared error sense.

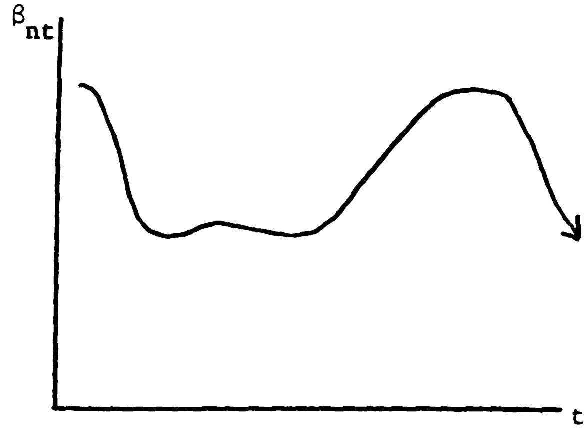

Figure 3.8

Illustration of Continuous Time-Varying Elasticity Estimations

CHAPTER 4

ESTIMATION OF RETAIL MEAT DEMAND AND IDENTIFICATION AND MEASUREMENT OF PARAMETER CHANGES

In Chapter 3 a review was undertaken of a rather comprehensive array of estimation techniques and statistical models which have been or may be applied to an analysis of structural change in demand relationships. These methods provide, in varying degrees of sophistication and appropriateness, means of obtaining insights into the changing nature of demand relationships and of consumer responsiveness to the forces influencing retail meat demand. Depending on the particular estimation technique used, coefficients of causal relationships are permitted to vary through time.

Not all estimation methods reviewed in Chapter 3 are applied in this chapter. In some cases, data are unavailable or in an inappropriate form to test those models. In other cases the inherent form or structure of the statistical model is not appropriate to test the economic model under consideration. In choosing the analytical tools the question asked was 'does this particular statistical model assist in addressing the economic problem at hand?' and not the question 'with this statistical model, what problem or question can be addressed?.' In

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either case, a statistical model merely provides results. Economic interpretation of those results remains the task of the analyst.[1]

The approaches adopted and the steps followed in these analyses of structural change in retail meat demand in the U.S. are:

a. estimation of a 'base' model of each demand equation, namely, table beef, hamburger beef, pork and broilers.[2]

b. graphical analysis of price-quantity relationships as an initial step in investigation of major shifts in demand over the period 1950-1982.

c. using graphical analysis as a guide, re-specification of the base model to include qualitative shift variables (i.e., dummy and quantity-time interaction variables) to estimate major shifts in demand. The hypothesis of irreversibility of demand is tested, assuming discontinuity between shifts.

d. linear and cubic spline functions are applied to the above economic models to provide continuity between structural shifts in retail demand. The spline function is applied to the switching regression model which allows more specifically for

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[1]Every attempt is made in this research to provide a priori economic reasoning in identifying changes in the structure of demand and hence militating against the more dubious activity of curve-fitting.

[2]An 'all beef' model is estimated for the purposes of comparison with table and hamburger beef models. However, this model was not used throughout.

time-varying shifts to be modelled. In essence, the coefficients of the estimated model are allowed to vary uniquely for identified periods between 1950 and 1982.

e. the specification of Legendre polynomials within a continuous time-varying parameter model, enables the estimation of a fully dynamic coefficient-varying model.

Before results from these estimations are presented, a number of preliminaries are completed. First, specification of the economic model and justification for this specification is presented. This includes a brief discussion of theoretical restrictions applicable to a price dependent demand function and some observations on interpreting the measured coefficients of consumer responsiveness. Second, the statistical model and estimation procedure are outlined: this includes the functional form of estimated equations, the method of estimation, details of the estimation period and data limitations. Third, the structural model and a discussion of candidate variables precedes the presentation of results from the estimated equations.

4.1 Specification of the Economic Model

The theory of consumer demand discussed in the previous chapter was based on the behavior of an individual consumer. It was reasonable to view the consumer as having no influence over the price paid for a given good, but as being able to determine the quantity of that good purchased. Hence, a change in price is thought of as causing a change in the quantity demanded by the consumer, under ceteris paribus conditions.

Aggregation of consumer behavior was viewed in much the same fashion but in terms of the 'representative' consumer.

From the standpoint of the entire market, however, the line of causality in retail demand, from prices to quantities is not so straightforward. For many agricultural commodities, supplies available for consumption determine prices rather than the other way around. It is argued here that this is the case for meats in the situation of short-run changes, from one year to the next; although in the long-run, supplies are responsive to changes in price.

These directions of influence may not apply to shorter-run (i.e., shorter than one year) or to local marketing situations, even for such perishable products as beef and pork. In many quarterly models of beef and pork, supplies available for consumption are assumed fixed at the retail level, although it is likely that quantities moving into and out of storage will have a greater effect on the quantity supplied than in annual models. Of course, as the time period is further reduced, the opposite is more likely. That is, consumption will be determined by prices, which are more likely to be exogenously determined. At any given time a retailer sets a price for each product and his customers adjust their purchases and consumption to that price.

Greater doubt arises as to whether consumption of poultry meat[3] in particular, commercial broilers, can be regarded as a predetermined variable. Within a period of a year, production of broilers is more

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[3]In this research meat refers to all meats, including poultry meat, i.e., chicken and turkey.

likely than beef or pork to be influenced by prices of broiler and, for that matter, by supplies and prices of other meats. Certainly in a more detailed analysis of the poultry meat subsector such questions about an annual specification of retail demand for commercial broilers would be examined more closely.[4]

The significance of this identification problem in agricultural commodities was noted almost 60 years ago by Working (1927). Where supplies coming off the market and made available for consumption in any year are almost wholly the result of decisions made in previous periods, price will have little influence on supplies in the same period (i.e., a year). In this case, where there is likely to be a much greater shifting of the supply schedule of sellers than of the demand schedule of buyers, a demand curve is obtained by fitting a function to a series of points which represent the quantity of a good sold at various prices. Otherwise, a supply curve is identified. Working added the caveat that although shifts in the actual supply and demand curves may be correlated, an attempt to estimate a demand curve will not give a useless result. On the contrary, such a curve would be useful for price forecasting purposes, 'provided no new factors are introduced which did not affect the price during the period of study...so long as the shifts of

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[4]It is not uncommon nor unreasonable, when estimating annual models of beef and pork demand to specify broiler demand in the same fashion (Fox, 1953, pp. 48-53). This avoids the complexities of a mixed annual and quarterly model and maintains consistency among equations. Complexities avoided with an annual model, but which arise from a shorter term analysis of prices for storable commodities are due partly to the potential importance of fluctuations in inventories relative to adjustments in final consumption.

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the supply and demand curves remain correlated in the same way and...shift through approximately the same range' (p. 227).

Fox (1953, 1954, 1955) in a series of papers considered this identification problem in the context of measurement of demand for farm products and in deciding upon the theoretical and practical appropriateness of single equation methods for estimating structural relationships of food demand. He demonstrated, within the simultaneous equation theory, that the demands for beef and pork can be satisfactorily approximated by single least squares equations. That is, when production is virtually equal to consumption, then consumption may be regarded as a predetermined variable and hence, the demand functions may be fitted with price as the dependent variable and give unbiased estimates of the demand coefficients. This is indeed the case with beef, pork and broilers, since the magnitude of changes in stocks of these products is small relative to production. Also, imports and exports of these commodities are small compared with production. Therefore, the characteristics of domestic demand are of predominant importance in determining how meat prices change in response to changing meat production.

An explicit and restrictive assumption regarding the elasticity of supply in the short-run is made when either prices or consumption is chosen as predetermined in a demand relationship. To accept prices as predetermined and to estimate demand elasticities is to assume supply is highly elastic. An inelastic supply assumption is presuppositional to a model specification of price as some function of the level of demand, resulting in price flexibilities. Where neither postulate can be made about the nature of the elasticity of supply, that is, where both price

and quantity are regarded as current endogenous variables, a simultaneous equation approach is necessary.

A price dependent specification of an annual model of retail meat demand becomes more obvious when the structure of the meat market is examined. In the case of beef, the number of animals on farms at the beginning of a marketing period is largely unaffected by current price. Beef, as distinct from veal, is produced from heavier, more mature animals. Therefore, beef production must come mainly from animals in existence at the beginning of that year. In particular, steers are affected only slightly by current prices in any one year. Marketings of cows and heifers are more subject to economic decisions based on current prices. But, even decisions to expand or contract the breeding herd and the scale of the beef enterprise are made with longer-term expectations in mind. Certainly meat production can be affected to some extent by current economic forces during a given year, e.g., when a rising price of hogs causes farmers to feed their hogs to heavier weights before marketing. Yet despite this qualification, the large proportion of supply is predetermined in the current period.[5]

Some analysts, who use annual data, have employed simultaneous models. Authors of models falling under this category include Langemeir and Thompson (1967), Hunt (1973) and Freebairn and Raussar (1975). They regarded the level of supplies to be jointly determined with prices.

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[5]See Fox (1953), Working (1954) and Breimyer (1961) for further details of these arguments.

They would argue that production has time to respond to price changes and hence they assume price elasticity in product supplies.

An argument that may suggest simultaneity at the retail level between prices and consumption is based upon the butcher's decision to cut-out the carcass into table cuts and other beef cuts and products. The process of retail pricing, discussed in Chapter 2, is relevant here. The total value of a carcass to the retailer is dependent, not only upon the retail price per pound, but also upon the cut-out, i.e., the saleable retail meat obtained. Two carcasses of identical weight and quality grade can yield significantly different quantities of saleable meat.[6] Moreover, the carcass cut-out is likely to vary over time. This would suggest that while total quantities of beef may be predetermined in the current period, the exact quantities of various cuts from of given carcass may be endogenously determined, within the period, by retail prices prevailing for those specific cuts. There would be bounds on the degree of flexibility in cut-out percentages for a given carcass and this range would vary between type of carcass, e.g., between choice steer carcasses and commercial cow carcasses. Intuitively, price would, therefore, be a major factor determining this range in a given period.

There is no readily available documented evidence, however, on the degree of flexibility of cut-out percentages or of the extent to which retail prices influence these percentages. In the absence of such evidence and on the assumption that the large proportion of variation in domestic consumption is determined by forces of an earlier period, a

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[6] Elaboration of these arguments is presented by McCoy (1979), pp. 236-240.

price dependent single equation model is adopted. Therefore, using the arguments presented earlier, single equations can be used to measure the interrelationships between consumption, price and income in either the table beef or processed beef market, given the amount that moved through each outlet. However, a simultaneous system of equations would be needed to estimate the relative proportion of total beef production moving through each outlet in any given year.

Some researchers have argued that the specification of an annual model of retail demand for beef, pork and broilers be quantity dependent. For completeness of treatment, it is perhaps useful to look briefly at some of their arguments. In a study of the Canadian livestock industry Tryfos and Tryphonopoulos (1973) justified their single equation estimation of quantity dependent retail demand equations for beef, veal, lamb, pork, and chicken on the basis of exogenously determined U.S. livestock prices. Hence, in their annual model, the absence of any supply considerations follow from the dominance of the U.S. livestock markets allowing separate estimates of demand and supply functions. Hassan and Johnson (1976) adopt similar arguments in their Canadian demand study. They add, however, that at least in Canada's case, the demand curve is identified as quantity dependent because of the importance of government programs in shifting supply. Certainly these arguments do not hold for the U.S. meat markets.

For broadly similar reasons, Australian retail meat demand studies by Main, Reynolds, and White (1976) and by Fisher (1979) assumed quantity variables were endogenous and that prices at retail were predetermined. Overseas prices, in large measure, determine Australian farm level prices, upon which retailers base their prices to domestic consumers (Papadopoulos, 1973, Hinchy, 1978). Furthermore, they argue that retail price leveling and price averaging activities, for all meats, cause 'smoothing' of retail prices and provide consumers with prices which fluctuate much less than farm level prices.[7] However, in these two quarterly model studies, quantities coming into the market may have some effect on retail prices. Therefore, the estimates of the parameters in those models may contain some simultaneous equation bias.

Undoubtedly, on these aspects of identification, a sizeable quantity of subjectivity goes into some studies, and in any case some degree of subjectivity is unavoidable. Economic models of meat demand are estimated over different data periods, different time periods (monthly, quarterly, annually), may use slightly different data sets and definitions, and are often constructed for different objectives and uses. For example, Tomek and Cochrane (1962) estimated quarterly and annual single equation models to obtain the long-run demand for beef, pork and red meat. They recognized quantities as predetermined in their annual model and the effects of changes in stored quantities on price in their quarterly model. However, they conclude in deference to 'some practical experience (of a study of apple supply and demand) that quantity as the dependent variable provides "better" results' (pp. 721-722). They add blandly, in apparent justification of this specification that 'a

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[7]See Reeves (1979, p. 191) for references in which these practices are discussed. He defines these two activities: 'Price leveling refers to the practice of marketing firms holding retail prices stable over time in the face of fluctuating farm level prices. Price averaging refers to the practice of firms setting a low margin on one meat type and recouping any losses on that meat line by setting high margins on the other meat lines.'

considerable portion of single equation demand analysis has been conducted with quantity as the dependent variable' (p. 722). Foote (1958) makes the observation that if R^2 is near one then it makes little difference which variable is treated as independent. However, the statistical convenience of these observations seems hardly consistent with or of relevance to the desire of a correctly specified economic model.

It would seem that for many authors the question of whether to treat price or quantity as the dependent variable in econometric analysis is, indeed, not completely settled. Chang (1977), in his otherwise informative article, quotes Schultz (1938), Working (1954) and Fox (1954) in justifying his own use of single equations to estimate an annual model of U.S. demand for meat, but provides no economic reasoning for specifying the functions as quantity dependent with predetermined prices. Pope, Green and Eales (1980), like Chang, estimate single equation models on the accepted logic that shifts in the supply function of agricultural products are much greater than those of the demand for farm products. Hence, a demand relation can be estimated without serious problems associated with simultaneity. However, they, like Chang, make the dubious transition from the traditional demand theory and its associated notion of a 'representative' consumer, by specifying prices endogenously in an annual model of retail demand for beef, pork, poultry and fish. At the market level, as pointed out by Working (1954), the representative consumer approach is inappropriate. It is the market which responds to quantities available. Goodwin, Andorn and Martin (1968) also appear far less concerned about the economic specification of their retail beef demand model then they are about the statistical properties of their quarterly model. They argue that in distributed lag models, whether price or quantity is used as the dependent variable makes little difference in the statistical (as opposed to economic) validity of the results. Hence, quantity consumed is chosen as the dependent variable in their study.

From an investigation of the structure of the U.S. retail meat market in aggregate and from an assessment of the analyses of other researchers in this area, the assumption that quantities of meats and their respective substitute products, available for civilian consumption, are predetermined in the current period, and that retail prices adjust to clear the market, appears reasonable for beef and pork. This may not be so for broiler demand given its shorter production cycle. However, in the interests of model consistency within an annual framework, a similar specification was adopted for broilers.[8] On this basis the following general economic model of the U.S. retail demand for meats is adopted;

$$p_{it} = f(q_{it}, q_{jt}, y_t, z_t) \tag{5.1}$$

where, in time period, t, p_{it} is retail price of the ith commodity, q_{it} is the supply of the ith commodity available for retail consumption, q_{jt} is the supply of the jth substitute (or complementary) commodity available for retail consumption, y_t is income, and z_t represents all other influences on price, p_{it}.

[8] A further reason for specifying an annual broiler equation is for compatibility within the Michigan State University Agricultural Model, discussed in the following Chapter 5.

4.1.1 Restrictions on a Price-Dependent Demand Function

Having resolved for this research, the general specification of the economic model of the retail demand for meats, i.e., price as a function of quantity supplied, one must ask how this specification relates to the restrictions on demand theory discussed in the previous chapter. More specifically, what are the relationships between the elasticities derived from the traditional quantity dependent demand function and the flexibilities derived from a price-dependent specification?

The classical utility-maximizing framework described earlier in Chapter 3 is based upon the economic behavior of individual buyers to changes in prices and incomes which, when making a purchase, they consider as given. They respond to decisions on quantities demanded; demand elasticities measure this response with respect to changing prices and income. The carefully reasoned set of theoretical restrictions which apply to direct and cross-price and income elasticities of demand are firmly embedded in this theory. As discussed above, although individuals make quantity decisions based on given prices, at the market level many agricultural production processes are such that market supplies of related commodities are determined largely in advance of current prices. That is, these supplies are fixed in the short-run so that prices must bear virtually the entire adjustment burden.

Consequently, the focus is on the amount by which market prices change in response to supply availability. Therefore, direct and cross-quantity flexibilities are the appropriate measure of 'consumer' or more correctly, market responsiveness.[9] Quantity flexibility refers to the percentage change in the price of a commodity associated with say a one percent increase in the quantity 'demanded' or available from supplies,[10] ceteris paribus. A cross-quantity flexibility refers to the percentage change in a commodity's price associated with a one percent increase in the quantity demanded for another good, ceteris paribus.

So that an economic demand model, where prices are a function of quantities demanded, is consistent with the classical theory developed in Chapter 3, there is a need to establish that the virtually complete set of restrictions among demand elasticities have a corresponding set of theoretical relationships among demand flexibilities. For the most part, these theoretical relationships have been presented by Houck (1966), who obtained the corresponding restrictions for a price dependent demand equation by beginning with the traditional elasticity restrictions imposed on quantity dependent demand functions.[11] Counterpart restrictions among demand flexibilities are the column sums (Cournot aggregation) condition, row sums (zero homogeneity) condition, and the cross-coefficient symmetry (symmetry or Slutsky) condition.

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[9]If a quantity dependent function gives a price elasticity then more consistently, a price dependent function should give a quantity flexibility.

[10]Where stocks and imports are zero or negligible, production or supply availability approximates the amount consumed.

[11]The traditional, though simplistic, assumptions of constant preferences, and no aggregation or income distribution problems are made.

In an earlier article, Houck (1965) also demonstrated that

> under rather general conditions, the reciprocal of the direct price flexibility is the lower absolute limit of the direct price elasticity. The departure of the true price elasticity from the flexibility reciprocal depends upon the strength of the cross effects of substitution and complementarity with other commodities (p. 789).

That is, for the ith commodity

$$\left| e_{ii} \right| \geq \left| \frac{1}{f_{ii}} \right| \tag{5.2}$$

If all the cross effects are zero, then the elasticity will equal the reciprocal.[12]

Colman and Miah (1973) pose some important qualifications to the condition in equation (5.2). They argue that this condition is meaningful only for partial elasticities and flexibilities in which cases the ceteris paribus conditions also hold. This would be true of elasticities or flexibilities calculated from the structural equations, whether they be of a single equation model or of a simultaneous model. When these calculations are made from simultaneous systems of equations after taking into account the effect among equations then they are correctly termed total elasticities and flexibilities. These are obtained from the reduced form equations. Because of the unique feedback relationships built into the structural system, the total direct elasticities and flexibilities cannot logically be expected to be each other's inverse. Moreover, when, perhaps more realistically, both prices and

[12]Likewise, the flexibility will equal the lower absolute limit of the direct flexibility, if all cross effects are zero.

quantities are treated as endogenous in a structural system of equations, the total direct elasticities and flexibilities do not exist. This is because the reduced-form coefficients do not provide estimates of relationships between endogenous variables. When, however, a single equation model is estimated the partial and total elasticities and flexibilities are equivalent, respectively.

One final point on demand restrictions; of the nine conditions, which the theory imposed on demand functions, only two are applicable to the case of a single equation model (Intrilligator, 1978, p. 217). They are the homogenity condition and the non-negativity condition.[13]

4.1.2 Some Observations on Interpreting Consumer Responsiveness

Given the above specification of the economic model, i.e., price as a function of quantities available, consumer responsiveness will be interpreted in this research in terms of quantity and income flexibilities. This specification explicitly reflects the underlying causality assumed to exist in the retail market for meats and, therefore, it is not appropriate to assume that upon mathematical manipulation, to give price and income elasticities, the economic meaning is unchanged.[14]

In causal terms, a demand flexibility has a different economic meaning to a demand elasticity. More specifically, under the above assumption of causality, to derive a price elasticity is to imply that

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[13]These conditions require that the sum of elasticities or flexibilities be equal to zero and that the demand curve be downward sloping, respectively.

[14]Colman and Miah (1973) take a strong stance in this regard.

current price influences current consumption. The policy implications for correctly identifying these structural relationships is clearly of major importance.

Despite the apparent force of these arguments, the temptation of researchers and users of such coefficients of consumer responsiveness to derive elasticities, is often strong. No such derived elasticity estimates are presented in this research. Of course, the tempted reader may wish to make a mental qualitative check of the flexibilities obtained by considering the inverse of the estimated flexibility to be somewhere around the lower limit of the derived 'elasticity'.

Many of the observations made in the past regarding the interpretation of estimated elasticities[15] may be relevant to the interpretation of direct[16] and cross-flexibilities. In time series analyses, as with own-price elasticities, own-quantity flexibilities are likely to be different in the long run compared to the short run, and, to depend upon the sample period, the estimation procedure, and the functional form of the estimated equations. In a logarithmic specification the flexibility is constant across all price-quantity combinations. In this case a change in flexibility represents a shift in the demand curve. While there is some convenience in this specification it may be too restrictive in representing reality. The arithmetic linear form provides greater flexibility of interpretation since it allows for the

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[15] A succinct treatment of some of these issues is contained in Manderscheid (1964).

[16] The term 'direct' is used throughout this research in place of the term 'own-quantity' in referring to flexibilities.

possibility of slope and price-quantity changes to be observed. Presented in Table 4.1 are six possible theoretical situations of change in an estimated demand flexibility arising from the well-known flexibility formula:

$$f_i = \frac{\Delta p_i}{\Delta p_i} \cdot \frac{p_i}{q_i} \quad , \tag{5.3}$$

Observing that the flexibility has changed over time does not necessarily indicate what has actually happened to demand. For example, a change in an estimated flexibility over time may arise in three general ways: (a) a movement along a given demand curve[17] (b) a parallel shift of that curve, i.e., a change in the level of demand, or (c) a non-parallel shift of the curve, i.e., a change in the relationship (slope) between price and quantity. In the first case, a change in flexibility may not require a shift in demand structure but come about merely by a change in the price-quantity ratio, resulting from a shift in supply. In cases (b) and (c) a change in the price-quantity ratio must occur for the flexibility to change. Even when the demand curve has shifted (i.e., along a static supply curve), the slope may have changed as well as the intercept. In reality, it is more likely that demand and supply changed simultaneously. Similar confusion in interpretation may arise when the flexibility is observed not to have changed over a given time period (Table 4.1).

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[17]This occurs when the curve is linear in arithmetic terms as opposed to linear in logarithms.

Table 4.1

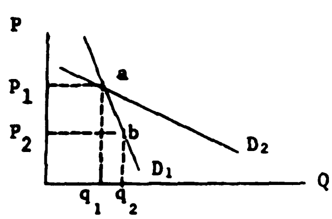
Decomposition of Components of Change in Direct-Quantity Flexibility of Demand ($f = \frac{\Delta p}{\Delta q} \cdot \frac{q}{p}$)

Direct Flexibility (or Elasticity)	Slope Coeffient			
	Constant		Changed	
	Quantity-Price Ratio		Quantity-Price Ratio	
	Constant	Changed	Constant	Changed
Constant	Null Set	c	Null Set	e
Changed	Null Set	b,d (2 cases)	a	f

Note: 1. Single lower case letters in table refer to cases illustrated below.

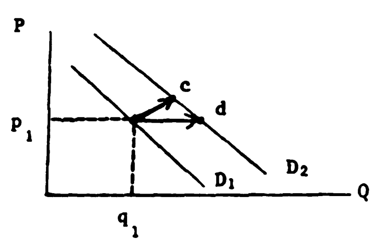
2. Additional combinations could be obtained by differentiating between quantity and price changes.

3. Similar cases are obtained from price elasticity of demand ($E = \frac{\Delta Q}{\Delta P} \cdot \frac{P}{Q}$)



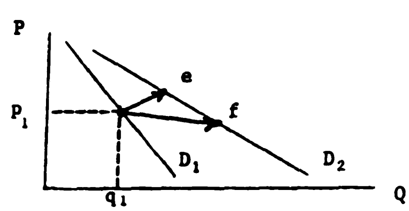
a. Δ slope, $\overline{q\text{-}p}$ => Δf

b. $\overline{\text{slope}}$, $\Delta q\text{-}p$ => Δf



c. $\overline{\text{slope}}$, $\Delta q\text{-}p$ => $\overline{f}$

d. $\overline{\text{slope}}$, $\Delta q\text{-}p$ => Δf



e. Δ slope, $\Delta q\text{-}p$ => $\overline{f}$

f. Δslope, $\Delta q\text{-}p$ => Δf

A central focus in this study is on how market responsiveness to changes in quantities available and in incomes has influenced retail prices of individual meats in the U.S. over the past 30 years or so. The importance of understanding the nature of these changes in market response, as measured by elasticities or flexibilities, was discussed in Chapter 3. A number of researchers have observed that flexibilities and elasticities have not remained constant during this time. More particularly, they have shown that estimated demand curves (linear in arithmetic values) have generally become flatter over time.[18] This may imply an increasing demand elasticity. However, this graphical evidence is not in accord with empirical evidence that, in the case of elasticities, demand has become less elastic (more inelastic) and for flexibilities, demand has become more flexible. Breimyer (1961), Tomek and Cochrane (1962) and Tomek (1965) have been among those to make this observation.

Tomek recognized the need to explain these changes in empirical measures of consumer responsiveness. To do this requires that the three sources of change in responsiveness be examined. Most commonly, economists explain changes in demand flexibility as being due to demand curve shifts through time in response to changes in incomes, available quantities of substitute commodities, or tastes and preferences. However, this interpretation ignores the slope of the demand relation, i.e., the relationship between quantity and price, which may also change.

A bound on the nature of some of these changes may be obtained by applying the Slutsky relation and the homogeneity condition of consumer

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[18]This phenomenon is illustrated later in this chapter in the graphical analysis of retail meat demand.

demand. As incomes increase, the related increases in food consumption generally become smaller. In consequence, income elasticities (in this case), for food will decline.[19] From the Slutsky equation, when transformed into elasticities, a decrease in the income elasticity implies, via the fall in the income effect, that price elasticities will also become smaller.[20] That is, as incomes rise relative to the price of a commodity, the income effect of a price change will be smaller.

Using the homogeneity condition, a fall in income elasticity, assuming no change in substitutes or complements, will result in the own-price elasticity becoming smaller in absolute magnitude (less elastic or more inelastic). As discussed earlier in this chapter, the homogeneity condition also holds for demand flexibilities. Hence, in an opposite direction, as the income flexibility rises, the absolute magnitude of direct price flexibility will become larger, i.e.,more flexible. Demand flexibilities for meats are likely to rise over time. First, as disposable incomes increase and income flexibilities rise, direct flexibilities become larger in absolute value; and second, as an economy develops, consumer preferences change in a way that makes the demand for certain foods more price flexible. Offsetting these effects are the

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[19] Empirical evidence supporting this observation is contained in Fox (1958, pp. 125-129, 141).

[20] This follows from the Slutsky equation

$$\frac{\partial q}{\partial p_1} = \left.\frac{\partial q}{\partial p_1}\right|_{\bar{u}} - q \cdot \left.\frac{\partial q}{\partial y}\right|_{\bar{p}} ,$$

where utility, $\bar{u}$ and prices, $\bar{p}$ are constant. By multiplying each term by p/q and the last term by y/y the gross price elasticity equals the net price elasticity less the income elasticity times expenditure on that good as a proportion of income.

possible changes in prices, number and closeness of substitutes. Changes in consumer responsiveness to the availability of substitutes suggest that the substitution effects, i.e., cross-product flexibilities, may also be subject to change over time.

Theoretical reasoning suggests that cross-product flexibilities would be higher for close substitutes. An increase in the quantity available for a close substitute will shift the own-product demand to the left. Own-product demand, $D(q_1,q_2,\ldots,q_n)$, is a function of cross-product quantities. This shift and, hence, the effect on price of the own-product, will be greater for a close substitute. Another way of viewing this substitution effect is in terms of effective demand. From a position of equilibrium, increases in quantities available of a strong substitute will divert demand away from the own-quantities causing a greater excess supply situation and a greater concomitant own-price adjustment than if the substitute were a weak one.[21]

Advertising, promotion and the forms of market and consumer education of substitute commodities will make them stronger substitutes and will tend to make the own-product more quantity flexible and increase the impact of substitutes on demand for that good in question. On the other hand, to the extent that attempts to product differentiate result successfully in less substitutability, demand flexibilities will tend to be smaller.

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[21] Note the parallel in the interpretation of cross-price elasticities and cross-product flexibilities. In both cases the closer the substitute, the stronger the cross effect and hence the larger the cross-elasticity and the cross-flexibility.

On balance, a reasonable hypothesis is that direct flexibilities of demand for individual foods are becoming greater through time. Certainly, food aggregates are becoming more quantity flexible, simply because incomes are rising and aggregation implies fewer substitutes. For specific products like meats, subject to production cycles, it may be more realistic to hypothesise, not continuous increase in flexibilities, but cycling change in demand flexibilities.

One theoretical note needs to be made regarding the interpretation to be given to an income flexibility. Houck (1966) has argued that, on theoretical grounds, the income flexibility of demand must be unitary. This result is derived from the homogeneity condition for elasticities when all products are considered. If the estimated income flexibility differs widely from unity, he argues, that meaningful interpretation of it becomes difficult. Houck further states that 'when zero-degree homogeneity is assumed among prices, income and quantities demanded, the flexibility coefficient on income is not a behavioral measure in the same sense as the elasticity (pp. 228-229). He acknowledges, however, that not only may the flexibility differ from unity in practice, but the underlying conditions of homogeneity may not apply in any given empirical research problem.

The interpretation of the income flexibility estimates in the current research is accepted at an intuitive level. A change in the 'aggregate' purchasing power of consumers can be expected to increase the demand for a commodity (except for inferior goods) and hence put upward pressure on market prices. This results in a positive relationship between income and market prices. Alternatively, a fall in consumer purchasing power will influence their willingness and ability to pay for a particular good or to buy as much of it. For a given level of product availability over a specific time period, assuming a normal or superior good, consumer demand will not be as strong and so the price will tend to fall adjusting supply with demand. Also note that the stronger the demand for a good in response to a rise in income, the higher the income flexibility (and income elasticity).

4.2 Statistical Model and Estimation Procedure

The discussion in Chapter 3 and in this chapter provided the main theoretical foundations for consumer behavior and how this theory relates to empirical analyses at the retail market level. This review was desirable as the theory is a useful guide and provides a justification for the demand functions chosen. The theory is a guard against 'some of the absurdities and inconsistencies which may arise from pragmatic models if the latter are used without considerable care and expertise' (Brown and Deaton 1972, p. 1152). This gives the estimated demand functions theoretical plausibility.

Nevertheless, as also pointed out earlier, a substantial gap exists between the theory of consumer behavior, on the one hand, and empirical analysis on the other. It is in recognition of this gap that economists have chosen certain specifications of demand functions over others. Houthakker and Taylor (1970, p. 1) refer to practical considerations in the design and development of their study. They report that 'common sense' and a 'long process of experimentation and elimination' were necessary before a final equation was selected.

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Not all economists subscribe fully to this perspective. In defense of theoretical plausibility, Phlips (1974, p. 112) was encouraged to write

> Houthakker and Taylor's choice among specification is based on goodness of fit. ...while much has been gained in terms of descriptive power, much has been lost in theoretical plausibility. By introducing more realistic changes of the income elasticities, Houthakker and Taylor lose contact with the theory of utility maximization. Indeed, there is no longer any reference to a specific utility function. Much more, these specifications are not compatible with utility maximization, as they do not satisfy the adding-up criterion exactly. The approach is entirely pragmatic (p. 112).

On the other hand, Brown and Deaton (1972, pp. 1151-1152), in their review of applied models of consumer behavior gave support, albeit qualified, to the pragmatic approach.[22] They saw a clear role in many practical situations for the procedure of estimating a set of single equation models, one for each commodity:

> Single equation models, even if less satisfactory from a theoretical point of view, may still be able to out-perform complete models in terms of past experience and ability to project the future (pp. 1157-58).

In empirical analysis it is often necessary, when attempting to measure consumer demand from a time series of annual consumption and prices of a commodity, to go beyond the specification of the theoretically derived demand function. Most econometric analyses of demand in

[22] Deaton and Brown meant 'pragmatic in the sense that it includes those variables in which we are directly interested, ignoring or summarizing others.' (p.1151)

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agriculture do not use explicit utility function formulations, but use arbitrary or ad hoc reduced forms.[23] This approach is more commonly adopted 'because of increased ease of estimation and the ability to incorporate greater complexity in the dynamic formulation.' (Pope, Green and Eales, 1980, p. 778). Moreover, there are variables which directly influence consumer demand in addition to relative prices, quantities and income, as suggested by the classical theory. This is the view taken in this research.

The statistical model to be estimated may be written in general terms, the demand for the ith meat specified as

$$\left(\frac{p_i}{CPI}\right)_t = a_i + \sum_{j=1}^{n} b_{ij} \left(\frac{q_j}{POPC}\right)_t + c_i \left(\frac{y}{POPC \cdot CPI}\right)_t + d_i z_{kt} + u_t \quad (5.4)$$

where i=1,...,4 (table beef, hamburger beef, pork, broilers), where p_{it} is the real price of meat i at retail in period t, CPI is the Consumer Price Index (1967=100), POPC is U.S. civilian population, q_{jt} is the domestic consumption of meat j, at retail weights, per person, y_t is real personal disposable income per person in the U.S., z_t represents all other variables considered to influence retail prices, and u_{it} is a random error term. Coefficients a_i (intercept), b_{ij}, c_i and d_i are to be estimated.[24]

The signs expected on b_{ij} (i=j), the own-quantity coefficient, are negative, implying a negatively sloped demand curve. The signs expected

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[23] One recent exception is the paper by Green, Hassan and Johnson (1978).

[24] Later specifications of (5.4) will allow these coefficients to be functions of time.

on the b_{ij} $(i \neq j)$, coefficients on substitute products, are negative also. For complements the sign would be positive. An increase in the quantity available for consumption of a substitute good should cause its price to decrease. This decrease in the price of the substitute causes a decrease in demand for the particular product in question, i.e., the demand curve shifts to the left. Assuming some upward slope on the supply curve, this shift brings about a fall in the price of the product. Therefore, a negative relationship exists between the quantity of a substitute and the price of the product in question.

The coefficient, c_i, on disposable income may be positive or negative depending upon whether the product is an inferior or normal good. For the four meat products considered in this analysis a positive sign is expected.

4.2.1 Functional Form of Equations

Behavioral theory of demand does not provide much guide to the choice of algebraic forms of the equations to be estimated. The computational burden is simplified considerably by using functions linear in the parameters. Most common among these functions are the linear and the log-linear functional forms. The quest for an integrator of demand theory and empirical work has favored the use of the double-logarithmic demand form. This functional form provides a means to implement the desirable homogeneity restriction plus it provides the relevant flexibilities (or elasticities) directly from its coefficients.

Hassan and Johnson (1976, p. 22) appear less accommodating of the double-logarithmic form in demand theory because of inconsistencies with classical demand theory. Yet, despite its ad hoc framework, these authors use this functional form and concede its superior fit in many cases, ease of estimation and the ready interpretation of the estimated coefficients when compared to utility maximization derived demand curves.

Although the linear and log-linear models are the most widely used among linear economic models, there is evidence to suggest that neither of these formulations is to be preferred. Research indicates that more flexible functional forms obtained from Box-Cox transformations, using maximum likelihood techniques[25] (Pope, Green and Eales 1980; Chang 1977). The approach in this research is to test both linear and log linear functional forms and make a choice based on Theil's test of residuals (Theil 1971, pp. 544). These results are described in a later section.

4.2.2 Method of Estimation

Each model of retail demand was estimated using ordinary least squares. To check the appropriateness of this choice some alternative estimation methods were examined. For instance, with price equations estimated separately there is a possibility of contemporaneous correlation among the dependent variables.[26] This may result from prices of

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[25] Tolley, Wang and Fletcher (1969) found mostly small effects on price and income elasticities and flexibilities of food demand from the use of logarithmic juxtaposed linear forms.

[26] Contemporaneous correlation among dependent variables and among disturbance terms implies that these variables and terms in different equations are correlated, respectively, at a given point in time but are not correlated over time (Judge, et.al., 1980, pp. 245-251).

one meat being affected by price levels or changes in prices of other meats in the retail market. If this occurs, disturbance terms in different equations will be contemporaneously correlated and OLS is not an efficient method of estimation. Estimation will, however, lead to consistent and unbiased parameter estimates. In such a case of correlated disturbance terms, Zellner's[27] 'seemingly unrelated regression' (SUR) will yield asymptotically more efficient estimates than those obtained by OLS provided the set of exogenous variables is not identical in each equation.[28] The equation set is estimated as if it were a simultaneous equation system: in the first stage an estimate is made of the error terms' variances and covariances, based on the residuals derived from an equation by equation application of OLS. In the second stage the estimates are used to contrast the Aitken generalized least squares estimator of the regression coefficients in all equations. To examine the possibility of contemporaneous correlation of the residuals, SUR estimates are obtained for the set of meat demand equations. The more usual simultaneity between prices and qualities, using two-stage least squares (2SLS) is also examined.

Finally, the hypothesis that total adjustment to a long-run equilibrium might not occur within one year is tested by introducing a lagged dependent variable in each of the beef equations. Lagged adjustment of prices to a change in quantity available may be due to imperfect knowledge, habit persistence or institutional delays. The coefficient

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[27] For details see Zellner (1962; 1963).

[28] In meat demand studies see, for example, Tryfos and Tryphonopoulos (1973), Main, et al. (1976) and Hassan and Johnson (1976).

of adjustment, λ, can be obtained by subtracting from one, the coefficient for the lagged dependent variable. This specification permits estimation of a short-run and long-run direct flexibility.

4.2.3 Estimation Period and Data Limitations

The model was estimated using annual observations over the period 1950-1982, providing 33 observations. Shorter data periods are frequently preferred in many studies, primarily because of an explicit forecasting objective or in order to circumvent the need to model such changes in structure as might occur over a longer estimation period. Since an important objective in this research is to investigate structural changes in demand, a long data series was used.

Market adjustments are continually taking place and hence, there exists no natural time period (in terms of observation steps) with which to capture structural change. The periodicity in the economic relationships concerned had much to do with choosing annual observations. Monthly and even quarterly observations would tend to reflect brief and passing phenomenon as well as seasonal influences on consumption and prices of meats. These rather short-term phenomenon were not of interest here. Even so, the choice of annual data is to some degree also arbitrary where economic adjustments are continuous.

Breiymer (1961, p. 60) provides some insights to the problems arising from the choice of data points. He argues that the actual production span or cycle from which the empirical data arise is central to this choice. He felt that

> the results of a statistical analysis can be interpreted in terms of the length of run only by examining closely the particular time series incorporated in the analysis. That is, it is necessary to look into the reasons which explain why the series of annual data depart from their mean as they do. If long-run trends are the dominant factor, the results relate principally to long-run trends. If production cycles are instrumental, results relate thereto. If only erratic annual fluctuations are to be found, results apply to them.
>
> It follows that if any continuous trend exists, the longer the time span included in the statistical study the more does the long-run trend influence the result. The shorter the number of years that are included, the more do cyclically-evolving or even briefer phenomena. (p. 60)

One major difference between Breimyer's analysis and the present analysis relates to his assumption of constancy of estimated parameters. In his study, fixed coefficients estimated over a long series will give coefficients which reflect average response over the period.[29] In the following analysis, progressive relaxation of this assumption of fixed coefficients should provide additional insights into the character of these structural changes in meat demand.

Actual data used in computations and all sources of these data are provided in Appendix A1 and Appendix C. Derivations of the prices and consumption series, in particular, the fed and nonfed data series, are given. Some limitations inherent in data used are discussed in the following section.

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[29] Breimyer did relax this assumption somewhat breaking the estimation period into three periods.

4.3 Structural Model and Candidate Variables

The estimated structural model may be written, in terms of selected candidate variables, as the following set of retail meat demand equations.

RPBFR = f(DCFBFRC, DCNFBFRC, DCPKRC, DCBRC, DICR, Z) (4.5)

RPHMBR = f(DCFBRC, DCNFBFRC, DCPKRC, DCBRC, DICR, Z) (4.6)

RPPKR = f(DCFBFRC, DCNFBFRC, DCPKRC, DCBRC, DICR, Z) (4.7)

RPBRR = f(DCFBFRC, DCNFBFRC, DCPKRC, DCBRC, DICR, Z) (4.8)

A description of variable codes and other variables used in subsequent analyses is presented in Table 4.2.

It should be well recognized that beef is not a homogeneous product, particularly at the retail level. Clearly, at the retail level a 'commodity' such as beef is a collection of distinct cuts and grades, most of which are closely competitive with respect to a given end use. The decision to disaggregate beef into two categories, namely, table beef (roasts, steaks) and hamburger beef (ground beef, processed beef products) is based on (a) an attempt to recognize the heterogeneity in beef especially at the retail level, (b) a desire to relate the nature of that heterogeneity back to the broad categories in beef production, namely, fed beef and non-fed beef respectively, and (c) pragmatic considerations with respect to data availability and analytical feasibility.

Table 4.2

Description of Candidate Variable Codes

Variable Code Name	Units of Measure	Description
RPBFR	$	Retail price, choice beef, real, retail weights.
RPHMBR	$	Retail price, hamburger, real, retail weights.
RPPKR	$	Retail price, pork, real, retail weights.
RPBRR	$	Retail price, broilers, real, retail weights.
DCFBFRC	lbs.	Domestic consumption, fed beef, retail, per person.
DCNFBFRC	lbs.	Domestic consumption, non-fed. beef, retail, per person.
DCPKRC	lbs.	Domestic consumption, pork, retail, per person.
DCORMRC*	lbs.	Domestic consumption, other red meat, retail, per person.
DCBRC	lbs.	Domestic consumption, broilers, retail, per person.
DCPMC	lbs.	Domestic consumption, poultry meat, retail, per person.
DICR	lbs.	Disposable income per person, real.
CPI	index	Consumer Price Index (1967 = 100).
POPC	millions	Population, Civilian, U.S.
Z	—	Collective term for all other candidate variables.
5 to 24	%	Proportion of population aged 5 to 24 years.
25 to 64	%	Proportion of population aged 25 to 64 years.

*DCORMRC is a variable combining pork, veal and lamb.

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This classificatory scheme is largely production derived[30] since retail consumption (disappearance) data are based on whether or not the animal came out of a feedlot. Feedlot produced beef, steers and heifers mainly, are assumed to supply all choice beef cuts. However, as pointed out in Chapter 2, fed steers and heifers also contribute though to a much smaller degree, to ground beef supplies. This approach is an improvement on studies which classify all steers and heifers into the choice beef category. Hamburger beef is assumed to be provided by non-fed beef, cull cows and bulls and grass fed steers and heifers plus imports. Again, there is a proportion of this beef that finds its way into table beef supplies, though the proportion is considered small. An additional advantage of this classification of beef type is the close relationship between U.S. non-fed beef and Australian imported beef. Both are considered to be manufacturing quality going primarily into ground beef and other processed beef products.[31]

Since no official data series on table (fed) beef and hamburger (non-fed) beef consumption exists, various approaches to measuring and estimating these data have developed. The simplest approach is to classify all steers and heifers as table beef, although this would result in some overestimation of fed beef. Crom (1970) developed and used a data

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[30] Some researchers have preferred an end-use approach, attempting to measure the quantities of high grade and low grade beef entering the market. See Bain (1977, pp. 16-18) for a discussion of the two approaches and reference to authors who have used them in classifying beef.

[31] This dichotomy of beef products is not new. Langemeir and Thompson (1967), Crom (1970), Hunt (1972), Freebairn and Raussar (1975), Macauley (1975), Bain (1977), and more recently, Reeves (1979) used this approach.

series for fed and non-fed beef production/consumption which has been used by Freebairn and Raussar, Macauley, Bain, and Reeves.[32]

An alternative data series of fed and non-fed beef production/consumption has been developed for this research.[33] This series, while similar to Crom's takes advantage of new data series available and overcomes problems of discontinued data series. In essence, fed cattle are fed steers and heifers only. Non-fed cattle are cull cows, bulls and grass fed steers and heifers. Adjustments are made to accommodate inventory, and imports to provide estimates of domestic disappearance in retail weights.

Limitations of available data prevent any major improvement on this classification. Some 25 percent of a fed steer or heifer carcass becomes ground beef. On the other hand, a portion of a non-fed (forage fattened) steer or heifer carcass and certain cuts from cow carcasses are sold as choice or table feef. Also, the cut-out of a given carcass into table beef or ground beef depends on relative prices and hence that cut-out will vary over time. In this study fed steer and heifer carcasses (fattened in feedlots) only are classified as choice or table beef. The remainder is classified as processing or ground beef. During years of low farm prices for fed beef, an increased proportion of steers and heifers are marketed directly from forage-based operations and,

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[32]See Bain (1977, p. 16) for an outline of this method of estimation.

[33]Details of the method are presented in Appendix Table A2. These estimates are based around a method developed by Ferris of Michigan State University.

therefore, do not enter feedlots. These cattle are classified as non-fed beef although meat from these animals will be marketed as table beef. Therefore, some inflation of the data on non-fed beef (or 'hamburger' beef) occurs during these low farm price years. Perhaps a more accurate dichotomy is fed beef and 'other' beef. However, the only retail price series for lower quality beef is the hamburger/ground beef price series. To the extent that 'other' beef is of manufacturing quality this price series should be representative. The underlying assumptions and associated limitations should be borne in mind when interpreting results.

Retail prices of choice grade beef and retail price of hamburger beef, as defined by the USDA, are the normalized endogenous variables in the two beef demand equations. At the retail level these two price series, while being readily available[34] would appear to be representative of the prices of the two beef categories mentioned. To the extent that institutional prices for ground beef, i.e., at fast food restaurants, deviate from this retail series some bias may be present. The retail price of pork and the 4-region average retail price of young chickens (broilers) are the normalized endogenous variables for the pork and broiler demand equations, respectively. Separate data series, each for domestic consumption of table beef, hamburger beef, pork and broilers, in retail weight equivalents, per person, were specified in each demand equation.

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[34] The hamburger price series has recently been discontinued. Updates of this series would need to make use of the ground beef price data series of the BLS.

Personal disposable income, provides the budgetary constraint on demand. This variable is included to account also for the increased purchasing power of the U.S. population over the sample period.There are two reasons disposable income is exogenously determined in this model. The first is simply that beef, pork, and broilers comprise a very small part of total per person disposable income. All red meat and poultry meat amounts to little more than 4-5 percent of total expenditures per person (USDA 1981, p. 21). A second reason follows from the classical theory of consumer demand. Since total expenditures made for each commodity group is determined in the initial budgetary allocation process of the consumer, the group expenditure for individual demand functions is predetermined (George and King 1971, p. 27). Hence, the group expenditure is a predetermined variable for the demand function of an individual product within the group.

Population is usually incorporated into demand studies by expressing consumption and income data on a per person basis. This study does not deviate from this common practice. However, it may be of use to restate the implications of this practice, along with its difficulties, especially given the potential role changes in the population may have had on consumer demand for meats in the U.S. Expressing these variables on a per person basis is consistent with the underlying theory of consumer choice which refers primarily to individuals. More importantly, for market level demand studies, per person relationships are likely to be more meaningful and stable than relationships between aggregates. A potential difficulty of this use is the assumption that all persons be given equal weight irrespective of age and sex.

In principle, a different scale of weights or 'adult-equivalent scale' (AES) should be used at least for each commodity. However, available evidence suggests that equal-weight scales do not produce much distortion (Houthakker and Taylor, 1970, p. 29). This is because the distribution of the population by age and sex is fairly stable. Claffey (1982) estimated an AES for use in meat demand analysis. Since children consume less than adults the AES population is smaller than the official civilian population, causing AES per person consumption to be larger than the 'official' per person consumption of meat. However, following examination, there was very little difference at the national level in the two series. Although, it was acknowledged that the AES approach may have value in regional studies of meat.

In the present study, there are, nevertheless, a priori grounds for including specific demographic variables to account for a particular demand relation phenomenon due to the impacts of certain segments of the population. For instance, in Chapter 2 it was shown that younger segments of the population consume more ground beef although older segments consume more roasts and steaks.

Like population, changes in the general price level, represented by the CPI, are included implicitly in each equation. That is, prices and income per person are deflated by the CPI to express these data in real terms, hence adjusting for the effect of inflation.[35] The assumption underlying deflation of price and income is that consumers are not subject to money illusion. In terms of the theory of consumer demand this implies that the demand functions are homogeneous of degree zero in prices and income per person. However, deflation is also a pragmatic compromise since it is impossible to accommodate the theory precisely. The usual approach is to include in the demand relation all those substitutes and complements as prices and quantities and use a price index such as the CPI for all other goods (expressed in terms of prices).[36] This price index may be used as a deflator or as a separate independent variable. Here, CPI is used implicitly as a deflator as these equations appeared superior to expressing it as a separate variable.

The variable, Z, in equations (4.5–4.8) represents all other shifter variables, explaining changes in retail prices of table and hamburger beef, pork and broilers. Demographic variables, i.e., of specific age segments of the population, have already been mentioned. Theoretically, changes in tastes and preferences result in a different utility function and, therefore, a whole new set of demand relations.

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[35] Tolley, Wang and Fletcher (1969, p. 704) found in price dependent equations of aggregate food demand that the total bias in price elasticity estimates due to incorrect deflation was greater than in the consumption dependent case, partly as a result of the effect of correlation of the deflator with the residual. Total bias in income elasticity estimates is small in both cases. Total food is an important component of the CPI and therefore some correlation is expected. Such correlation between deflated prices for individual meats is likely to be very small.

[36] See Zellner, Gallo and Levey (1980, pp. 20-21) for a discussion of alternative measures of inflation.

Intuitively, these changes in demand relationships may cause more significant shifts in demand than those caused by changes in incomes or quantity availability. Tastes may encompass a multitude of effects such as fashion, attitudes to health and preference for leisure. Habits develop after tastes and preferences have been formed. Historically, tastes for meats have not changed rapidly over time. As discussed in Chapter 2 there has been in recent years, a decline in beef demand which some observers feel have been due to taste changes. The treatment of analyses of these changes in demand are discussed later.

4.4 Results of the Base Model of Demand

4.4.1 Estimation of a Base Model

The estimated retail demand equations for the four meats plus an equation for 'all beef' were estimated as linear functions using OLS and are shown in Table 4.3.[37] For the beef equations, the statistical estimates were improved by combining pork, veal and lamb consumption into a variable of 'other red meat' consumption.[38] Similarly, in the table beef

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[37] Tests for choice of functional form were inconclusive so the linear form was chosen. Contemporaneous correlation of the residuals was tested by estimating Zellner's SUR (Appendix Table A1). Notably, unexpected positive and insignificant signs were obtained on pork in the table and hamburger beef equations.

[38] In the case of the all beef equation, consumption of veal and lamb was estimated as a separate variable from pork. In this case no improvement was gained by combining these variables. However, in the table and hamburger beef equations this separate specification was not stable in later analyses.

Table 4.3

Estimated Retail Demand Equations For Meat: Base Model
Estimated Over the Period 1950-1982

Dependent Variable	Explanatory Variables										
		Domestic Consumption Per Person, Retail						Income			
Deflated Retail Price	Constant	DCFBFRC Table Beef	DCNFBFRC Hamburger Beef	DCORMRC Other Red Meat	DCPKRC Pork	DCPMC Poultry	DCBRC Broilers	DICR Income	$\hat{\sigma}/m$	$\bar{R}^2$	D.W.
Table Beef (RPBFR)	136.557 (6.05)	-1.362 (6.46)	-1.717 (8.43)	-.295 (1.35)		-1.487 (5.33)		.056 (6.28)	.048	.72	1.31 inc.
Hamburger Beef (RPHMBR)	103.890 (4.67)	-1.012 (5.25)	-1.750 (9.36)	-.302 (1.39)			-1.168 (4.71)	.040 (5.49)	.075	.77	1.23 inc.
Pork (RPPKR)	109.852 (8.10)	-.486 (3.58)	-.556 (3.83)		-1.176 (7.50)		-1.575 (9.19)	.043 (8.25)	.045	.81	1.99
Broiler (RPBRR)	55.682 (5.00)	-.875 (7.84)	-.621 (5.20)		-.023 (.18)		-2.150 (15.27)	.042 (9.83)	.055	.97	1.65 inc.
		DCBFRC Beef	DCLMVLRC Lamb, Mutton and Veal								
All Beef (RPBFR)	189.43 (8.19)	-1.161 (6.71)	-3.824 (4.42)		-.165 (.99)	-1.669 (7.21)		.036 (4.03)	.039	.82	1.50 inc.

1. $\hat{\sigma}/m$ = standard error of regression divided by the mean of the dependent variable;
   $\bar{R}^2$ = coefficient of multiple determination, adjusted for degrees of freedom;
   D.W.= Durbin-Watson statistic; inc. = test of autocorrelation inconclusive at 5 percent level.
2. Students 't' values for regression coefficients given in parentheses below coefficients.
3. See Table 4.2 for identification of symbols used.

equation, broilers and turkey consumption were combined in a 'poultry meat' consumption variable.[39] Elsewhere, specific product variables were maintained. Fish consumption was included initially but later excluded because of its unexpected positive sign. In recent retail demand studies using quantity dependent specifications, considerably greater amalgamation of variables was found necessary, preventing the individual product effects to be estimated.[40]

These particular equations form the base model and do not represent the final specifications. Other specifications are tested, in later analyses of structural change, by allowing the regression coefficients to change over time. Nevertheless, several important observations may be made from these equations. First, all the estimated coefficients are significantly above the 99 percent confidence level, except the substitute products, pork and other red meat. Other red meat in the beef equations is significant at the 90 percent level, but pork is insignificant in the broiler equation. Multicollinearity among explanatory variables might explain the low significance on an expected substitute like pork. However, the correlation matrix for first-order correlation among explanatory variables, did not indicate this possibility. It is possible that the nature of multicollinearity is higher than first order. A

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[39] This procedure saved degrees of freedom and did not greatly affect the other estimates in the equation. Generally, autocorrelation was lessened, the standard errors of the coefficients were reduced slightly, and explained variation in the equation was increased.

[40] See, for example, Reeves (1979), Freebairn and Raussar (1975) and Houck (1974), where, in fed and non-fed beef equations, cross-price effects were not estimated or at least were estimated as 'other meat.'

low level of significance of the estimated coefficient on the pork consumption variable has been found in other meat demand studies. These variables were retained in the equations even when insignificant because they had the expected negative sign of a substitute product. It should not be overlooked that pork may have an inherently low cross effect on other product prices.

Second, the $\bar{R}^2$ values on equations, except for broilers, suggests some variation in the dependent variables remains unexplained. However, prices tend to vary considerably less at the retail level (because of certain retail pricing practices, e.g., price smoothing and other lapses from perfect competition) than they do at the wholesale or farm level.[41] This will tend to result in a relatively lower $\bar{R}^2$ at retail. Deflated retail prices also tend to fluctuate less than consumption per person and therefore $\bar{R}^2$ values derived from quantity dependent equations tend to be higher. Moreover, considering the change which the retail market has undergone over the past 33 years since 1950, it is perhaps too much to expect that the same combination of traditional variables would explain the at times complex and dynamic set of forces influencing

[41]For empirical evidence, see in George and King (1971, p. 62) the elasticities of price transmission from farm to retail. For a one percent change in the farm prices, each of beef, pork, lamb and chicken, retail prices change by between .5 and .8 percent, in the same direction.

retail prices over this period. When some of these changes are explicitly accommodated into the model specification, a greater degree of explanation can be expected.[42]

Third, the Durbin-Watson statistic, an index measuring the existence of first-order serial correlation in the disturbance term, suggests either the absence or inconclusive evidence of such correlation.

Estimated mean price and income flexibilities, derived from equations in Table 4.3, are presented in Table 4.4. A common practice is to draw comparisons and to establish the extent of agreement between ones own estimates and those of other economists. However, there is a dirth of comparable studies in which flexibilities have been estimated and so no direct comparisons are possible. Qualitative comparisons only are made.

Fox (1953, p. 43. 52) and Breimyer (1961, pp. 61-78) are among some of the earlier studies in which flexibilities were estimated from annual data. Compared to each other and to this study they use different functional forms, data transformations and model specifications. Fox used first differences of logarithms whilst Breimyer used logarithms, undeflated retail prices, deflated income and included the CPI as an explicit variable. The estimates of Fox cover a period before

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[42]The coefficient of determination is a useful index of the goodness of fit of a regression equation to data. Predictive precision of the equation, however, may be of more practical value than the $\bar{R}^2$. In this regard, the closeness of say, a 95 percent confidence band about the regression is more important than the size of the $\bar{R}^2$, per se (Bartlett, 1974).

Table 4.4

Estimates of Base Model Quantity and Income Flexibilities of Retail Meat Demand

Deflated Retail Price	Domestic Consumption Per Person						Deflated Per Capita Income
	DCFBFRC	DCNFBFRC	DCORMRC	DCPKRC	DCPMC	DCBRC	DICR
Table Beef	-.62	-.58	-.22		-.68		1.63
Hamburger Beef	-.72	-.93	-.35			-.59	1.83
Pork	-.30	-.46		-1.03		-.69	1.68
Broilers	-.80	-.43		- .03		-1.41	2.47
	DCBFRC	DCLMVLRC					
All Beef	-.92	-.31		-.11	-.77		1.05

Note: Flexibilities are calculated at data means from regression estimates given in Table 4.3.

1941; Breimyer's estimates are pre-1961. Both studies deal with aggregate beef and in most cases have used substantially different variable definitions. Fuller and Ladd (1961) estimated a quarterly model of beef and pork, at the wholesale level, and also aggregated beef.

The few more recent estimations of direct and income flexibilities provide only limited opportunity for comparisons. Langemeir and Thompson (1967) estimated fed and non-fed beef (farm and retail) own-quantity and income flexibilities using an annual simultaneous equation model. Their estimates of own-quanity and income flexibilities were higher than those in Table 4.4 and those published by Fox and by Breimyer. Also, as expected of data from the pre-1970s, the retail cross-effect of non-fed beef consumption on fed beef prices is smaller and the cross-effect of fed-beef consumption on non-fed prices is larger than those estimates in Table 4.4. Non-fed beef (hamburger beef) has become a closer substitute with fed beef and has achieved a greater degree of favour in many consumers' minds.

Crom (1970), who along with Langemeir and Thompson, was among the first to make a serious attempt to disaggregate beef into fed and non-fed beef, estimated quarterly price equations of wholesale demand. In that study flexibilities from linear OLS estimations were not presented. Colman and Miah (1973) estimated a quarterly model, also of wholesale prices, of major meats in the U.K. The quarterly flexibilities for beef (aggregate) and pork were about equal to or slightly less than those for all beef and for pork in Table 4.4. A priori, one would expect that, largely because of adjustment delays due to habits and lags in market flows, the shorter the period between sample observations the lower the consumer response (smaller flexibility) to a change in quantities available. There is simply less time to respond to a given change. Also, flexibilities estimated at wholesale may be expected to be greater than those estimated at the retail level. This is because of the more competitive structure of the market at the farm level, if not the wholesale level, than that which exists at retail. For example, as noted earlier, price leveling and price averaging by retailers tend to restrict the response of changes in quantities on retail prices. Empirical support of these observations is provided in two papers by Ferris (1974, 1981). Using annual data, the direct flexibility for fed beef was -1.5 at wholesale and -.87 at retail. The relative inflexibility of the estimate at the retail level would seem consistent with figures in Table 4.4.

The only other available meat demand study in which flexibilities were estimated is that by Roberts and Heady (1979). In an annual model covering the years 1953-1976, retail price equations were estimated, using OLS (linear arithmetic), for beef, pork, lamb, chicken and turkey. Beef, pork and lamb were estimated in carcass weights in contrast to retail weights in the present study. No disaggregation of beef was attempted. Specification of a lagged dependent variable (retail price) provided short and long-run flexibilities. Results of that study are compared in the following section.

Bearing in mind that these are not final results, the relative magnitudes among flexibilities in Table 4.4 seem consistent with expectations. The direct table beef flexibility may be slightly under estimated or the cross flexibility on poultry meat may be over estimated in the table beef price equation. This apparent biasedness, due most likely to misspecification, is largely corrected in later models. Nevertheless, the relative magnitudes of direct flexibilities appear to be in the expected order. For instance, the greater inflexibility of table beef demand vis-a-vis hamburger beef demand reflects consumer preferences for quality of beef cut. A one percent increase in quantity of table beef supplied per person is absorbed into effective demand more readily than a one percent increase in hamburger beef because of its preferred quality status. At the consumer level, another reason could be the more inelastic demand for hamburger beef at fast food restaurants. Hence, the increase in table beef supply has a smaller price depressing effect on table beef prices than does the increase in hamburger supply on hamburger beef price. Similar reasoning can be used for hamburger vis-a-vis pork and pork vis-a-vis broilers.

Also expected is the greater cross-quantity effect of table beef on hamburger beef than the contrary effect of hamburger beef qualities on table beef prices. Although, hamburger beef quantities appear to have a greater effect on pork prices while table beef quantities have a more important effect on broiler prices. Recall that the higher the cross-flexibility, the closer is that product a substitute. The cross-effect of broilers on table beef may be overestimated. The likely cause of this over estimation is misspecification error due to omitted variables and the constant coefficient specification. This problem is addressed in the estimation of later models.

Nevertheless, broilers (chicken) are the closest substitute in consumers' eyes for table beef and pork. Table beef is the closest substitute for hamburger beef and chicken. Pork is the weakest substitute in all other meat equations.

The results raising the greatest concern are the income flexibilities. Products which are luxuries tend to be more highly preferred and tend to be consumed by higher income groups. These products are expected to have the highest income flexibilities. A priori, table beef demand should fit this catagory more so than hamburger beef. That is, table beef should have a stronger income effect and be more responsive to changes in incomes. Multicollinearity between income and consumption of table beef and poultry meat exists, given the high first order correlation between these explanatory variables. However, this causes inefficient estimators, not biased ones. More likely, the apparent biasedness in the income coefficient is due to specification error, i.e., the omission of relevant variables, incorrect mathematical form or incorrect inclusion of the error term.

Remember that these are average effects over a 33 year period, flexibilities of which are derived from a fixed coefficient model. Broilers have grown to greater prominence in consumption and more recently, attitudes have appeared to have moved unfavorably for beef. Relationships in more recent years, which are also likely to have changed, will be examined in subsequent analyses.

4.4.2 Beef Price Adjustment Model

Estimated price adjustment equations of retail demand for table beef, hamburger beef, and all beef are presented in Table 4.5. Short and long-run direct and income flexibilities, derived from this table, are shown in Table 4.6. The price adjustment model is obtained by inclusion of a one-period lag on the dependent price variable.

For various reasons, total price adjustment following a given price change in a causal variable may not occur within one year. Imperfect knowledge, the persistence of consumer habits and institutional impediments to market processes are primary factors. The coefficient of adjustment indicates the proportion of adjustment that is instantaneous. For beef products the proportion of adjustment in prices estimated to take place in one year is around 70 percent. The short-run flexibility for an independent variable at the variable mean may be estimated by multiplying the coefficient of the independent variable by the ratio of the independent variable mean and the mean of the retail price. The long-run flexibility at the variable mean is derived by dividing the short-run flexibility by the coefficient of adjustment. Therefore, the greater the amount of adjustment in the current period, the closer is the long-run flexibility to the short-run-flexibility. From Table 4.6, the direct flexibility for table beef implies that a one percent increase in domestic available supply of table beef per person will result in a .47 percent decrease in the short-run and .67 percent in the long-run retail prices for table beef, ceteris paribus. Similarly, a one percent increase in real disposable income per person will, as a result of an increased demand for choice beef, cause a 1.28 percent

Table 4.5

Estimated Price Adjustment Equations of Retail Meat Demand:
Estimated Over the Period 1950–1982

Dependent Variable	Explanatory Variables								$\hat{\sigma}/m$	$\bar{R}^2$	D.W. (h)
		Domestic Consumption Per Person				Lagged Dep. Variable		Income			
Deflated Retail Price	Constant	DCFBFRC	DCNFBFRC	DCORMRC	DCPMC	RPBFRL	RPHMBRL	DICR			
Table Beef (RPBFR)	114.880 (5.37)	-1.045 (4.77)	-1.469 (7.25)	-.393 (1.98)	-1.254 (4.74)	.303 (2.97)		.044 (4.97)	.043	.76	1.49 (1.81)
Hamburger Beef (RPHMBR)	96.133 (4.93)	-.935 (4.60)	-1.574 (7.92)	-.302 (1.62)	-1.039 (4.21)		.276 (3.03)	.037 (4.51)	.064	.82	1.60 (1.35)
		DCBFRC									
All Beef (RPBFR)	91.902 (4.45)	-1.302 (6.33)		-.223 (1.11)	-1.245 (4.34)	.273 (2.49)		.052 (5.70)	.047	.72	1.29 (2.63)

Notes: 1. h = h-statistic, used in the presence of lagged dependent variable. Critical value is h > 1.645 for acceptance of no autocorrelation at 5 percent level (Harvey, 1981, p. 274).

2. See Table 4.3 for explanation of other summary statistics.

Table 4.6

Short and Long-Run Quantity and Income Flexibilities of Retail Demand Price Adjustment Model: Estimated Over the Period 1950-1982

Deflated Retail Price	Domestic Consumption Per Person								Income		Coefficient of Adjustment
	DCFBFRC		DCNFBFRC		DCORMRC		DCPMC		DICR		
	Short Run	Long Run	Short Run	Long Run	Short Run	Long Run	Short Run	Long Run	Short Run	Long Run	
Table Beef	-.47	-.67	-.50	- .71	-.26	-.37	-.58	- .83	1.28	1.83	.70
Hamburger	-.66	-.92	-.84	-1.17	-.35	-.49	-.75	-1.04	1.68	2.33	.72
	DCBFRC										
All Beef	-1.03	-1.41			-.16	-.22	-.57	- .78	1.51	2.07	.73

increase in retail table beef prices in the short-run, and a 1.83 percent increase in retail prices in the long-run, ceteris paribus.

Note that the base model flexibilities in Table 4.4 fall between their short-run and long-run estimates. Since some 70 percent of adjustment occurs in one year, i.e., the current period, estimated flexibilities using annual data seem to be predominantly short-run measures. This is consistent with the reasoning of Tomek (1962) that for many foods, including meats, complete adjustment (in the 'long-run') is nearer to one year than to several or many years. Certainly the differences between the short-run and long-run estimates do not appear large.

It is expected that the long-run flexibility will exceed the flexibility in the short-run. In the short run the impact of imperfect knowledge and habit persistence on the market adjustment mechanism will prevent complete and instantaneous adjustment of market prices to clear the market. Only after some time has elapsed in subsequent periods will these final adjustments in prices take place. This implies greater longer run flexibility of retail prices to the initial change in the explanatory variable. The short-run and long-run flexibilities presented in Table 4.6 are consistent with this reasoning.

Larger long-run flexibilities were also reported by Fuller and Ladd (1961, p. 202) and by Roberts and Heady (1979, pp. 35-36) for beef (aggregate) and pork. Authors of both papers expressed concern that these results of long-run flexibilities which are greater than short-run flexibilities, contradict the usual arguments relating to the short-run and long-run demand curves and the behavior of demand elasticity through time. They gave as an explanation the premeditated over adjustment to prices by 'enlightened' consumers, knowledgeable of the cyclical patterns of beef prices. That is, when beef prices are low relative to prices of substitutes, consumers purchase more beef than if the present price relativities were expected to continue indefinitely.

This argument rests on the doubtful assumption that consumers are knowledgeable of beef cycles and that they can consistently over adjust their reactions to market prices at the retail level to accommodate for these cycles. A more defensible explanation is one that is couched in the validity of the original specification of the economic model, namely, that prices adjust to changes in supply availability. The classical utility maximizing theory, from which Marshallian demand curves are derived, says nothing in its formulation about the short-run and the long-run (See Chapter 3). Moreover, the distributed lag model has no theoretical underpinning with respect to utility maximizing theory. The lagged specification is ad-hoc and pragmatic. Its justification is based simply upon a pre-specified structure of an underlying economic model of the market under analysis. As discussed at some lengths, it is not appropriate to judge estimated flexibilities against Marshallian demand curves or demand elasticities to ascertain their correctness or otherwise. The underlying causality inferred by a flexibility does not make meaningful this type of comparison. Given this causality, and the related assumption that adjustments in the retail meat markets are through prices, it then becomes clearer that the long-run flexibility will exceed the short-run flexibility in the manner hypothesized earlier and supported by the results in all three studies.[43]

4.4.3 Effect of Age Composition and Expenditure Away From Home on U.S. Meat Consumption

In Chapter 2 it was considered that variables, in addition to the traditional price-quantity and income variables, may explain some of the changes in demand for retail meats, particularly over the past, relatively volatile, 10 years or so. Among such influences on the retail meat demands, were changes in the age composition of the population and the apparent trend towards increased eating away from home and the associated growth in fast food outlets and institutional food-service programs, e.g., school lunches.

In some respects these two developments may be related. For example, the consumption of ground beef is greatest among the younger portion of the population which have contributed to the growth in meals away from home. Variables tested in each of the four equations were (a) the proportion of the population aged between 5 and 24 years and the proportion aged between 25 and 64 years, and (b) away from home expenditure on food per person, in real dollars. These are some apparent shortcomings with these proxy variables. Ad hoc inclusion of a specific

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[43]Grounds for rejection of these arguments and this conclusion would seem, therefore, to be more reasonably based on the assumptions underlying the economic model and not whether there is correspondence between elasticities and the flexibilities.

age variable does not address the total age dynamics of population change. On the other hand, the use of an adult-equivalent scale to weight meat consumption by sex and age has not proven successful. After studying this problem, Houthakker and Taylor (1970, p. 29) advocated use of specific demographic variables for population segments where, in the case of a particular commodity, such an influence could be identified.

A priori, a positive sign is expected on the 5 to 24 age variable and a negative sign on the 25 to 64 age variable in the hamburger beef equations. This follows from the evidence presented in Chapter 2 that the young segment are the heaviest consumers of ground beef. Therefore, an increase in the proportion of the population in the 5 to 24 age group, which in the past has reflected largely the baby boom phenomenon, will result in an increase in demand and upward pressure on hamburger beef prices. Conversely, the 25 to 64 age group are lower consumers of ground beef and have as a group decreased since 1950, the first observation point. Hence, an increase in the proportion of this group reduces demand for hamburger beef and places downward pressure on hamburger beef prices.

The effect of these age groups on table beef demand may be less clear because fed beef provide table cuts and a proportion of ground beef. Also, table beef is eaten at restaurants and some fast food outlets, by all ages of the population. Notwithstanding this, the expected sign is negative for the 5 to 24 group and positive for the 25 to 64 group on the grounds that the latter group are the heaviest consumers of table beef and much lighter consumers of other beef.

The expected signs for pork and broilers is even less clear. Pork consumption appears neither age specific nor eaten predominantly away from the home. Chicken consumption is also eaten by all age groups, although in recent years, as with ground beef, chicken parts are eaten mainly by younger consumers and at fast food outlets. By contrast, whole chicken and roast pork is consumed mainly by older segments of the population and at home. On balance, the signs on age variable coefficients for pork are expected to be the same as for table beef and signs for chicken are expected to be the same as for hamburger beef.

No data are available on the quantity of ground beef or table beef retailed through fast food restaurants or of the total quantities eaten away from home. The only readily available proxy for this data is aggregate away from home expenditure on food per person.[44] This data series includes all food expenditures, excluding only alcoholic beverages. Individual meats are a relatively small component of this total expenditure and therefore their effects on retail prices is likely to be masked. An alternative specification of this upward trend in away from home food expenditure is the ratio of that expenditure to total food expenditure.

Intuitive reasoning would suggest a positive influence of away-from-home food expenditure on demand in the case of convenience-type meats, hamburger and to a lesser extent, chicken. As expenditure on food away from home increases, demand for the products increase, putting

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[44] See various issues of USDA, <u>National Food Review</u>.

upward pressure on hamburger beef and broiler prices. A negative influence is hypothesized on table beef and on pork although the evidence is unclear. As the share of expenditure away from home increases the demand for beef and pork roasts and certain steaks, more commonly eaten at home, will fall leading to a downward pressure on prices. On the other hand, certain other table cuts are a common item on many restaurant menus.

As predicted, results of the above analysis were mixed. For this reason, selected results are presented only for the beef equations, and then, only those for the age variables. Coefficients on the 'away-from-home' variables had the expected positive sign in the hamburger and broiler equations and negative signs in the beef and pork equations though insignificant. Multicolliniarity with real disposable income caused some of these problems. The retail price of hamburger beef may not be appropriate when considering the influences of away-from-home purchases of ground beef foods. Counter-intuitive signs were obtained on the age variables in the pork and broiler equations and coefficients were not highly significant.

The age variables in the hamburger beef equation were significant and had the expected signs (Table 4.7). A one percent increase in the proportion of the population aged 5 to 24 years will result in a 1.42 percent increase in retail hamburger beef prices, ceteris paribus. The increased demand by this young, heavy ground beef consuming group places upward pressure on hamburger beef prices. A one percent growth in the population of older consumers will result in a 1.24 percent decrease in retail prices, ceteris paribus. A major factor in the growth in the

Table 4.7

Estimates of the Influence of Age Structure of Retail Beef Prices:
Estimates Over the Period: 1950-1982

Dependent Variable	Explanatory Variables											
	Domestic Consumption Per Person						Age Segment		Income	δ/m	$\bar{R}^2$	D.W.
Deflated Retail Price	Constant	DCFBFRC	DCNFBRC	DCPKRC	DCPMC	DCBRC	5 to 24	25 to 64	DICR			
a. Table Beef	68.112 (1.85)	-1.890 (5.06)	-1.797 (7.88)	-.090 (.39)	-1.292 (4.44)		1.701 (1.73)		.060 (6.70)	.048	.73	1.31
b. Table Beef	132.942 (5.55)	-1.576 (4.46)	-1.756 (7.21)	-.119 (.48)	-1.462 (5.12)			-.503 (.80)	.062 (5.50)	.050	.70	1.30
a. Hamburger Beef	11.279 (.34)	-1.830 (5.37)	-1.916 (9.44)	-.030 (.14)		-1.009 (4.43)	2.432 (2.84)		.049 (6.70)	.068	.81	1.56
b. Hamburger Beef	152.002 (3.96)	-1.538 (4.54)	-1.865 (8.52)	-.042 (.18)		-1.267 (5.04)		-1.571 (1.90)	.053 (5.48)	.073	.78	1.43

Age Flexibilities:	5 to 24	25 to 64
Table Beef	.64	-.25
Hamburger Beef	1.42	-1.24

Notes: $\bar{R}^2$ = Coefficient of multiple determination, adjusted for degrees of freedom.
D.W. = Durbin-Watson statistic; for all values, the test of autocorrelation is inconclusive at the 5 percent level.

proportion of this younger segment has been the U.S. baby boom. This might suggest that as these younger consumers grow older and move into older age cohorts, characterized by low hamburger beef consumption, demand for ground beef will decline, causing a decline in hamburger beef prices. However, this assumes constancy of age based meat consumption patterns. Militating against this is the degree to which the young consumers of ground beef carry or maintain their tastes and preferences into older age. Extrapolation of these trends, therefore, must be considered cautiously since habits and tastes and preferences of consumers can be expected to change through time.

The coefficient signs on the age variables in the table beef equation, contrary to the initial hypothesis, are the same as in the hamburger beef price equation. This possible outcome was mooted earlier. Even though older groups are considered heavier consumers of table beef, fed beef provides some 25 percent of ground beef. Also, as the younger group expanded over the past 33 years, so did the demand for beef, causing prices to rise. Note, however, that the impact of this age variable on table beef prices is substantially less than it is on hamburger beef prices. Also, the coefficient on the 25 to 64 age variable, though negative, is not significant.[45]

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[45]These equations were tested over a more recent period, 1960-1982, although the equations were generally inferior. It may be that young people eat more of both types of beef provided their parents have adequate income. Similarly, poorer consumers over 25 years of age may be heavy consumers of hamburger beef. This indicates the need for a more detailed analysis of these factors.

4.5 Examination of Structural Shifts in Demand

4.5.1 Graphical Analysis

Graphical analysis provides the first indication that the underlying structure of demand for a particular commodity is changing. By plotting a series of price-quantity points, valuable insight may be gained about these data and the apparent movements of observation points along and shifts in a demand relation. General reasons for some of these changes in demand structure were discussed in previous sections of this chapter. Many of the specific causes of demand structure change in the meat markets were discussed in the previous chapters. However, as with other means of quantifying structural shifts, graphical analysis identifies approximately when certain shifts occurred but not why they occurred.

Plots of retail prices and quantities for table beef, hamburger beef, pork and broilers are illustrated in Figures 4.1 through 4.4. A cursory examination of these plots will reveal the changes in these price-quantity relationships which have occurred over time. Fitting freehand drawn linear demand curves through particular sets of data highlights periods when price-quantity movements along the curve as distinct from shifts in demand. These demand curves for table beef, broilers and to a lesser extent hamburger beef, appeared steeper in the earlier years of the 1950s but became increasingly flatter through the 1960s. This trend was not as apparent for pork demand.

In the case of table beef, between 1968 and 1973, demand shifted outward. Retail prices of all four products rose sharply over this

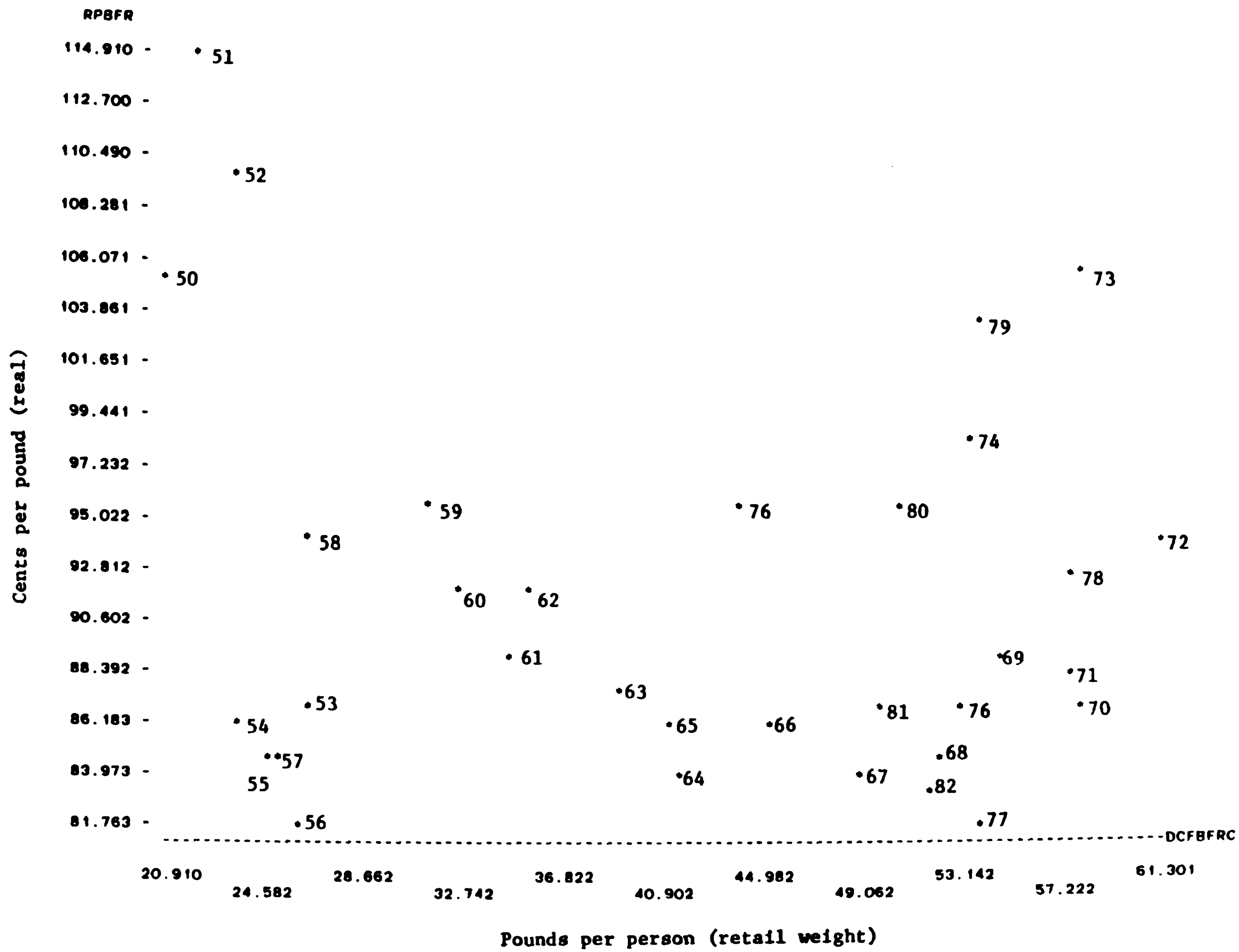

Figure 4.1 - Plot of Retail Prices and Domestic Consumption of Table Beef

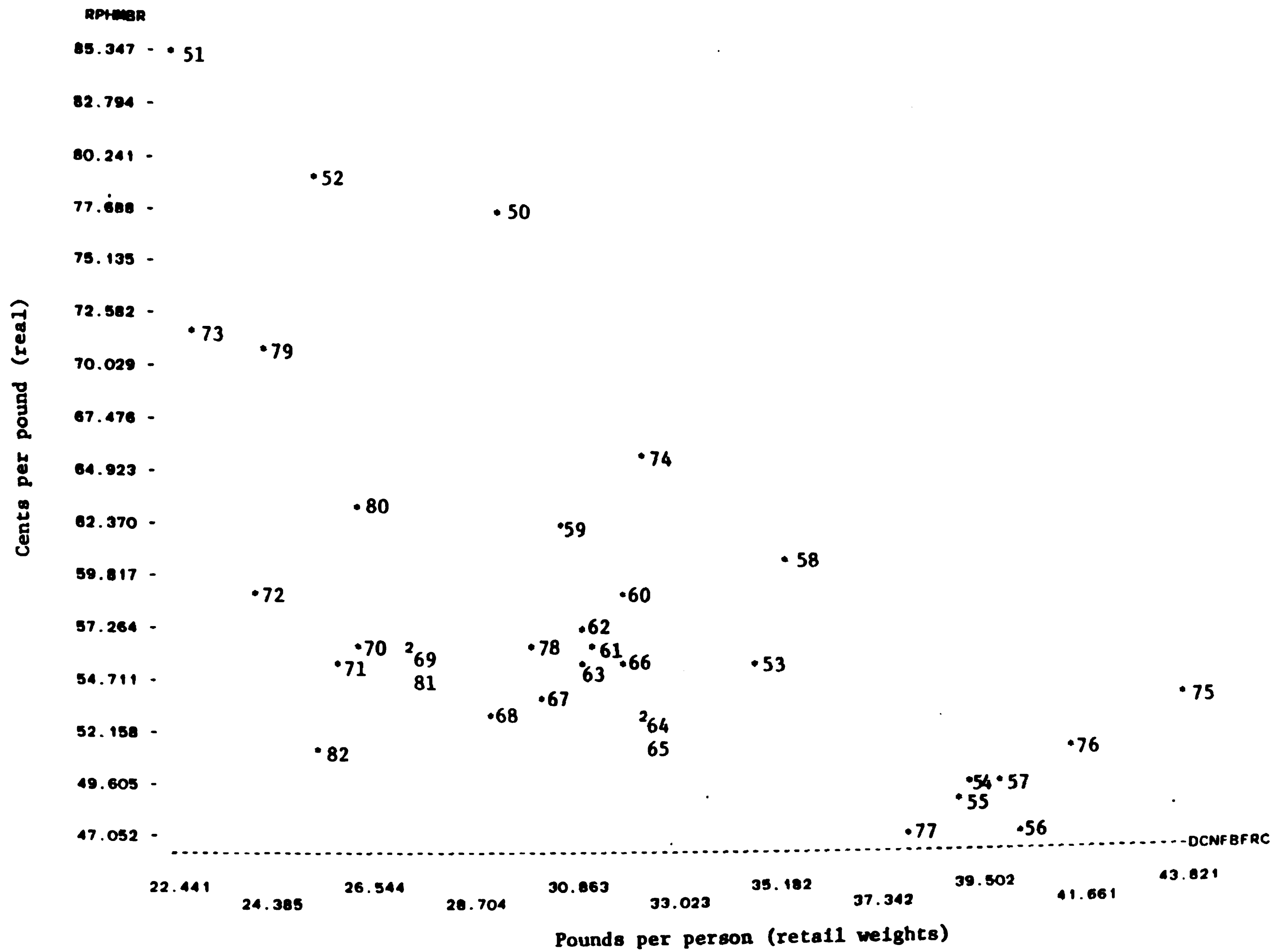

Figure 4.2 - Plot of Retail Prices and Domestic Consumption of Hamburger Beef

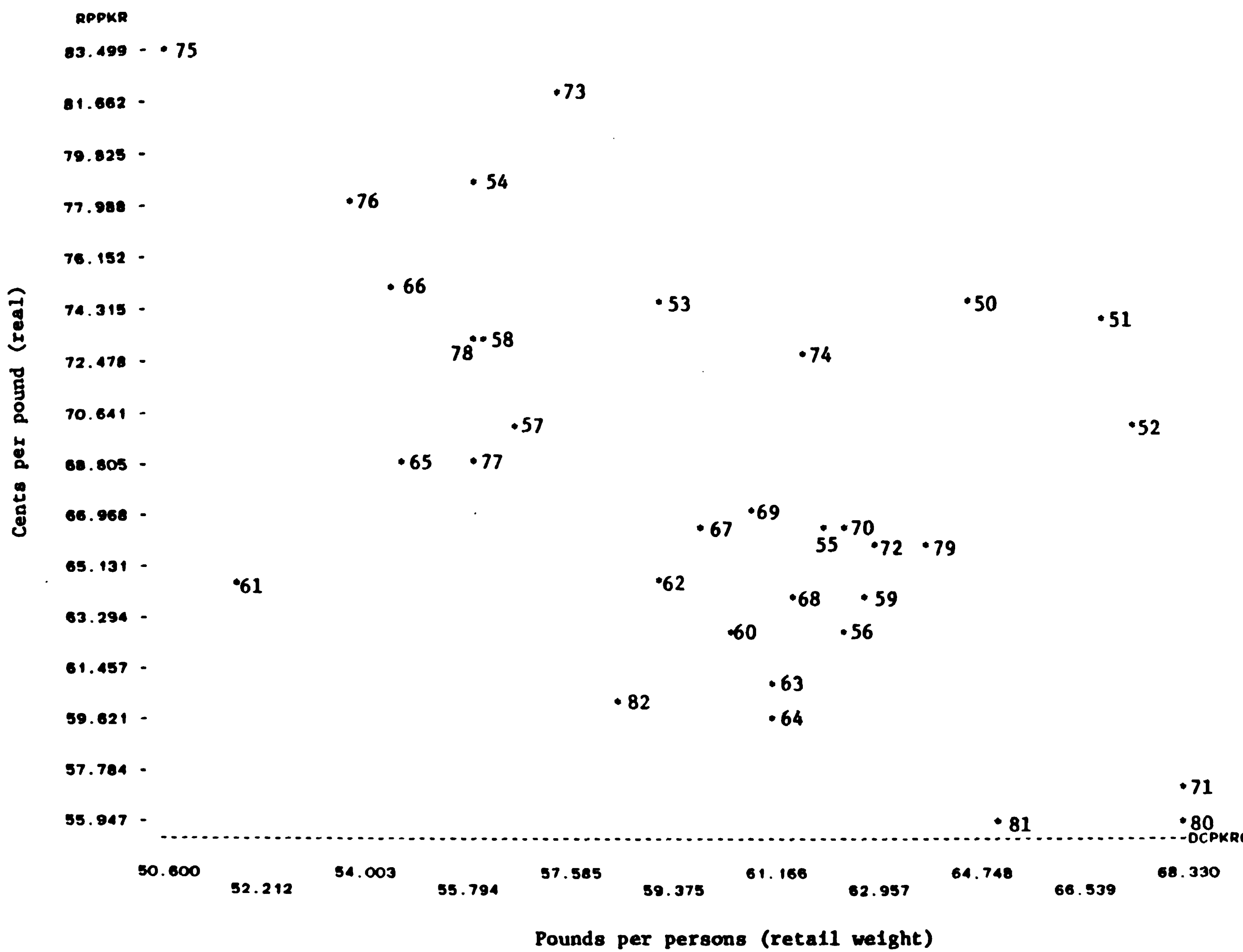

Figure 4.3 - Plot of Retail Prices and Domestic Consumption of Pork

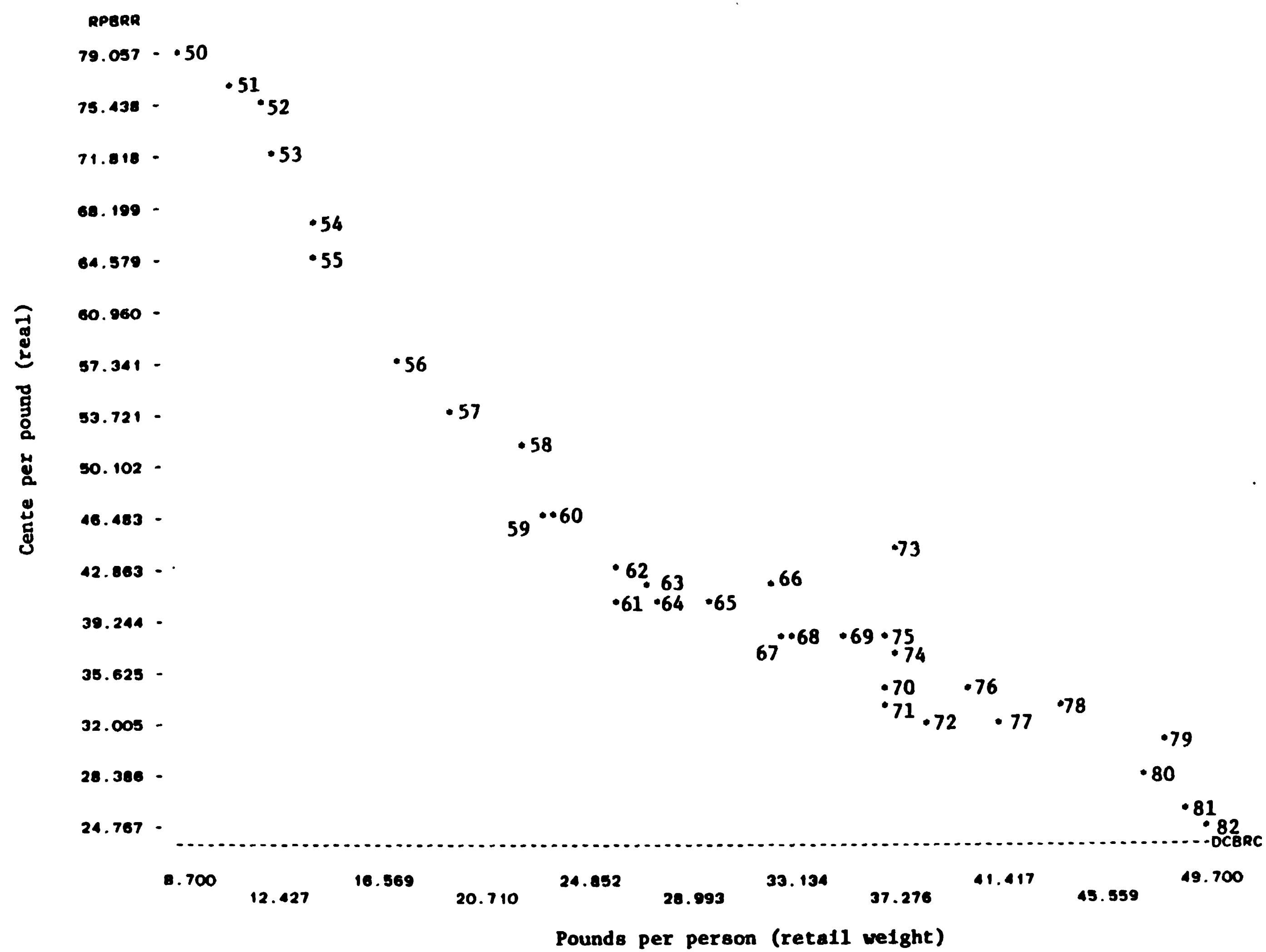

Figure 4.4 - Plot of Retail Prices and Domestic Consumption of Broilers

period. Eventually, high prices caused demand to shift back to the left.[46] This shift ushered in a period of volatile quantity-price relationships, associated with a general fall in real prices and a decline in consumption per person from the high levels of 1972-73. Declines in consumption stabilized during 1980-82, although real prices continued to fall. It was during the period of the late 1970s and early 1980s that shifts in both supply and demand occurred and it is the latter part of this period that has caused forecasters the greatest problems.

Hamburger beef followed a rather different path to that characterizing table beef. Formost of the 1950s, consumption of beef from non-fed animals exceeded consumption of fed beef (Simpson and Farris, 1982, p. 39). The majority of U.S. cattle were still produced on grass and a substantial portion of table beef came from grass-fed cattle. During the 1960s and early 1970s fed-beef production grew rapidly and non-fed beef filled largely a residual role in consumption. After this period, with the beginning of high table beef prices, consumers turned increasingly to its cheaper substitute, hamburger beef. As Figure 4.2 illustrates, between 1973 and 1977 consumption of hamburger beef grew rapidly, then remained at the high levels of the 1950s. However, as the general demand for beef declined and fed-beef prices fell, consumption of hamburger beef returned to the low levels of the early 1970s, and, since 1980, consumption per person has remained relatively stable, although real prices have continued to decline.

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[46] Discussions in Chapter 2 cover further details of these price-quantity movements.

In contrast to beef during the 1950s through to the early 1970s, pork has not fared as well. For much of this period the demand for pork has tended to shift downward. More recently, in the wake of the malaise in beef consumption, pork consumption has increased.

A further contrast to both beef and pork products is the path of domestic consumption of broilers per person which has been one of steady growth and falling real prices. As shown in Figure 4.4, the retail broiler demand has tended to become flatter over time.

These general observations from the graphs are supported empirically in Table 4.8 in which are presented the four base model equations with the addition of a time-quantity interaction variable (T*Q) in each equation. T is time and Q is the respective own-quantity. In the simplest fashion, this variable allows the slope coefficient on own-quantity to vary as a continuous linear function of time. The signs on the T*Q coefficients are positive for table beef, hamburger beef and broilers, although the coefficient in the table beef equation was not significantly different from zero.[47] The coefficient sign in the pork equation was negative and also insignificant. These signs agree with visual inspection of the plots. In the case of the hamburger beef and broiler price equations, the own-quantity slope is becoming significantly flatter over the 33 year period.[48] For table beef and pork,

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[47] In the 'all beef' equation, not shown, the coefficient on T*Q was also positive and insignificant. The substantial change of the 1970s and early 1980s offset the steady growth trend in the previous period.

[48] In a price equation the smaller the slope coefficient the flatter the curve.

demand may be tending toward a flatter and a steeper position, respectively, although not significantly.

From these observations from Table 4.8, it can be concluded that at least in the case of hamburger beef and broilers, if the quantity-price ratio in each year remains constant, then, given their declining slope coefficients, the direct flexibility is declining. This conclusion is contrary to the arguments presented earlier: that of a tendency towards increasing flexibility over time. For this to occur, domestic supply per person will need to have increased at a faster rate than real retail prices and the slope over this period.

To determine the direction of change in direct flexibilities in each commodity over time, evidence on trends in consumption and prices were combined with information on changes in the slope coefficients contained in Table 4.8. This information on changes in the components of their respective direct flexibilities is presented in Table 4.9 together with the expected change in flexibilities over time. From this information it is possible to hypothesize that direct flexibilities for table beef and broilers have increased, those for hamburger beef have decreased and in the case of pork no significant change is expected.

Given earlier discussions on interpreting flexibilities in demand relations, these directions of change are of considerable interest. The lower the direct flexibility, the greater the extent to which increases in quantities available per person are absorbed by demand and hence the

Table 4.8

Effect of Time on Slope Coefficient of Retail Meat Demand:
Time-Quantity Interaction Variables

Dependent Variable	Explanatory Variables											
		Domestic Consumption Per Person							Income	δ/m	$\bar{R}^2$	D.W.[b]
Deflated Retail Price	Constant	DCFBFRC	DCNFBFRC	DCORMRC	DCPKRC	DCPMC	DCBRC	T*Q[a]	DICR			
Table Beef (RPBFR)	139.650 (3.60)	-1.366 (6.24)	-1.713 (8.13)	-.301 (1.30)		-1.511 (4.02)		.001 (.10)	.055 (3.91)	.049	.71	1.31 inc
Hamburger Beef (RPHMBR)	132.53 (5.88)	-.870 (4.81)	-2.244 (9.13)	-.181 (.90)			-1.480 (5.93)	.031 (2.75)	.027 (3.42)	.067	.82	1.51 inc
Pork (RPPKR)	96.653 (3.01)	-.515 (3.39)	-.524 (3.20)		-1.054 (3.38)		-1.345 (2.52)	-.006 (.454)	.044 (6.74)	.045	.81	1.97
Broilers (RPBRR)	92.313 (8.32)	-.322 (2.31)	-.455 (4.84)		-.173 (1.74)		-2.829 (16.35)	.023 (4.90)	.023 (4.62)	.041	.99	2.15

[a]T*Q is a time-own quantity interaction variable, the coefficient of which is additive to the respective own-quantity coefficient; T = 1, 2, 3,....33.

[b]inc = inconclusive.

Note: See Table 4.3 for description of summary statistics.

Table 4.9

Expected Direction of Change in Direct Flexibilities Obtained From Decomposition of Actual Changes in Components of Direct Flexibilities

Direction of Change in:	Meat Product			
	Table Beef	Hamburger Beef	Pork	Broilers
Slope coefficient[a]	positive (n.s.)	positive	negative (n.s.)	positive
Quantities available per person[b]	positive	negative (n.s.)	negative (n.s.)	positive
Real retail prices[c]	negative (n.s.)	negative (n.s.)	negative (n.s.)	negative
Expected change in flexibility (absolute magnitude)[d]	increased	decreased	no change	increased

[a]Obtained from Table 4.8 ; n.s. = not significant.

[b]Obtained by fitting a linear trend line to own-quantity data.

[c]Obtained by fitting a linear trend line to real retail price data.

[d]Hypothesized from the above evidence.

smaller the adjustment of price to clear the market. This could mean that over time, given supplies made available to consumers, that quantities of hamburger have been more readily absorbed by demand than have table beef or poultry meats. Relatively speaking, the preference for hamburger beef has been growing vis-a-vis table beef and poultry meats. On the other hand the position of pork demand has remained unchanged.

A simple way of testing this hypothesis is to estimate flexibilities, using the base model in Table 4.3, over the first half and compare them with those of the second half of the data period. Flexibilities estimated over these two periods are presented in Table 4.10. As hypothesized, the direct-quantity flexibilities of table beef and broilers increased over the two periods, the flexibility for hamburger beef declined, and that for pork remained approximately the same.

An alternative test of this hypothesis is to derive flexibilities directly from equations in Table 4.8, by plugging in incremental values for time, T. For example, in the hamburger beef price equation direct flexibility can be written as $f = (-2.244 + .031T)*\ (q/p)$, for T = 1,2,...,33. These calculations, contained Table 4.11, can only be taken as indicative of the direction of change and of the relative magnitude of the change. Table beef and in particular, broiler direct flexibilities show a distinctive rising trend over time. Flexibilities for hamburger beef show a downward trend although subject to considerable annual change. Pork, by contrast, has revealed considerable variability over this period, switching frequently between flexibility and inflexibility of demand.

Table 4.10

Average Retail Quantity and Income Flexibilities Estimated Over Two PERIODS: 1950-1966 AND 1967-1982

Deflated Retail Price	Domestic Consumption Per Person												Income	
	DCFBFRC		DCNFBFRC		DCORMRC		DCPKRC		DCPMC		DCBRC		DICR	
	Period 1	Period 2	Period 1	Period 2	Period 1	Period 2	Period 1	Period 2	Period 1	Period 2	Period 1	Period 2	Period 1	Period 2
Table beef	-.45	-.80	-.61	-.55	-.22	-.21			-.53	-.85			1.34	1.93
Hamburger beef	-.52	-.93	-.96	-.89	-.35	-.34					-.40	-.80	1.48	2.18
Pork	-.22	-.38	-.26	-.24			-1.02	-1.05			-.46	-.93	1.38	2.00
Broilers	-.50	-1.35	-.36	-.53			-.02	-.04			-.78	-2.49	1.67	3.84
	DCBFRC		DCLMVLRC											
	Period 1	Period 2	Period 1	Period 2										
All beef	-.80	-1.05	-.42	-.19			-.11	-.11	-.59	-.96			.86	1.24

It is not possible to understand the cause of every change in direction in these flexibilities, even if these estimates were identical to actual movements in direct flexibilities. Even when patterns of change have been recognized, interpretation or the relating of these to actual phenomena have to be made with caution.

With this caveat, it may be instructive to attempt to relate, in a general way, observations of economic change in the meat markets to the estimated flexibilities contained in Table 4.11. The purpose is to establish the existence of any structural relationship: to simplify the discussions the more recent period of the late 1960s to date is examined.

For a considerable period from the 1950s to the early 1970s the market for beef, especially table beef has been characterized by strong demand, expanding supplies and growing consumption per person. Real prices were kept low over this period by low inflation rates, relatively cheap inputs and scale economies in feed-lot production. With no significant change in the quantity price relationship (slope) over this time (assumed from Table 4.8) and growth in quantities available per person exceeding growth in real prices, the own-quantity or direct flexibility should increase, which indeed it did up to 1972 (Table 4.11). The peak in beef supply did not occur until several years later although one would expect the retail market and consumer response to lead the changes in the direction of beef production. The flexibilities in Table 4.11 for the years after 1972 first decline and then fluctuate to 1982. The logic of these changes is less clear, except to recognize that both demand and supply appear to have shifted over this period (see Figure

Table 4.11

Direct Flexibilities for Retail Meat Demand:
Estimation Used T*Q Interaction Variable

Year	Direct Flexibilities			
	Table Beef	Hamburger Beef	Pork	Broilers
1950	-.269	-.822	-.916	-.308
1951	-.259	-.573	-.960	-.377
1952	-.291	-.687	-1.023	-.427
1953	-.414	-1.310	-.850	-.461
1954	-.373	-1.625	-.769	-.570
1955	-.398	-1.631	-1.011	-.548
1956	-.427	-1.727	-1.083	-.794
1957	-.404	-1.596	-.886	-.925
1958	-.375	-1.136	-.843	-1.107
1959	-.443	-.936	-1.086	-1.258
1960	-.476	-1.022	-1.073	-1.285
1961	-.524	-1.018	-.896	-1.588
1962	-.517	-.988	-1.032	-1.500
1963	-.600	-1.000	-1.140	-1.614
1964	-.667	-1.076	-1.170	-1.691
1965	-.642	-1.050	-.911	-1.765
1966	-.703	-.978	-.832	-1.840
1967	-.776	-.927	-1.043	-2.053
1968	-.825	-.892	-1.118	-2.054
1969	-.820	-.778	-1.063	-2.150
1970	-.889	-.732	-1.104	-2.473
1971	-.868	-.718	-1.408	-2.509
1972	-.869	-.622	-1.135	-2.657
1973	-.727	-.473	-.837	-1.889
1974	-.722	-.719	-1.017	-2.210
1975	-.614	-1.156	-.733	-2.089
1976	-.818	-1.129	-.830	-2.472
1977	-.880	-1.110	-.986	-2.709
1978	-.824	-.706	-.934	-2.779
1979	-.689	-.448	-1.187	-3.273
1980	-.698	-.523	-1.499	-3.415
1981	-.758	-.602	-1.446	-3.758
1982	-.824	-.597	-1.204	-4.153

4.1). In the last few years, quantities available have remained at relatively stable levels and prices have fallen. If the relationship between quantities and prices remained constant as assumed, then as shown in Table 4.11, the table beef flexibilities will have risen. This means that demand shifted leftward in a parallel fashion.

As fed-beef production expanded in response to a growing table beef demand, hamburger beef supply availability and, hence, consumption fell from the mid-1960s to a low in per person consumption in 1973 (Figure 4.2). With this decline in hamburger beef supply, quantities available to consumers moved more in line with effective demand, and consequently, retail price adjustments became increasingly smaller. In turn, direct flexibilities of demand for hamburger beef became increasingly smaller, in absolute terms. As indicated in Table 4.11 this decline continued until 1973. In effect, the demand curve for hamburger beef was shifting leftward and becoming flatter (Figure 4.2).

However, by 1973 table beef prices were at high levels and consumers turned steadily to ground beef and other meat substitutes. For a period, demand for hamburger beef rose (demand curve shifted out) and hamburger beef direct flexibilities rose to higher levels over 1974-77. Over time table beef prices began to fall, hamburger beef again faced increased competition and demand declined. The opportunity cost of hamburger beef supplies from cows and heifers rose as the demand for breeding stock increased. A greater portion of fed beef carcasses was cut out as table beef. As these reduced quantities of hamburger beef could be more readily absorbed in demand, than as reflected in Table 4.11, direct flexibilities of hamburger beef also fell.

4.5.2 Slope and Intercept Changes in Demand

From the foregoing discussion, considerable change in the structure of U.S. demand for meats, especially table and hamburger beef and broilers, appeared to have occurred over the past several decades. Thus far, through the use of time-quantity interaction terms, namely T*Q, changes in slope have been measured as an average linear change over the total 33 year period. However, as may be seen in Figures 4.1-4.4, over certain periods within this total period the slopes appear relatively stable, while over other subperiods substantial change in slope has occurred. In an attempt to measure these changes, slope and intercept dummy variables were tested separately and within the same equation. The choice of periods over which these variables were to operate was somewhat arbitrary, although based upon the plots in Figures 4.1-4.4. While some experiment was necessary, examination of groupings of price-quantity data does reveal periods when these prices and quantities appeared to move along the same broad demand curve as opposed to periods when a shift in demand took place.

For each of the four meats being examined, the following subperiods were chosen.

Table Beef:	1950-1957	Hamburger Beef:	1950-1958
	1958-1965		1959-1966
	1966-1668		1967-1972
	1969-1982		1973-1976
			1977-1982
Pork:	1950-1954	Broilers:	1950-1964
	1955-1959		1965-1982
	1960-1965		
	1966-1979		
	1980-1982		

It is recognized that for table beef the period 1969-82 could not adequately be modelled as a homogeneous period. The latter half of this period was particularly volatile in terms of demand and supply shifts. It is partly for this reason that it is separated from the other periods. Also, in order to keep the number of subperiods within manageable limits and within the restrictions on degrees of freedom in estimation, this grouping was chosen. A further difficulty arises from the inclusion of both slope and intercept changes. When both variables were included in the same equation, except the broiler equation, multicollinearity prevented efficient estimation of the coefficients. Therefore, the intercept dummy variables were excluded in most cases. The bases for this choice were first, that the primary interest is on how the structural relationship between prices and quantities (slope) changes over time, and second, that the interpretation associated with the value of the intercept is somewhat doubtful since no data points have been observed at or near zero quantities. The remaining discussion focuses primarily on changes in slope coefficients of specific demand relationships.

Results of the addition of slope interaction variables are summarized in Table 4.12. The slope of the demand for table beef has become significantly flatter in each subperiod.[49] This change has been associated with a rightward shift of the curve and substantial increases in supply availability. The slope of the demand curve for hamburger beef has also become flatter in each subperiod, though significantly only in the fourth period, 1973-76. This period covers the years when demand for hamburger beef expanded as consumers substituted out of high priced table beef.

Consistent with earlier results, the slope of pork demand has become steeper over time. In this model, these changes were statistically significant at or above the 90 percent level for all but the fourth subperiod, 1966-79. Only one shift in the demand for broilers was measured, namely, that during the mid-1960s. This was the time of an important watershed for the broiler industry in terms of diminishing gains in labor productivity, output per farm and feed efficiency (Reimund, Martin and Moore, 1981). The first broiler equation in Table 4.12 indicates that the demand curve became flatter over the latter period. Because there was only one shift it was statistically possible to specify a slope and intercept variable as shown in the second broiler equation. This equation suggests that in this later period the demand curve rotated to give a lower intercept and a flatter curve.

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[49] Changes in slope are to be measured with respect to slope in the first period, for example, as represented by the coefficient on DCFBFRC.

Table 4.12

Slope and Intercept Changes in Retail Demand for Meats

Dependent Variable	Explanatory Variables														
	Constant[a]	Domestic Consumption Per Person[a]										Income	$\hat{\sigma}/m$	$\bar{R}^2$	D.W.
Deflated Retail Price		DCFBFRC	DCNFBFRC	DCORMRC	DCPKRC	DCPMC	DCBRC	DVQ2	DVQ3	DVQ4	DVQ5	DICR			
Table beef price	149.020 (7.55)	-2.413 (8.23)	-1.588 (10.57)	-.062 (.34)		-1.787 (7.83)		.546 (4.46)	.646 (3.96)	.835 (4.69)		.055 (6.86)	.035	.85	2.18
Hamburger beef price	115.512 (4.77)	-.776 (2.31)	-1.893 (11.99)	-.017 (.09)			-.774 (2.80)	.084 (.97)	.105 (.72)	.471 (3.35)	.225 (1.32)	.021 (1.59)	.059	.86	1.42 inc
Pork price	119.412 (7.89)	-.472 (2.36)	-.414 (2.70)		-1.060 (6.24)		-.873 (3.11)	-.076 (1.90)	-.127 (2.19)	-.045 (.51)	-.139 (1.39)	.028 (4.43)	.040	.85	1.96
Broiler price	67.569 (5.57)	-.834 (7.73)	-.557 (4.73)		-.027 (.22)		2.106 (15.56)	.155 (2.00)				.034 (6.22)	.052	.98	1.87
Broiler price	89.531 (9.79)	-.382 (3.49)	-.429 (5.14)		.217 (2.41)		2.413 (22.46)	-26.213[b] (5.57)	.958[b] (6.24)			.024 (5.78)	.036	.99	2.31

[a]The DVQ variables are own-quantity interaction variables, where Q represents the respective own-quantity in each equation, and the number refers to the period of the dummy variable.

[b]This equation includes both dummy and interaction variables, respectively.

Notes: See Table 4.3.

It should be noted that the income flexibilities derived from the equation in Table 4.12 and calculated at mean values were 1.65, .99, 1.13 and 1.41 for table beef, hamburger beef, pork and broilers (second equation), respectively. The relative magnitude of these values agrees with a priori expectations.

4.5.3 Measurement of Irreversibility of Demand

There are researchers who have theorized that these shifts in demand structure are more systematic and follow distinct cycles and phases. The existence of consumption habits as well as cyclical patterns of prices and consumption has led to some investigations into beef demand and of the hypothesis that coefficients in demand models are different for rising and falling phases of consumption, prices and incomes. This is the hypothesis of irreversibility in demand, discussed in Chapter 3.[50]

In a quantity dependent demand relation the usual hypothesis is that the quantity demanded by consumers, following a change in prices, is more elastic in an increasing consumption (decreasing prices) phase and more inelastic in a decreasing consumption (increasing prices) phase. This is consistent with the hypothesis that because of habits in consumption patterns consumers adjust consumption by less during the increasing price phase than during the decreasing price phase. Also hypothesized within this model is that income elasticities are higher

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[50]See Chapter 3 for a review of literature in which this hypothesis has been tested.

(lower) in periods of decreasing (increasing) prices because of a stronger response to income changes in these periods.

There have been several analyses of demand testing these hypotheses in terms of quantity dependent demand equations, dealing with measures of elasticity. However, at the time of writing no studies have been conducted on the demand for meats when price is specified as the dependent variable and quantities are assumed predetermined. In this model specification, it is hypothesized that own-quantity or direct flexibility will tend to be more flexible during decreasing consumption phases and less flexible (inflexible) during increasing consumption phases. From an initial equilibrium, for a given level of demand, market prices adjust less when available supplies are increasing. Existing consumer habits are reinforced by more product at lower prices and since demand and supply are more closely in balance price adjustments are smaller.[51] When available supplies are decreasing relative to a given level of demand, prices by necessity, are more flexible in clearing the market.

Another, more market oriented, explanation for this apparent demand irreversibility relates to the nature of retail pricing. That is, at the retail level, the average response of retailers over one year given predetermined quantities available is to increase prices when supplies are low but not to decrease prices by a commensurate amount when supplies are high. Therefore, there is some degree of downward rigidity but upward flexibility in the process of pricing at the retail level.

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[51] A given level of demand is quite realistic since demand usually moves less and more slowly over time, compared to supply. This would seem the case especially within the short-run period of a year.

The a priori behavior of income flexibilities seems less clear. Two arguments may be made, each giving rise to different conclusions. The first is based on the assumption of habits in consumption patterns and institutional impediments to adjustment. As incomes fall, the demand for a particular good falls. Because of the persistence of consumption patterns associated with a given level of income, a fall in income is not associated with as large a reduction in demand as the rise in demand resulting from a rise in income. When incomes rise, existing consumption patterns are reinforced and hence prices tend to be more flexible in response to upward movements in income.

The alternative argument is based less on individual consumer behavior and more on market behavior. During periods when incomes are low or declining, retailers pay greater attention to competing for the consumers' dollars. The effect of an increasing budgetary constraint on consumer spending is, from the retailers' standpoint, the more frequent offer of specials and greater price discounts, and from the consumer's standpoint, a greater sensitivity in terms of their willingness to pay a certain price for a particular good. Hence, in response to downturns in consumers' incomes a greater direct flexibility can be expected. Conversely, when incomes are rising consumer demand increases, but as retailers would find, consumers are less sensitive to price increases, since their overall budgetary constraint is less apparent. No theory is available to choose between these alternative hypothesis, hence it becomes an empirical question to be investigated.

Irreversibility of demand is usually tested in terms of increasing and decreasing phases of consumption even in quantity-dependent demand models when changes in prices seem the more logical reference point. Logically, the irreversibility should be with respect to the variable to which the consumer is responding, i.e., the particular explanatory variable, and not the dependent variable which is the outcome of the causes of irreversibility.[52] Given this causality a number of possible explanatory variables may be used to test the irreversibility hypothesis in beef demand.[53] These variables include consumption, production, and cycles in cattle numbers. In each model tested domestic consumption per person, retail, remained the actual explanatory variable. When changes in aggregate production and in cattle inventory were chosen as the underlying cause of demand irreversibility, changes in these variables were only reflected in domestic consumption in choosing cut off periods and were not specified directly. Therefore, measures of change in flexibility remain in terms of retail prices and quantities.

Goodwin et.al. (1968) used consumption changes to test irreversibility. Uvacek (1968) argued that the irreversible nature of demand curves was linked to cycles in cattle inventories. During supply reducing periods demand curves are more inelastic (flexible). He felt that the high positive correlation between cattle cycles and slaughter levels made possible the link with consumption shifts.

Various demand models were tested for all beef, table beef and hamburger beef. The procedure was to specify an interaction dummy variable

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[52] The study by Goodwin et.al. (1968) appears to suffer from this flaw in logic.

[53] This analysis is restricted to beef demand since in an annual model, demand irreversibility is more likely to be identified.

on own-quantity, over the period of years, for each increase and each decrease in the chosen causal variable. In most instances this resulted in a large number of interactions (slope) variables. It would not be statistically possible or indeed economically meaningful to specify each and every decrease and increase observed. Therefore, broad groupings of periods were chosen as an increasing or a decreasing period. Subperiods were overlapped at the beginning and ending years in order to achieve some continuity in change of direction and maximize available degrees of freedom.

The first set of estimates using direct changes in domestic consumption per person were disappointing and at best inconclusive.[54] Largely because of the many changes in direction in consumption and the problem of large variances associated with multicollinearity, many of the estimated coefficients were not significantly different from zero.

Results of applying changes in aggregate beef production to the identification of quantity interaction variables also proved unsatisfactory except for all beef.[55] This model estimated in logarithms[56] is

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[54] In the first model tested, one overall slope interaction variable was specified that took the value of zero when consumption was increasing and one times consumption in that year when consumption was decreasing over the period 1950-82. The sign on the estimated coefficient of this interaction dummy variable was positive, indicating a direct flexibility which is relatively high during periods of consumption decline, hence giving support to the stated hypothesis of irreversibility in demand.

[55] Results may be improved by choosing fed beef and non-fed production as the underlying variables of change in the table beef and hamburger beef equations.

[56] The logarithmic model was chosen for convenience in estimation, all other factors being equal.

shown in Table 4.13. Coefficients may be interpreted as flexibilities. Specification of consumption flexibility was based on eight changes in direction of production observed between 1950 and 1982. Pork consumption was excluded from this model since its inclusion resulted in increased variances in other coefficients.

Although the differences are quite small, the estimated direct flexibilities agree, except for the last period, with the relative magnitude of flexibilities expected under the hypothesis of irreversibility of demand. When supplies of beef are decreasing following the liquidation phase of the cattle cycle lower quantities of beef are made available to the consumer. During this time there is an 'accumulated' demand, and prices, being more responsive to supply changes, are more flexible during this period. The opposite occurs when cattle inventories are expanding and supplies are increasing. The previously 'pent-up' demand is now satisfied. With supplies moving more into line with demand, price adjustments become increasingly smaller; hence direct flexibilities tend to become lower during this period.

Two postscripts may be made to these results. First, these estimated flexibilities measure predominantly short-term phenomena. This follows from annual time series models. Second, the overall hypothesis of irreversibility is expected to be strongest when demand is strong. If an increase in supplies occurs simultaneously with a weakening of demand, implying an adjustment of supply and demand, then the direct flexibilities may not be low as hypothesized. In fact they may be relatively high if the market continues for sometime in disequilibrium. This may partly explain the relatively higher and 'unexpected'

Table 4.13

Irreversibility in Retail Demand for Beef Based on Changes in Aggregate Beef Production

Dependent Variable (in logarithms)	Constant	DCBFRC	DCPMC	DVBF2	DVBF3	DVBF4	DVBF5	DVBF6	DVBF7	DVBF8	DICR	DVDICR	∂/m	$\bar{R}^2$	D.W.
	Explanatory Variables (in logarithms)														
		Logarithms of Domestic Consumption Per Person									Income				
All beef price	1.073 (.89)	-1.188 (10.69)	-.355 (1.98)	.001 (.15)	-.007 (1.16)	.021 (3.07)	.016 (2.47)	.022 (3.28)	.020 (3.25)	-.013 (1.21)	1.240 (4.84)	.009 (3.05)	.007	.86	1.55

Years of Change in Beef Production		Direction of Change	Expected Relative Magnitude of Direct Flexibility	Estimated Direct Flexibility	Estimated Relative Magnitude of Direct Flexibility
1950-51	DVBF1	↓	high	-1.188	high
1951-56	DVBF2	↑	low	-1.186	low
1956-58	DVBF3	↓	high	-1.195	high
1958-72	DVBF4	↑	low	-1.167	low
1972-73	DVBF5	↓	high	-1.172	high
1973-76	DVBF6	↑	low	-1.166	low
1976-79	DVBF7	↓	high	-1.168	high
1979-82	DVBF8	↑	low	-1.200	high

Notes: See Table 4.3.

flexibility during 1979-82 when demand for beef weakened and as a result demand irreversibility appears less in evidence.

Also specified in the all beef equation in Table 4.13 is a slope dummy on income, DVDICR. This variable is zero for periods of increasing income and one times the income level in that year during periods of decreasing income. A single interaction variable to cover all periods of decreasing income was chosen in the interests of preserving degrees of freedom, in lieu of separate dummies for each group of years when income was observed to change. The estimated coefficient on DVDICR is positive and significant suggesting that the flexibility on income is higher during periods when incomes are decreasing. This result agrees with the second proposed income hypothesis that, because of the effect of a tighter budgetary constraint, consumers (and retailers in pricing) are more responsive to decreases in income.

As alluded to above and as suggested by Uvacek (1968), changes in the cattle inventory or more generally, cattle cycles may provide the underlying momentum behind irreversibility in demand. This possibility was investigated by identifying upturns and downturns in U.S. beef cattle cycles between 1950 and 1982. Seven such periods of change; increase followed by decrease and so on (see bottom of Table 4.14), were investigated. These changes in cattle numbers were used to provide the breakpoints in consumption (slope) interaction variables. The results of this analysis are presented in Table 4.14. Even though a strong positive correlation exists between beef production and cattle cycles, the cattle cycle provides slightly different subperiods to those specified for aggregate beef production. Nevertheless, a very similar

Table 4.14

Irreversibility in Retail Demand for Beef Based on
Changes in U.S. Cattle Cycles

Dependent Variable	Explanatory Variable																
		Domestic Consumption Per Person											Income		$\hat{\sigma}/m$	$\bar{R}^2$	D.W.
Deflated Retail Price	Constant	DCBFRC	DCFBFRC	DCNFBFRC	DCORMRC	DCPMC	DVQ2	DVQ3	DVQ4	DVQ5	DVQ6	DVQ7	DICR	DVDICR			
Table beef	-.303		-.765	-.492	-.065	-.085	-.017	.022	-.003	.018	.017	-.025	1.185		.009	.77	2.06
	(.14)		(5.27)	(7.67)	(.36)	(.41)	(1.81)	(2.79)	(.38)	(2.21)	(1.77)	(1.55)	(3.65)				
Hamburger beef	-1.926		-1.010	-.821	.231	-.101	-.030	.029	.005	.022	.021	-.041	1.511		.017	.77	2.26
	(.51)		(4.05)	(7.65)	(.75)	(.28)	(2.06)	(2.15)	(.34)	(1.56)	(1.10)	(1.19)	(2.71)				
All beef	1.566	-1.135			-.046	-.255	-.003	.012	-.008	.017	.031	-.010	1.132		.009	.76	1.82
	(.93)	(8.34)			(.28)	(1.27)	(.41)	(1.87)	(1.18)	(2.36)	(1.63)	(.82)	(3.77)				
All beef	.587	-1.159				-.303	-.007	.013	-.007	.012	.010	-.023	1.268	.005	.009	.79	1.95
	(.39)	(9.13)				(1.64)	(1.02)	(2.11)	(1.17)	(1.74)	(1.36)	(1.74)	(4.38)	(1.85)			

Years of Change in Cattle Inventory		Direction of Change	Expected Relative Magnitude of Direct Flexibility	Estimated Direct Flexibility				Estimated Relative Magnitude of Direct Flexibility			
				Table Beef	Hamburger Beef	All Beef	All Beef	Table Beef	Hamburger Beef	All Beef	All Beef
1950-55	DVQ1	↑	low	-.765	-.821	-1.135	-1.159	low	low	low	low
1955-58	DVQ2	↓	high	-.782	-.851	-1.138	-1.166	high	high	high	high
1958-65	DVQ3	↑	low	-.743	-.792	-1.123	-1.146	low	low	low	low
1965-67	DVQ4	↓	high	-.768	-.816	-1.143	-1.166	high	high	high	high
1967-75	DVQ5	↑	low	-.747	-.799	-1.118	-1.147	low	low	low	low
1975-79	DVQ6	↓	high	-.748	-.800	-1.122	-1.149	high	high	high	high
1979-82	DVQ7	↑	low	-.790	-.862	-1.145	-1.182	high	high	high	high

Notes: See Table 4.3.

pattern emerges in changes in estimated direct flexibilities; higher in periods of cycle or cattle inventory upturn and lower in cycle downturns. Again the exception is the last year which for the reasons stated above may be coincident with a weakening demand for meat over that period. The fact that this pattern also emerges for the beef subcategories, table and hamburger beef may be surprising. More precise estimates may be obtained by using changes in numbers of fed-beef animals and non-fed animals. The problem is how to allocate in any one year the investment component of the herd, namely, breeding cows and bulls and calves which to some extent may be turned out as fed animals or nonfed animals.

Finally, note again, the test of irreversibility with respect to income changes, and that the coefficient flexibility on the interaction term of DVDICR suggests increased income flexibility in periods of decreasing incomes. One avenue for further analysis concerns the hypothesis that income and consumption interact systematically during different phases of demand change. This hypothesis was referred to in Chapter 2.

4.6 Time-Varying Switching Regression Model

Thus far all attempts to identify changes in demand structure and to measure those changes through estimated flexibilities have focused on models of discontinuous and disjointed changes in structure. Models estimated first, were of broad changes in slope as illustrated in plots of prices and quantities and, second, were specified in a manner to test the hypothesis of irreversibility in demand relationships. In reality, shifts in demand from one structure to another are likely to be more continuous. Such continuity seems more in accord with the inherent and psychic nature of people and more consistent with the role played by expectations in smoothing abrupt changes in market behavior. One tends to underestimate the continuity of mass economic behavior. In noting this strong continuity in our economic behavior, Fox (1956, p. 418) observed that the structure of demand had undergone a gradual evolution rather than a dramatic upheaval.

Discussions now return to the broad changes in demand illustrated by the plots of Figures 4.1 to 4.4. Results are presented of demand models capturing this continuity of regression coefficients across structural shifts.

4.6.1 Linear and Cubic Splines

As discussed in Chapter 3, spline functions offer a means of modelling continuous, though not necessarily smoothly continuous, changes in demand structure. Only cubic splines allow distinct line segments to be joined smoothly at known join points (the assumed points of change). These spline functions have continuity in their second and first derivatives. It is this character which gives cubic splines greater reality in economic applications in which a discontinuous shift may be unexpected, as in shifts in elasticities, flexibilities and in various marginal concepts.

The general model applied is a time-varying switching regression model (Poirier, 1976). This model permits slope parameters to change over some periods of time and remain constant over others. And, through the use of splines, the periods of change are modelled in a continuous fashion.[57] This model is to be distinguished from continuous time-varying parameter models, estimated in the next section, which permit the slope parameters to vary in every period. The estimating models are represented below.

Linear spline:

$$p_{it} = \gamma_{0i} + \gamma_{1i}q_{it} + \gamma_{2i}q_{it}\, t + \gamma_{3i}q_{it}(t-\bar{t}_k)D_k \tag{4.9}$$

$$+ \delta_{ji} \sum_{j=i}^{3} q_{jt} + \lambda_i y_t + e_t$$

Cubic spline:

$$p_{it} = \gamma_{0i} + \gamma_{1i}q_{it}t + \gamma_{3i}q_{it}t^2 + \gamma_{4i}q_{it}\, t^3 \tag{4.10}$$

$$+ \gamma_{5i}\, q_{it}\, (t-\bar{t}_k)^3 D_k + \delta_{ji} \sum_{j=1}^{3} q_{jt} + \lambda_i yt + e_j$$

where the retail price of the ith meat, p_{it} for $i=1,\ldots,4$, is a function of the ith meat quantity, q_{it} and other variables of the composite spline in q_{it}; namely time t for $t=1,\ldots,33$, $\bar{t}_k$ over k join points (points of change in demand structure) and dummy variables, $D_k = 1$ if $t \geq t_k$, and 0, otherwise. Other variables are substitute meat quantities, q_{jt}, disposable income per person, y_t, equation error term, e_t and regression coefficients, γ, δ, and λ, to be estimated. All variables remain as previously defined. In contrast to the specification of most spline functions in time series analyses, the splines in (4.9) and

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[57]Models in which change is measured in an abrupt, discontinuous fashion were discussed earlier and include slope-interaction dummy variable models.

(4.10) are defined in terms of time, t and with respect to a particular explanatory variable. This is to allow explicitly for a time-varying character in the estimated regression coefficients.

Using special notation, the previously estimated base model for each price equation may be written as $P = B(X) + e_1$. Hence, the base model with the composite spline variable, S(X), may be represented as $P = B(X) + S(X) + e_2$, where e_1, and e_2 are error terms. The statistical significance of the contribution made by the addition of a composite spline variable may be tested by following the procedure outlined in Table 4.15. The coefficient of partial determination associated with each spline is calculated and its significance tested by comparing residual sums of squares in the spline models with the respective base models as in an analysis of variance table. The F-value is used as the test statistic.

Both linear and cubic splines are tested for each meat product and the results of these tests are summarized in Table 4.16–4.19. Contained in each table are the respective partial R^2 values and the associated F-values. Except for the broiler price model, only equations in arithmetic values (linear functional form) are presented, as these were superior to equations in natural logarithms in terms of signs, statistical significance, and fit to the data. Spline join points are located at points of structural shift in demand identified earlier from plots of

TABLE 4.15

Procedure for Testing Contribution of Composite Spline Variables Relative to the Base Models of Meat Demand

	Sum of Squares	Degrees of Freedom[a]	Mean Square
Residual from B(X)	Σe_1^2	27	
Residual from B(X)+S(X)	Σe_2^2	23	$\Sigma e_2^2/23$
Contribution of S(X)	$\Sigma e_1^2-\Sigma e_2^2$	4	$(\Sigma e_1^2-\Sigma e_2^2)/4$
Partial R^2	$(\Sigma e_1^2-\Sigma e_2^2)/\Sigma e_1^2$		
F-value	$\dfrac{(\Sigma e_1^2-\Sigma e_2^2)/4}{\Sigma e_2^2/23}$		

[a]Numbers of degrees of freedom are illustrative only.

Table 4.16

Table Beef Price Equation[a]: Spline Functions and Contribution of Linear and Cubic Splines

Dependent Variable: Table Beef Price	Explanatory Variables: Constant	Terms of Composite Spline Variable: DCFBFRC	Q^*T	$Q(T-\bar{T}_1)D_1$	$Q(T-\bar{T}_2)D_2$	$Q(T-\bar{T}_3)D_3$	DCNFBFRC	DCORMRC	DCPMC	DICR	$\hat{\sigma}/M$	$\bar{R}^2$	D.W.
Linear Spline	150.504	-3.070	.023	-.034	.077	-.080	-1.822	- .389	-1.269	.056	.047	.73	1.51
	(2.31)	(.66)	(.33)	(.96)	(1.63)	(2.10)	(7.77)	(1.67)	(1.83)	(3.35)			

Dependent Variable: Table Beef Price	Constant	Terms of Composite Spline Variable: DCFBFRC	Q^*T	Q^*T^2	Q^*T^3	$Q(T-\bar{T}_1)^3D_1$	$Q(T-\bar{T}_2)^3D_2$	$Q(T-\bar{T}_3)^4D_3$	DCNFBFRC	DCORMRC	DCPMC	DICR	$\hat{\sigma}/M$	$\bar{R}^2$	D.W.
Cubic Spline	190.116	96.559	-5.305	.094	-.0006	.0008	-.0007	.0001	-1.736	- .250	.027	.018	.028	.91	2.01
	(4.53)	(.60)	(.62)	(.62)	(.61)	(.61)	(.69)	(.12)	(11.00)	(1.82)	(.063)	(1.53)			

Contribution of Time-Varying Parameter Specification to Table Beef Price Equation: Coefficient of Partial Determination, Partial R^2 and F-Values

Type of Spline	Partial R^2	F-Value	Critical F-Value (.01% level)
Linear Spline	.19	1.35	4.26
Cubic Spline	.75	10.43	3.81
Test of Equality Between Linear and Cubic Spline Models		23.37	5.78

Notes: See Table 4.3.

a. Functional form is linear.

Table 4.17

Hamburger Beef Price Equation[a]: Spline Functions and Contribution of Linear and Cubic Splines

Dependent Variable: Hamburger Beef Price — Explanatory Variables

Hamburger Beef Price	Constant	DCFBFRC	DCNFBFRC	Terms of Composite Spline Variable: Q^*T	$Q(T-\bar{T}_1)D_1$	$Q(T-\bar{T}_2)D_2$	$Q(T-\bar{T}_3)D_3$	$Q(T-\bar{T}_4)D_4$	DCORMRC	DCBRC	DICR	$\hat{\sigma}/m$	$\bar{R}^2$	D.W.
Linear Spline	132.713 (8.72)	-1.786 (8.61)	-.109 (.09)	-.035 (1.68)	.062 (2.50)	.040 (2.15)	-.115 (3.27)	-.196 (4.03)	.009 (.07)	.846 (1.80)	.014 (2.02)	.041	.93	2.67

	Constant	DCFBFRC	DCNFBFRC	Terms of Composite Spline Variable: Q^*T	Q^*T^2	Q^*T^3	$Q(T-\bar{T}_1)^3D_1$	$Q(T-\bar{T}_2)^3D_2$	$Q(T-\bar{T}_3)^3D_3$	$Q(T-\bar{T}_4)^3D_4$	DCORMRC	DCBRC	DICR	$\hat{\sigma}/m$	$\bar{R}^2$	D.W.
Cubic Spline	116.887 (6.15)	-1.658 (8.07)	79.505 (.96)	-4.054 (.92)	.067 (.86)	-.0004 (.81)	.0005 (.65)	.0005 (.58)	-.003 (.94)	.009 (1.15)	.050 (.34)	.833 (1.77)	.017 (2.37)	.035	.95	2.65

Contribution of Time-Varying Parameter Specification to Hamburger Price Equation: Coefficients of Partial Determination, Partial R^2 and F-Values

Type of Spline	Partial R^2	F-Value	Critical F-Value (.01% level)
Linear Spline	.76	13.78	3.99
Cubic Spline	.83	14.24	3.71
Test of Equality Between Linear and Cubic Spline Models		4.48[b]	5.85

a. Functional form is linear.

b. Significant at .05% level - critical F-Value is 3.49.

Table 4.18

Pork Price Equation[a]: Spline Functions and Contribution of Linear and Cubic Splines

Dependent Variable — Explanatory Variables

Pork Price	Constant	DCFBFRC	DCNFBFRC	DCPKRC (Terms of Composite Spline Variable)	Q^*T	$Q(T-\bar{T}_1)D_1$	$Q(T-\bar{T}_2)D_2$	$Q(T-\bar{T}_3)D_3$	$Q(T-\bar{T}_4)D_4$	DCBRC	DICR	$\hat{\sigma}/M$	$\bar{R}^2$	D.W.
Linear Spline	110.710 (3.16)	-.338 (1.32)	-.442 (2.08)	-.240 (.21)	-.017 (.91)	.0006 (.03)	.011 (.54)	.002 (.16)	-.054 (1.43)	-.926 (1.47)	.033 (3.20)	.046	.80	1.84

	Constant	DCFBFRC	DCNFBFRC	DCPKRC (Terms of Composite Spline Variable)	Q^*T	Q^*T^2	Q^*T^3	$Q(T-\bar{T}_1)^3D_1$	$Q(T-\bar{T}_2)^3D_2$	$Q(T-\bar{T}_3)^3D_3$	$Q(T-\bar{T}_4)^3D_4$	DCBRC	DICR	$\hat{\sigma}/M$	$\bar{R}^2$	D.W.
Cubic Spline	143.117 (4.16)	-.815 (2.83)	-.566 (2.87)	-48.064 (.22)	2.486 (.20)	-.043 (.19)	.0002 (.17)	.0003 (.14)	-.0008 (1.05)	.0001 (.48)	.005 (.47)	-.082 (.13)	.019 (1.88)	.041	.84	2.36

Contribution of Time-Varying Parameter Specification to Pork Price Equation: Coefficient of Partial Determination, Partial R^2 and F-Values

Type of Spline	Partial R^2	F-Value	Critical F-Value (.01% level)
Linear Spline	.12	.61	3.99
Cubic Spline	.38	1.74	3.71
Test of Equality Between Linear and Cubic Splines		4.14[b]	5.85

a. Functional form is linear.

b. Significant at .05% level -- Critical F-Value is 3.49.

Table 4.19

Broiler Price Equation: Spline Functions and Contribution of Linear and Cubic Splines

Dependent Variable	Explanatory Variables													
					Terms of Composite Spline Variable									
Broiler Price	Constant	DCFBFRC	DCNFBFRC	DCPKRC	DCBRC	Q^*T	Q^*T^2	Q^*T^3	$Q(T-\bar{T}_1)D_1$	$Q(T-\bar{T}_1)^3D_1$	DICR	$\hat{\sigma}/M$	$\bar{R}^2$	D.W.
					(Linear Functional Form)									
Cubic Spline	63.710 (2.94)	-.292 (1.94)	-.346 (3.21)	-.167 (1.71)	110.141 (1.88)	-5.116 (1.90)	.078 (1.87)	-.0004 (1.84)		.0004 (1.56)	.024 (3.37)	.039	.99	2.47
					(Double Log-Linear Functional Form)									
Linear Spline	-6.676 (2.70)	-.375 (2.41)	-.136 (1.92)	-.316 (2.14)	.290 (.96)	- .013 (3.43)			.005 (1.51)		1.961 (5.68)	.012	.98	1.87
Cubic Spline	-2.022 (.58)	-.375 (2.41)	-.249 (2.86)	-.352 (2.55)	-17.440 (2.11)	.815 (2.18)	-.013 (2.27)	.00007 (2.34)		-.0001 (2.77)	1.55 (3.57)	.011	.98	2.04

Contribution of Time-Varying Parameter Specification to Broiler Price Equation: Coefficients of Partial Determination, Partial R^2 and F-Values

Type of Spline	Partial R^2	F-Value	Critical F-Value (.01% level)
Cubic Spline (Linear)	.58	7.78	4.26
Linear Spline (logs)	.56	15.65	5.57
Cubic Spline (logs)	.65	10.63	4.26
Test of Equality Between Linear and Cubic Splines (in logs)		3.05[a]	5.66

a. Not significant at .05% level.

prices and quantities of each meat, used in section 4.5.2 in estimating slope and intercept changes in demand.[58] These individual splines, for each line segment, provide constant slope within line segments and continuity across periods or points of structural shift. That is, within periods it is assumed that prices and quantities adjust along a given demand curve.

The models presented in Tables 4.16-4.19 were estimated by OLS with usual regression techniques. Within this framework of least squares a number of hypotheses may be tested. First, the overall test of the contribution of the particular spline in explaining variation in retail prices, relative to the base model may be conducted in the way outlined in Table 4.15. This F-test is a test of the hypothesis that $\gamma_2 = \gamma_3 = 0$ in the linear spline and that $\gamma_2 = \gamma_3 = \gamma_4 = \gamma_5 = 0$ in the cubic spline. Acceptance of the null hypothesis is acceptance of no variation in the regression coefficients of the own-meat quantity over time. That is, the classical model of constant coefficients is appropriate.

This null hypothesis was accepted in the linear spline table beef model and in both the linear and cubic spline pork models. Everywhere else the hypothesis of constancy in regression coefficients was rejected at the one percent level. Notably consistent with earlier models of structural change, the relationship between pork prices and quantities, i.e., slope of the pork demand curve, has not changed significantly over time. This is not to say that increases and decreases in demand have

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[58] There were 4,5,5 and 2 periods identified in table beef, hamburger beef, pork and broilers, respectively. This implies 3, 4, 4, and 1 join points in each case.

not occurred, but that the demand for pork has responded almost entirely to the relative prices of substitutes.

Second, using the test of equality between sets of coefficients in two linear regressions,[59] an F-test of the statistical significance between the linear and cubic spline models may be made. Results of these tests are presented in Tables 4.16-4.19 and indicate the superiority of the cubic spline in terms of fit of the actual data in each model of retail meat demand, of course, with the exception of the pork model.

Third, as is most usual in regression estimation, the significance of an individual coefficient can be determined by use of the standard t-statistic. This test may be meaningful in the linear spline model. However, in a cubic spline model the spline is a composite variable, coefficients of components of which are not readily interpreted. In this case the previous F-tests provide the relevant information on the nature of parameter variation. Therefore, the procedure of Suits, Mason and Chan (1978), that of providing regression statistics on $\bar{R}^2$ for the whole regression, D.W. statistics, and on the significance of the partial $\bar{R}^2$, has been adopted here.[60]

Examination of the linear spline equations, however, do provide some insight into the nature of changes in demand for beef and broilers. For example, the log-linear spline model of broiler price indicates that the direct flexibility is not constant, that it has been increasing

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[59]For details see Pindyck and Rubinfeld (1979, p. 205) and Chow (1960).

[60]See Huang and Raunikar (1981) where both individual t-statistics and partial R^2 values are used in hypothesis testing.

linearly over time (significant coefficient on Q*T), but that the rate of increase has slowed since the mid-1960s. This result is consistent with the observations that the consumption of chicken in becoming saturated and that the impact of gains from technology in the broiler industry, which have kept real prices down, may be slowing. This may mean that the competitive advantage in prices enjoyed by chicken over beef will steadily be diluted.

Direct flexibilities estimated from price equations in Tables 4.16–4.19 are shown in Table 4.20 for table beef and hamburger beef and in Table 4.21 for pork and broilers. The linear splines, using a linear functional form, in the beef price equations give larger (and probably overestimated) estimates of direct flexibilities than the cubic spline, which may have under-estimated flexibilities during the 1970s. Also, the range on the linear spline for table beef is unexpectedly large. Consistent with other estimates, nevertheless, is the tendency for table beef flexibilities to rise, especially over the late 1970s and early 1980s. This indicates that the table beef market is subject to larger price variations as supply fluctuates. The tendency is for hamburger beef price flexibilities to fall in the latter half of the period. Notably, the relatively low flexibility during the early 1970s when hamburger beef was more price competitive with table beef agrees with results of Table 4.11 in section 4.5.1.

Very little difference exists between splines in the pork equation largely because they do not make a significant contribution to the explanation of demand for pork. Therefore, the results in Table 4.21 are very similar to the model results shown earlier in Table 4.11. In

Table 4.20

Direct Flexibilities of Table and Hamburger Beef
Estimated From Linear and Cubic Splines

Year	Type of Spline:			
	Linear	Cubic	Linear	Cubic
	Table Beef		Hamburger Beef	
1950	- .376	- .383	- .699	- .459
1951	- .358	- .369	- .504	- .347
1952	- .398	- .410	- .624	- .444
1953	- .559	- .571	-1.229	- .889
1954	- .498	- .502	-1.574	-1.142
1955	- .525	- .517	-1.632	-1.177
1956	- .557	- .534	-1.785	-1.268
1957	- .520	- .484	-1.702	-1.184
1958	- .477	- .430	-1.252	- .849
1959	- .667	- .485	-1.065	- .700
1960	- .830	- .497	-1.168	- .764
1961	-1.036	- .521	-1.168	- .758
1962	-1.144	- .488	-1.139	- .730
1963	-1.471	- .536	-1.158	- .730
1964	-1.791	- .559	-1.251	- .771
1965	-1.878	- .502	-1.227	- .735
1966	-2.225	- .506	-1.149	- .664
1967	-2.596	- .507	-1.094	- .604
1968	-2.907	- .481	-1.037	- .552
1969	-3.040	- .420	- .889	- .451
1970	-3.509	- .394	- .823	- .395
1971	-3.635	- .327	- .792	- .355
1972	-3.849	- .274	- .674	- .280
1973	-3.396	- .189	- .502	- .192
1974	-3.551	- .154	- .803	- .262
1975	-3.171	- .109	-1.359	- .394
1976	-4.419	- .125	-1.395	- .393
1977	-4.968	- .126	-1.442	- .447
1978	-4.853	- .122	-1.068	- .365
1979	-4.229	- .118	- .774	- .303
1980	-4.455	- .148	-1.029	- .450
1981	-5.024	- .209	-1.330	- .629
1982	-5.665	- .298	-1.474	- .717

Note: Flexibilities were derived from linear (arithmetic) equations in Tables 4.16 and 4.17.

Table 4.21

Direct Flexibilities of Pork and Broilers Estimated From Linear and Cubic Splines

	Type of Spline:				
	Linear	Cubic	Cubic	Linear (in logs)	Cubic (in logs)
	Pork		Broilers		
1950	- .927	- .984	- .022	-.360	-.834
1951	- .981	-1.018	- .064	-.373	-.810
1952	-1.056	-1.082	- .109	-.386	-.790
1953	- .885	- .903	- .153	-.399	-.774
1954	- .808	- .826	- .227	-.412	-.762
1955	-1.072	-1.105	- .250	-.425	-.754
1956	-1.158	-1.207	- .401	-.438	-.748
1957	- .956	-1.008	- .505	-.451	-.745
1958	- .916	- .976	- .642	-.464	-.744
1959	-1.188	-1.273	- .764	-.477	-.745
1960	-1.185	-1.269	- .808	-.490	-.747
1961	- .988	-1.059	-1.026	-.503	-.750
1962	-1.136	-1.212	- .989	-.516	-.754
1963	-1.253	-1.321	-1.079	-.529	-.757
1964	-1.284	-1.332	-1.143	-.542	-.760
1965	- .999	-1.016	-1.203	-.555	-.762
1966	- .911	- .908	-1.264	-.563	-.763
1967	-1.138	-1.111	-1.421	-.571	-.763
1968	-1.216	-1.166	-1.430	-.579	-.761
1969	-1.152	-1.087	-1.505	-.587	-.759
1970	-1.194	-1.112	-1.739	-.595	-.757
1971	-1.517	-1.404	-1.773	-.603	-.754
1972	-1.219	-1.130	-1.884	-.611	-.751
1973	- .896	- .839	-1.344	-.619	-.747
1974	-1.087	-1.037	-1.577	-.627	-.744
1975	- .780	- .768	-1.495	-.635	-.741
1976	- .882	- .906	-1.773	-.643	-.739
1977	-1.044	-1.131	-1.947	-.652	-.737
1978	- .986	-1.137	-2.001	-.660	-.736
1979	-1.250	-1.551	-2.360	-.668	-.736
1980	-1.573	-2.118	-2.467	-.676	-.737
1981	-1.577	-2.218	-2.718	-.684	-.739
1982	-1.361	-1.985	-3.010	-.692	-.743

Note: Flexibilities were derived from linear (arithmetic) equations of pork in Table 4.17 and from linear and logarithmic equations of broilers in Table 4.18.

the case of the broiler price equation, the cubic spline gave very similar results to those in Table 4.11 because of the strong linear effect in both cases. Direct broiler flexibilities have risen strongly over time.

The spline function has some important limitations as pointed out by Suits, Mason and Chan (1978). It is most useful when data are uniformly distributed throughout the observed range and when the scatter of observations is uniformly dense. The broiler data most characterize these aspects. By contrast the table beef data, particularly since the 1970s, does not lend itself as much to the spline function. This absence of uniformity over this period, i.e., 'the thin patches, sizeable gaps or isolated points, reduces the discipline (of the function) and the function is free to twist and squirm through the sparse path of the data to yield spurious curvature' (Suits, et al.,p. 139). The other major limitation of the spline function arises during attempts to extrapolate beyond the observed range of data. The spline function is not defined outside the range to which it has been fitted, and therefore, as with regression equations in general, some caution is necessary. Notwithstanding these limitations, the spline function provides a simple means of approximating complicated functions.

4.7 Continuous Time-Varying Parameter Model

It should now be clear how potentially misleading it may be to compute a single coefficient that purports to portray the response of retail meat prices to consumption and income changes through time or across sections of time. To varying degrees, the underlying structure of economic relationships in each of the major meat markets appears to have undergone considerable change over the past several decades. Such change has been induced by shifts in consumer tastes and preferences and by cycles and adjustments in production. In previous sections demand coefficients were estimated using statistical models which allowed regression coefficients to change a small number of times, and therefore, allowed for a similar number of changes in structure over that period. In this section an estimation model is presented which permits the structural coefficients to vary more continuously over time.

4.7.1 Legendre Polynomials

The model employed in the following analysis is based on a particular time-varying parameter model discussed in Chapter 3. The approach involved the integration of the COMPLEX optimization algorithm and Legendre polynomials to find optimal coefficients as continuous functions of time, using the weighted least squares criterion. Legendre polynomials, specified into the economic model, provide the means of introducing various degrees of polynomial, with a time dimension, into each coefficient.

As noted earlier, the particular advantage of these polynomials over, say, specifying a polynomial into the demand equation, by direct substitution, is the property of finality of coefficients. The addition of a higher degree term in time, does not change the coefficients previously estimated using the lower degree polynomial. Moreover, the same degree polynomial does not need to be set for each explanatory variable. Optimality over time may be attained for some of the β coefficients by specifying a linear, quadratic, cubic or higher degree of polynomial while for others the assumption of a constant coefficient value may be justified. Therefore, the β coefficients in each demand model are in essence polynomial functions of time. The role of COMPLEX is to find the coefficient values of the β functions which will optimize the objective function, i.e., to minimize the weighted regression sum of squares over the time path $0 \leq t \leq T$.

The central strength of the COMPLEX-Legendre polynomial method is in estimation of β coefficients which are inherently non-linear in parameters. The present model of retail demand is linear in parameters. This substantially simplifies the estimation procedure adopted in the following analysis and yet does not compromise the property of finality of coefficients which is preserved throughout the transformation. The use of the COMPLEX optimization algorithm is not necessary when inherently linear parameters are being estimated. The time-varying coefficients may therefore be estimated using least squares techniques, applying the standard tests of significance.

From equation (3.66) in the previous chapter, a simplified version of the time series regression model of retail demand for the ith meat may be reconstructed as

$$p_{it} = \gamma_{0i} + \gamma_{1it}q_{it} + \delta_j \sum_{j=1}^{3} + \lambda_i y_t + e_t \qquad (4.11)$$

Initially, let the parameter variation occur only in q_{it}, the own-quantity of meat consumption per person. Following the general form of equation (3.67), this parameter variation for the ith meat in time, t may be expressed through its coefficient, γ_{1i} as

$$\gamma_{1it} = a_{0i} + a_{1i}P_0(t) + a_{2i}P_1(t) + \ldots + a_{ni}P_{n-1}(t)$$

$$= a_{0i} + \sum_{k-1}^{n} a_{ki}P_{n-1}(t) \tag{4.12}$$

where $P_{n-1}(t)$ are the n-1 Legendre polynomials defined in (3.62). Substitution of (4.12) into (4.11) gives

$$P_{it} = \gamma_{0i} + a_{0i} + \sum_{k=1}^{n} a_{ki}P_{n-1}(t)q_{it} + \delta_{ji} \sum_{j=1}^{3} q_{jt}$$
$$+ \lambda_i\, y_t + e_t \tag{4.13}$$

where $\sum_{k=1}^{n} a_{ki}P_{n-1}(t)q_{it}$ is an interaction variable in q_{it}, and q_{jt} and y_t are the previously defined cross-product and income variables, respectively. Each estimated coefficient, a_{ki} becomes a time-varying coefficient, $a_{ki}P_{n-1}(t)$ and along with the constant coefficients, δ_{ji} and λ_i, they may be estimated and tested using standard regression techniques. The intercept term is γ and the error term is e_t.

To illustrate the structural form of this demand model, a cubic polynomial in one explanatory variable may be written as

$$p_{it} = \phi_0 + \phi_1P_0(t)q_{it} + \phi_2P_1(t)q_{it} + \phi_3P_2(t)q_{it}$$
$$+ \phi_4P_3(t)q_{it} + \delta_{ji} \sum_{j=1}^{3} q_{jt} + \lambda_iy_t\ , \tag{4.14}$$

although the estimating equation is written more simply,

$$p_{it} = \phi_0 + \phi_1Z_1 + \phi_2Z_2 + \phi_3Z_3 + \phi_4Z_4 + \delta_{ji} \sum_{j=1}^{3} q_{jt}$$
$$+ \lambda_iy_t + e_t \tag{4.15}$$

The regression coefficients presented below are the ϕ, δ and λ values.

Theoretically, Legendre polynomials may be specified in any or all of the explanatory variables, giving the time-varying character to each coefficient. Calculation of direct-quantity flexibilities, for example, from the cubic model in equation (4.14), when estimated in linear arithmetic form, is

$$f_{it} = [\phi_1 P_0(t) + \phi_2 P_1(t) + \phi_3 P_2(t) + \phi_4 P_3(t)] \frac{q_{it}}{P_{it}} \qquad (4.16)$$

This provides an estimated direct flexibility for the ith meat for each year, t, of the estimation period.

Recall that each polynomial is mapped over $0 \leq t \leq T$, so that they are orthogonal with respect to time. The orthogonality is a necessary and sufficient condition for the property of finality of coefficients. Each polynomial in the following estimations, therefore, takes the form

$$P_0(t) = 1$$

$$P_1(t) = \frac{2t}{32} - 1$$

$$P_2(t) = \frac{3}{2}\left(\frac{2t}{32} - 1\right)^2 - \frac{1}{2}$$

$$P_3(t) = \frac{15}{6}\left(\frac{2t}{32} - 1\right)^3 - \frac{9}{6}\left(\frac{2t}{32} - 1\right)$$

$$P_4(t) = \frac{105}{28}\left(\frac{2t}{32} - 1\right)^4 - \frac{189}{28}\left(\frac{2t}{32} - 1\right)^2 + \frac{3}{2}$$

$$P_5(t) = \frac{945}{140}\left(\frac{2t}{32} - 1\right)^5 - \frac{1981}{140}\left(\frac{2t}{32} - 1\right)^3 + \frac{39}{10}\left(\frac{2t}{32} - 1\right)$$

for $t = 0, 1, \ldots, 32$.

Calculated values for each Legendre polynomial up to the 5th degree over the 33 year period, 1950–82, are shown in Table 4.22.

All equations were estimated in linear arithmetic form using OLS. The initial objective was to permit, with varying degree polynomials, the coefficients of each explanatory variable to vary through time and hence obtain direct and cross-quantity flexibilities for all structural

Table 4.22

Calculated Values of Legendre Polynomials Up to the 5th Degree

Year		Degree of Polynomial				
		PT1	PT2	PT3	PT4	PT5
1950	.	-1.00000	.500000	-1.00000	-1.50000	3.50000
1951	.	-.937500	.378906	-.653687	-1.53583	3.11466
1952	.	-.875000	.265625	-.362305	-1.46979	2.60476
1953	.	-.812500	.160156	-.122192	-1.32178	2.03086
1954	.	-.750000	.625000E-01	.703125E-01	-1.11035	1.44272
1955	.	-.687500	-.273438E-01	.218872	-.852665	.880075
1956	.	-.625000	-.109375	.327148	-.564514	.373360
1957	.	-.562500	-.183594	.398804	-.260319	-.554702E-01
1958	.	-.500000	-.250000	.437500	.468750E-01	-.392188
1959	.	-.437500	-.308594	.446899	.345394	-.629517
1960	.	-.375000	-.359375	.430664	.624939	-.766365
1961	.	-.312500	-.402344	.392456	.876583	-.807043
1962	.	-.250000	-.437500	.335938	1.09277	-.760498
1963	.	-.187500	-.464844	.264771	1.26733	-.639540
1964	.	-.125000	-.484375	.182617	1.39545	-.460069
1965	.	-.625000E-01	-.496094	.931396E-01	1.47369	-.240302
1966	.	0.	-.500000	0.	1.50000	0.
1967	.	.625000E-01	-.496094	-.931396E-01	1.47369	.240302
1968	.	.125000	-.484375	-.182617	1.39545	.460069
1969	.	.187500	-.464844	-.264771	1.26733	.639540
1970	.	.250000	-.437500	-.335938	1.09277	.760498
1971	.	.312500	-.402344	-.392456	.876583	.807043
1972	.	.375000	-.359375	-.430664	.624939	.766365
1973	.	.437500	-.308594	-.446899	.345394	.629517
1974	.	.500000	-.250000	-.437500	.468750E-01	.392188
1975	.	.562500	-.183594	-.398804	-.260319	.554702E-01
1976	.	.625000	-.109375	-.327148	-.564514	-.373360
1977	.	.687500	-.273438E-01	-.218872	-.852665	-.880075
1978	.	.750000	.625000E-01	-.703125E-01	-1.11035	-1.44272
1979	.	.812500	.160156	.122192	-1.32178	-2.03086
1980	.	.875000	.265625	.362305	-1.46979	-2.60476
1981	.	.937500	.378906	.653687	-1.53583	-3.11466
1982	.	1.00000	.500000	1.00000	-1.50000	-3.50000
		1	2	3	4	5

variables. This, however, was not possible. Generally speaking, equations were rejected on any of the following somewhat arbitrary grounds. First, the time-varying specification did not make a significant contribution to the explanation of the dependent variable, i.e., retail price. Second, the sign of the coefficients do not reconcile with a priori expectations and economic theory. Some exceptions to these grounds of acceptance are made for the purpose of providing comparisons among individual demand equations or to present results when the null hypothesis of no significant parameter change is accepted.

Results of selected equations for five product categories, all beef, table beef, hamburger beef, pork and broilers are shown in Tables 4.23 - 4.27. Linear, quadratic, cubic and in some cases fourth-degree polynomials were tested. Direct, cross and income effects were examined for each product. However, because of problems in estimation in all but the broiler equations, polynomial specification was limited to own-quantity and income as these were considered to be of primary interest.[61]

The continuous time-varying parameter specification was found to make a significant contribution, beyond the classical model of fixed coefficients, in each product model with the notable exception of pork. The assumption of the constant coefficient model has been accepted consistently in each model of structural change tested for pork. A related conclusion was made in a study using a random coefficient model of pork production (Dixon and Martin, 1982). They explained that the move

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[61] A model with all coefficients systematically varying seems unreasonable in economic applications.

Table 4.23

Time-Varying Parameter Model of Retail Demand for All Beef

Dependent Variable: RPBFR	Explanatory Variables[a]													
		Domestic Consumption Per Person:												
Degree of Polynomial of Time-Varying Parameters	Constant	DCBFRC	PT1BF	PT2BF	PT3BF	PT4BF	DCORMRC	DCPMC	DICR	PT1DI	F test[b]: acceptance level	$\hat{\sigma}/m$	$\bar{R}^2$	D.W.
Quadratic: DCBFRC	179.314 (6.37)	-1.870 (9.36)	.398 (2.67)	- .197 (3.42)			- .006 (.03)	-1.987 (5.96)	.048 (4.90)		.01	.043	.78	1.74
Cubic: DCBFRC	190.858 (8.63)	-1.689 (10.46)	.299 (2.52)	- .153 (3.31)	- .140 (4.22)		- .170 (1.10)	- .751 (1.92)	.024 (2.49)		.01	.034	.86	1.33
4th Degree: DCBFRC	191.742 (12.34)	-1.909 (15.74)	.227 (2.68)	- .576 (6.53)	- .171 (7.08)	-.113 (5.16)	- .187 (1.72)	.017 (.06)	.017 (2.42)		.01	.024	.93	2.24
Linear: DCBFRC Linear: DICR	112.630 (4.89)	-1.605 (9.15)	.672 (3.09)				- .116 (.61)	- .962 (2.71)	.055 (5.75)	-.019 (3.32)	.01	.044	.77	1.27

[a] PTi refers to the Legendre polynomial comprising the multiplicative (interaction) variable with the respective explanatory variable, where i refers to the degree of the polynomial.

[b] Figures in column refer to probability of making a Type I error. F-test is test of significance of contribution of time-varying formulation to base model/classical linear model, or to the previous degree polynomial, if one is presented in the table.

Table 4.24

Time-Varying Parameter Model of Retail Demand for Table Beef

Dependent Variable: RPBFR	Explanatory Variables[a]														
		Domestic Consumption Per Person:													
Degree of Polynomial of Time-Varying Parameters	Constant	DCFBFRC	PT1FB	PT2FB	PT3FB	PT4FB	DCNFBFRC	DCORMRC	DCPMC	DICR	PT1DI	F-test[b] acceptance level	$\hat{\sigma}/m$	$\bar{R}^2$	D.W.
Quadratic: DCFBFRC	248.211 (5.07)	-2.245 (5.68)	1.280 (2.78)	- .751 (3.06)			-1.990 (9.74)	- .196 (.96)	-2.097 (5.54)	.033 (2.32)		.05	.043	.78	1.61
Cubic: DCFBFRC	232.225 (6.72)	-2.315 (8.32)	.939 (2.84)	- .611 (3.50)	- .317 (5.16)		-1.720 (11.24)	- .249 (1.73)	- .359 (.83)	.012 (1.08)		.01	.030	.89	1.79
4th Degree: DCFBFRC	216.611 (6.84)	-2.193 (8.60)	.660 (2.08)	- .927 (4.65)	- .288 (5.10)	- .127 (2.57)	-1.80 (12.75)	- .283 (2.17)	- .070 (.17)	.013 (1.31)		.05	.027	.91	2.00
Quadratic: DCFBFRC Linear: DICR	250.922 (4.67)	-2.224 (5.16)	1.225 (1.98)	- .747 (2.96)			-2.00 (9.37)	- .193 (.92)	-2.152 (3.86)	.032 (2.18)	.001 (.14)	.05	.044	.77	1.63

[a] See Table 4.23.

[b] See Table 4.23.

Table 4.25

Time-Varying Parameter Model of Retail Demand for Hamburger Beef

Dependent Variable: RPBFR

Degree of Polynomial of Time-Varying Parameters	Explanatory Variables[a]													
		Domestic Consumption Per Person												
	Constant	DCFBFRC	DCNFBFRC	PT1NF	PT2NF	PT3NF	DCORMRC	DCBRC	DICR	PT1DI	F-test[b]: acceptance level	$\hat{\sigma}/m$	$\bar{R}^2$	D.W.
Linear: DCNFBFRC	132.525 (5.88)	- .870 (4.81)	- 1.725 (10.27)	.489 (2.75)			- .181 (.90)	-1.480 (5.93)	.027 (3.42)		.05	.067	.82	1.51
Quadratic: DCNFBFRC	117.800 (5.12)	-1.259 (4.60)	- 1.904 (10.13)	.495 (2.90)	-.232 (1.84)		- .662 (.33)	-1.588 (6.46)	.039 (3.92)		n.s.	.064	.83	1.90
Cubic: DCNFBFRC	109.515 (6.05)	-1.650 (7.05)	- 1.746 (11.51)	.055 (.32)	-.316 (3.14)	-.436 (4.11)	- .163 (.10)	.073 (.16)	.026 (3.15)		.01	.050	.90	1.72
Linear: DCNFBFRC Linear: DCNFBFRC	84.802 (2.59)	-1.326 (4.54)	- 1.812 (10.92)	.618 (3.40)			- .059 (.29)	-1.017 (3.01)	.046 (3.74)	- .007 (1.94)	.05	.064	.84	1.79

[a] See Table 4.23.

[b] See Table 4.23.

Table 4.26

Time-Varying Parameter Model of Retail Demand for Pork

Dependent Variable: RPPKR	Explanatory Variables[a]													
Degreee of Polynomial of Time-Varying Parameters	Constant	Domestic Consumption Per Person: DCFBFRC	DCNFBFRC	DCPKRC	PT1PK	PT2PK	PT3PK	DCBRC	DICR	PT1DI	F-test[b]: acceptance level	$\hat{\alpha}/m$	$\bar{R}^2$	D.W.
Cubic: DCPKRC	116.765 (3.53)	- .591 (2.29)	- .439 (2.29)	-1.153 (6.91)	-.019 (.09)	-.006 (.11)	-.087 (1.89)	-.934 (1.63)	.0326 (3.38)		n.s.	.044	.82	1.94
Linear: DCPKRC Linear: DICR	98.848 (2.91)	- .469 (1.91)	- .506 (2.77)	-1.149 (6.60)	-.113 (.51)			-1.339 (2.46)	.043 (.24)	.0008 (4.14)	n.s.	.046	.80	1.95
Cubic: DCPKRC Linear: DICR	114.877 (2.95)	- .593 (2.24)	- .436 (2.19)	-1.155 (6.74)	-.006 (.03)	.002 (.02)	-.087 (1.85)	-.914 (1.47	.033 (2.83)	-.0006 (.10)	n.s.	.045	.81	1.94

[a] See Table 4.23.

[b] See Table 4.23.

Table 4.27

Time-Varying Parameter Model of Retail Demand for Broilers

Dependent Variable: RPBRR	Explanatory Variables[a]													
		Domestic Consumption Per Person:												
Degree of Polynomial of Time-Varying Parameters	Constant	DCFBFRC	PT1FB	DCNFBFRC	PT1NF	DCPKRC	PT2PK	DCBRC	PT1BR	DICR	PT1DI	F-test[b] acceptance Level	$\hat{\sigma}/m$	$\bar{R}^2$	D.W.
Linear: DCBRC	92.313 (8.32)	- .322 (2.31)		- .455 (4.84)		- .173 (1.74)		-2.430 (20.55)	.376 (4.90)	.023 (4.62)		.01	.041	.985	2.15
Linear: DCBRC Linear: DICR	65.232 (3.74)	- .382 (2.80)		- .401 (4.29)		- .202 (2.11)		-2.085 (9.94)	.693 (3.88)	.030 (5.01)	-.008 (1.95)	.01	.038	.986	2.24
Linear: All Variables	58.006 (2.61)	- .322 (1.97)	-.183 (.57)	- .370 (3.28)	-.122 (.81)	- .168 (1.52)	-.138 (.75)	-1.981 (5.89)	.587 (2.43)	.030 (4.62)	-.0005 (.05)	.01	.040	.985	2.26

[a] See Table 4.23.

[b] See Table 4.23.

toward capital intensive, confined production operations gives a production cycle with a smaller amplitude, and therefore, the hog prices response has declined systematically over time. This may explain at least the absence of production induced shifts in retail demand.

Typically, as a higher degree polynomial was specified the $\bar{R}^2$ increased significantly and autocorellation was usually reduced. The standard F-test was used to test the contribution of each polynomial specified. In some equations it appeared that terms in higher degree polynomials were becoming colinear with other explanatory variables causing sign change or a reduction in previously significant coefficients. Illustrative of this behavior is the transition from the cubic to the fourth degree polynomial in the all beef equation. This suggests that caution is required in the use of this approach in model specification. The linear polynomial is preferred in the broiler specifications, however the preferred polynomial varied in the beef equations.

The property of finality of coefficients, while being imposed upon the Legendre polynomials specified in each equation, does not reveal as strong a degree of constancy in the progressive coefficient values of those polynomials as would be expected in some engineering studies wherein errors in estimation may be considerably less or may be controlled. Nevertheless, the table beef equations, for example, illustrate the similarity in the coefficient of earlier polynomials after a higher degree has been added to the model specification.

Calculation of direct, cross and income flexibilities for each of these sets of product equations followed the formula illustrated for a cubic polynomial in equation (4.16). Derived flexibilities are contained in Tables 4.28 - 4.33.

Flexibilities estimated from the all-beef equations (Table 4.28) indicate that regardless of the Legendre polynomial specified, direct and income flexibilities are greater than unity in nearly every year. This suggests first that the beef market has been subject to larger price variations as supply fluctuates and second, that increases in real disposable income per person, although increasing demand for beef, have had a more than proportional impact on market prices.

Considerable change has occurred between years although it is recognized that all changes may not be significantly different from each other. Nevertheless, the pattern of change is the same among each of the sets of all-beef flexibilities. This similarity of pattern of change in flexibilities among the various degree polynomials was evident also in the other tables of product flexibilities. This reflects the consistency in the coefficient estimation procedures, since the data series of the quantity-price ratios used in determining the flexibilities are not obtained from the estimated equations. Also, consistent with previous analyses of the impact of cycle-induced structural changes on retail demand, the pattern of flexibilities of all beef characterizes production cycles over the period. For example, since the late 1960s, direct flexibilities for all beef (Table 4.28) tended to decline until 1973. Since quantities supplied per person increased only slightly (demand shifted out only slowly in response to increasing prices), the fall in flexibilities was due largely to upward price movements along the demand curve. The record retail prices in 1973 were associated with

Table 4.28

Direct and Income Flexibilities for All Beef
Estimated From Legendre Polynomial Model[a]

Year		Direct Flexibility	Direct Flexibility	Direct Flexibility	Flexibility: Direct	Flexibility: Income
	Degree of Polynomial:	quadratic	cubic	4th degree	linear	linear
1950		-1.118	- .909	-1.004	-1.076	1.321
1951		.893	- .746	- .806	- .861	1.209
1952		-1.009	- .862	- .919	- .974	1.255
1953		-1.560	-1.360	-1.436	-1.508	1.614
1954		-1.531	-1.410	-1.482	-1.538	1.600
1955		-1.604	-1.441	-1.514	-1.551	1.672
1956		-1.686	-1.532	-1.612	-1.628	1.754
1957		-1.577	-1.444	-1.526	-1.519	1.668
1958		-1.312	-1.209	-1.285	-1.261	1.450
1959		-1.275	-1.180	-1.263	-1.221	1.450
1960		-1.353	-1.254	-1.352	-1.290	1.491
1961		-1.406	-1.303	-1.414	-1.332	1.528
1962		-1.349	-1.249	-1.364	-1.270	1.499
1963		-1.477	-1.364	-1.498	-1.380	1.581
1964		-1.497	-1.469	-1.622	-1.479	1.701
1965		-1.524	-1.395	-1.545	-1.396	1.698
1966		-1.572	-1.431	-1.589	-1.425	1.727
1967		-1.627	-1.472	-1.636	-1.455	1.781
1968		-1.645	-1.480	-1.643	-1.450	1.783
1969		-1.555	-1.392	-1.542	-1.350	1.672
1970		-1.618	-1.441	-1.591	-1.380	1.699
1971		-1.559	-1.383	-1.521	-1.305	1.663
1972		-1.488	-1.318	-1.442	-1.220	1.574
1973		-1.233	-1.092	-1.189	- .989	1.433
1974		-1.401	-1.244	-1.349	-1.096	1.467
1975		-1.473	-1.315	-1.423	-1.123	1.467
1976		-1.736	-1.562	-1.692	-1.286	1.610
1977		-1.785	-1.625	-1.768	-1.282	1.700
1978		-1.484	-1.372	-1.506	-1.031	1.488
1979		-1.183	-1.115	-1.241	- .794	1.289
1980		-1.250	-1.206	-1.370	- .808	1.316
1981		-1.384	-1.372	-1.599	- .858	1.391
1982		-1.446	-1.480	-1.779	- .859	1.417

[a] Flexibilities were derived from Table 4.23.

Table 4.29

Direct and Income Flexibilities for Table Beef
Estimated From Legendre Polynomial Model[a]

Year		Direct Flexibility	Direct Flexibility	Direct Flexibility	Flexibility: Direct	Flexibility: Income
	Degree of Polynomial:	quadratic	cubic	4th degree	linear	linear
1950		- .769	- .639	- .560	- .754	.555
1951		- .709	- .612	- .528	- .695	.518
1952		- .763	- .681	- .583	- .748	.547
1953		-1.035	- .953	- .813	-1.015	.718
1954		- .892	- .845	- .720	- .875	.726
1955		- .908	- .882	- .754	- .891	.773
1956		- .932	- .924	- .794	- .914	.827
1957		- .841	- .850	- .736	- .826	.803
1958		- .747	- .767	- .671	- .734	.713
1959		- .841	- .875	- .774	- .826	.727
1960		- .863	- .909	- .813	- .849	.764
1961		- .907	- .963	- .871	- .893	.800
1962		- .855	- .913	- .836	- .842	.802
1963		- .949	-1.018	- .943	- .936	.865
1964		-1.007	-1.083	-1.015	- .995	.952
1965		- .929	- .999	- .946	- .918	.972
1966		- .975	-1.048	-1.001	- .965	1.013
1967		-1.033	-1.108	-1.067	-1.024	1.070
1968		-1.054	-1.129	-1.094	-1.047	1.098
1969		-1.009	-1.080	-1.050	-1.004	1.055
1970		-1.055	-1.128	-1.100	-1.052	1.100
1971		- .996	-1.066	-1.041	- .995	1.105
1972		- .967	-1.039	-1.014	- .968	1.074
1973		- .787	- .853	- .830	- .789	1.004
1974		- .763	- .837	- .814	- .767	1.057
1975		- .636	- .710	- .690	- .641	1.088
1976		- .832	- .951	- .924	- .841	1.229
1977		- .884	-1.041	-1.014	- .895	1.338
1978		- .821	-1.002	- .983	- .833	1.207
1979		- .684	- .871	- .863	- .695	1.079
1980		- .693	- .926	- .931	- .706	1.130
1981		- .756	-1.065	-1.091	- .772	1.244
1982		- .829	-1.236	-1.295	- .849	1.302

[a] Flexibilities were derived from Table 4.24.

Table 4.30

Direct and Income Flexibilities for Hamburger Beef
Estimated from Legendre Polynomial Model[a]

Year		Direct Flexibility	Direct Flexibility	Direct Flexibility	Flexibility: Direct	Flexibility: Income
	Degree of Polynomial:	linear	quadratic	cubic	linear	linear
1950		- .823	- .934	- .566	- .903	1.294
1951		- .574	- .645	- .429	- .628	1.190
1952		- .688	- .766	- .549	- .752	1.282
1953		-1.311	-1.448	-1.105	-1.430	1.864
1954		-1.627	-1.780	-1.429	-1.770	2.047
1955		-1.633	-1.772	-1.482	-1.772	2.185
1956		-1.730	-1.863	-1.609	-1.873	2.322
1957		-1.598	-1.709	-1.512	-1.725	2.183
1958		-1.139	-1.210	-1.090	-1.226	1.743
1959		- .938	- .991	- .903	-1.008	1.734
1960		-1.024	-1.076	- .988	-1.097	1.843
1961		-1.021	-1.068	- .983	-1.090	1.909
1962		- .991	-1.033	- .949	-1.055	1.937
1963		-1.004	-1.043	- .953	-1.066	2.014
1964		-1.080	-1.120	-1.015	-1.142	2.213
1965		-1.054	-1.092	- .981	-1.111	2.275
1966		- .983	-1.018	- .905	-1.032	2.259
1967		- .932	- .966	- .850	- .975	2.345
1968		- .897	- .932	- .812	- .935	2.424
1969		- .782	- .815	- .705	- .812	2.299
1970		- .737	- .771	- .665	- .762	2.302
1971		- .722	- .760	- .657	- .744	2.359
1972		- .626	- .664	- .578	- .642	2.274
1973		- .476	- .509	- .451	- .486	1.954
1974		- .724	- .781	- .709	- .735	2.058
1975		-1.166	-1.272	-1.193	-1.178	2.449
1976		-1.139	-1.258	-1.231	-1.144	2.619
1977		-1.120	-1.256	-1.294	-1.119	2.888
1978		- .713	- .812	- .890	- .708	2.424
1979		- .452	- .524	- .615	- .446	1.904
1980		- .529	- .624	- .791	- .518	2.026
1981		- .609	- .734	-1.009	- .592	2.252
1982		- .605	- .746	-1.118	- .584	2.441

[a] Flexibilities were derived from Table 4.25

Table 4.31

Direct and Income Flexibilities for Pork Estimated From Legendre Polynomial Model[a]

Year	Degree of Polynomial:	Direct Flexibility	Flexibility: Direct	Flexibility: Income	Flexibility: Direct	Flexibility: Income
		cubic	linear	linear	cubic	linear
1950		- .907	- .895	1.063	- .916	.862
1951		- .973	- .939	1.078	- .982	.872
1952		-1.056	-1.003	1.150	-1.067	.928
1953		- .889	- .834	1.122	- .898	.904
1954		- .812	- .755	1.065	- .820	.856
1955		-1.075	- .994	1.322	-1.085	1.060
1956		-1.155	-1.066	1.443	-1.166	1.154
1957		- .946	- .873	1.293	- .954	1.032
1958		- .898	- .831	1.224	- .906	.974
1959		-1.150	-1.070	1.447	-1.160	1.149
1960		-1.132	-1.060	1.494	-1.141	1.184
1961		- .938	- .886	1.463	- .945	1.156
1962		-1.071	-1.022	1.517	-1.079	1.196
1963		-1.172	-1.130	1.648	-1.180	1.296
1964		-1.190	-1.160	1.783	-1.197	1.399
1965		- .917	- .905	1.616	- .922	1.265
1966		- .828	- .827	1.537	- .832	1.201
1967		-1.026	-1.038	1.792	-1.031	1.396
1968		-1.088	-1.114	1.920	-1.092	1.492
1969		-1.023	-1.059	1.859	-1.027	1.442
1970		-1.054	-1.102	1.900	-1.056	1.470
1971		-1.332	-1.406	2.247	-1.334	1.735
1972		-1.067	-1.134	2.021	-1.067	1.556
1973		- .783	- .837	1.712	- .782	1.315
1974		- .949	-1.019	1.878	- .947	1.439
1975		- .683	- .734	1.636	- .681	1.251
1976		- .776	- .833	1.775	- .772	1.354
1977		- .926	- .990	2.067	- .921	1.571
1978		- .883	- .938	1.992	- .877	1.512
1979		-1.135	-1.194	2.205	-1.126	1.670
1980		-1.454	-1.508	2.503	-1.440	1.892
1981		-1.428	-1.457	2.530	-1.413	1.907
1982		-1.214	-1.214	2.334	-1.200	1.756

[a] Flexibilities were derived from Table 4.26.

Table 4.32

Direct and Income Flexibilities for Broilers
Estimated From Legendre Polynomial Model[a]

Year	Direct Flexibility	Flexibility: Direct	Flexibility: Income
1950	- .308	- .305	.915
1951	- .377	- .370	.939
1952	- .427	- .417	.955
1953	- .461	- .446	1.009
1954	- .569	- .547	1.107
1955	- .547	- .522	1.107
1956	- .793	- .749	1.309
1957	- .924	- .866	1.374
1958	-1.106	-1.027	1.396
1959	-1.256	-1.156	1.580
1960	-1.282	-1.169	1.575
1961	-1.584	-1.431	1.768
1962	-1.497	-1.339	1.719
1963	-1.609	-1.425	1.786
1964	-1.686	-1.478	1.922
1965	-1.759	-1.526	1.954
1966	-1.834	-1.574	1.946
1967	-2.046	-1.736	2.187
1968	-2.046	-1.716	2.209
1969	-2.141	-1.774	2.189
1970	-2.462	-2.015	2.394
1971	-2.498	-2.018	2.481
1972	-2.644	-2.108	2.569
1973	-1.879	-1.478	1.957
1974	-2.198	-1.704	2.211
1975	-2.077	-1.587	2.089
1976	-2.458	-1.849	2.302
1977	-2.692	-1.994	2.478
1978	-2.761	-2.012	2.421
1979	-3.251	-2.329	2.586
1980	-3.391	-2.386	2.615
1981	-3.730	-2.577	2.756
1982	-4.121	-2.793	2.944

[a] First degree polynomial was the preferred form. Flexibilities were derived from Table 4.27.

Table 4.33

Direct, Cross and Income Flexibilities for Broilers Estimate From Legendre Polynomial Model[a]

Year	Direct Flexibility	Cross Flexibility With Respect to: Table Beef	Hamburger Beef	Pork	Income Flexibility
1950	- .282	- .036	- .091	- .024	.720
1951	- .343	- .042	- .074	- .033	.747
1952	- .386	- .050	- .088	- .042	.769
1953	- .414	- .063	- .129	- .045	.824
1954	- .508	- .067	- .167	- .055	.915
1955	- .486	- .072	- .164	- .066	.926
1956	- .699	- .092	- .203	- .087	1.110
1957	- .808	- .101	- .219	- .093	1.180
1958	- .960	- .115	- .208	- .105	1.215
1959	-1.083	- .161	- .204	- .143	1.395
1960	-1.098	- .175	- .219	- .149	1.409
1961	-1.346	- .220	- .247	- .155	1.605
1962	-1.262	- .224	- .241	- .181	1.582
1963	-1.346	- .266	- .255	- .206	1.668
1964	-1.398	- .306	- .281	- .226	1.821
1965	-1.447	- .310	- .283	- .211	1.880
1966	-1.495	- .344	- .277	- .215	1.901
1967	-1.653	- .426	- .297	- .277	2.170
1968	-1.638	- .470	- .292	- .297	2.227
1969	-1.698	- .508	- .279	- .306	2.241
1970	-1.933	- .609	- .300	- .361	2.492
1971	-1.942	- .645	- .311	- .426	2.626
1972	-2.034	- .724	- .303	- .418	2.766
1973	-1.430	- .519	- .214	- .292	2.144
1974	-1.654	- .582	- .366	- .385	2.465
1975	-1.546	- .477	- .490	- .317	2.371
1976	-1.807	- .651	- .516	- .383	2.661
1977	-1.956	- .727	- .520	- .442	2.919
1978	-1.981	- .774	- .404	- .445	2.908
1979	-2.301	- .812	- .366	- .573	3.166
1980	-2.368	- .833	- .427	- .676	3.266
1981	-2.568	- .909	- .489	- .714	3.513
1982	-2.797	-1.058	- .504	- .721	3.833

[a] First degree polynomial was the preferred form. Flexibilities were derived from Table 4.27.

producers' decisions to withhold from slaughter, cattle for herd expansion, and the consequent consumer boycott of beef. Thereafter slaughterings were increased, and retail prices began steadily to fall. This pattern of increased supply availability and falling prices is reflected in increased flexibilities between 1973-77. Direct flexibilities fell between 1977-79 primarily in response to reduced supplies available for consumption following herd liquidation and subsequently rising real prices.

Therefore, between 1973 and 1979 the change in all-beef direct flexibilities appear largely due to movements along the prevailing demand curve and not due to dramatic shifts in demand. More recently, however, structural shifts in demand may have played a much greater role. Between 1979 and 1982 all-beef demand moved backwards to the left. Consumption per person over this four-year period has been relatively stable, although real prices have fallen, causing the direct flexibility to increase in each year. Over the past several years of a weakening demand for beef, this rising flexibility implies relatively large price adjustments in the market to small changes in quantities supplies. This same conclusion was reached by Chavas (1983) in his analysis of structural change and meat demand. He found in his time-varying parameter model using Kalman filters, that estimated direct price elasticities for aggregate beef per person tended to decline during the late 1970s. In broad terms this agrees with the above result that direct flexibilities would tend to rise over the same period.

Wohlgenant (1982) explained much of this decline in demand, i.e., negative shifts in demand for red meat, as being due to negative relative quality changes which have led to a substitution of poultry meat for red meats.

Estimates of income flexibilities for all beef in Table 4.28 show a broad tendency to rise through the middle 1960s, then fall during the late 1960s to the middle 1970s, then to rise again through to 1977, and eventually to be at relatively lower levels in 1982. Up to about 1970, this general pattern correlates positively with the changing direction in real disposable income per person. This means that the income response is strongest when incomes are rising, indicating support for the first income hypothesis discussed in section 4.5.3 on irreversibility of demand. However in the latter half of the period 1950-82, the periods of decreasing real disposable income per person were generally associated with rising income flexibilities, and vice versa. This supports the alternative hypothesis discussed earlier.

The specific decline in income response shown from 1977 to 1979 was also observed by Chavas (1983, p. 152) over a similar period of the late 1970s. From this relative decline in income flexibility he projected a decrease in the long term growth rate of the U.S. beef industry. This down trend in income flexibility between 1977 and 1979 also occurred for table and hamburger beef, the components of all-beef demand. Since 1979, however, income flexibilities have progressed steadily upwards for all beef categories. This would suggest the opposite conclusion of Chavas, namely, a prospect of an increase in the long-term growth rate of the U.S. beef industry. However, two points of caution are associated with this conclusion. First, recent changes in disposable income may have been correlated with factors not included in these estimates. Second, irreversibility of demand with respect to income levels may mean a smaller response to rising incomes.

Considerable fluctuation occurred in direct flexibilities of both table and hamburger beef (Tables 4.29 and 4.30). In terms of relative magnitudes these values were similar to those obtained in earlier structural models. Table beef direct flexibilities fluctuated in an upward direction throughout most of the 1950s and 1960s, and for the early part of the 1970s. This reflected the firm upward trend in beef supply availability and hence consumption per person during this period and the declining real prices for table beef. Although the demand curve became flatter (i.e., slope decreased), the rise in the quantity-price ratio more than offset the decreasing slope.

Up to the early 1970s consumers had developed distinct patterns and habits in the consumption of table beef. As a result, they became relatively insensitive to changes in prices which for the most part were still at relatively low real values. The market, however, was quite price sensitive to changes in beef supplies as illustrated by the tendency for direct flexibilities to rise over this period (Table 4.29). Eventually, as real table beef prices rose through the early 1970s and demand shifted leftward, consumers became more sensitive to price changes. Since the mid-1970s, both supply and demand shifts appear to have caused considerable fluctuation in estimated flexibilities. In more recent years from 1979 to 1982 direct flexibilities have tended to rise again. Compared to earlier years this increase would suggest, since real prices have fallen sharply over the period and consumption has remained virtually unchanged, that a substantial structural shift in demand occurred against table beef. Moreover, future increases in supply availability would cause large price variations in the table beef market largely because a flexible demand for table beef would result in proportionately large price adjustments to clear the market. By comparison the direct flexibilities of hamburger beef over the last four years from 1979 to 1982 have been lower than previous years (see the preferred linear models). This indicates a relatively inflexible demand in recent years for hamburger beef. At the consumer level, consumers are highly responsive to changes in retail prices. At the retail market level, an increase in supply availability would be closely matched by demand, requiring a less than proportional adjustment in market clearing prices.

As noted above, the level of income responsiveness for beef has declined relatively over the past several years. This is not a favorable trend for the long-term growth in the U.S. beef industry. Most significantly this decrease in income flexibilities (absolutely from 1977 to 1979 and relatively to 1982) occurred in both the table beef and hamburger beef markets. The study by Chavas (1983), in which similar declines in income response (income elasticities for all beef) were reported, covered the period only up to 1979. Since 1979 steady increases in income flexibilities occurred for all three beef product groupings. Perhaps as incomes rise, consumers are tending to spend proportionately more on non-meats. In the case of hamburger beef may be overestimated since a priori a stronger demand response is to be expected from table beef over hamburger beef. Certainly the upward trend in table beef income flexibilities is stronger whereas those for hamburger beef tend to fluctuate considerably.

As mentioned above, pork demand estimated with a constant coefficient model has been accepted consistently throughout this analysis. This is reflected by the non-significant F-test results shown in Table 4.26. This conclusion is also supported by the relative consistency of parameter estimates and by the magnitude and direction of estimated flexibilities presented in Table 4.31. The magnitudes of direct flexibilities shown in Table 4.11 using a time interaction variable, T*Q, and flexibilities in Table 4.21 using linear and cubic spline functions, bear a very close resemblance to those in Table 4.31. This is because the additional time-varying specification did not make a significant contribution to the fixed coefficient classical linear model. This is not to say that significant increases and decreases in demand did not occur.

It does indicate, however, that significant continuous changes in direct and income flexibilities have not occurred over the 33 year period. Recall, however, that slope interaction dummy variables testing for abrupt changes in structure did indicate significant demand shifts of slope.[62] Chavas also reported an absence of structural change from his continuous time-varying parameter model using Kalman filters. Pork was shown, however, to have significant cross-effects on both beef and poultry. In the present study, pork has shown an increasing income

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[62] The overall contribution of these slope dummy variables was significant at the .05 level. Intercept dummies were also tested and found to be statistically significant.

flexibility over time. Much of this rise in income response has been due to the relatively stable real retail prices for pork and the steadily rising real disposable incomes per person.

From an examination of the price-quantity plots in Figure 4.4 it is perhaps not surprising that the linear polynomial model is preferred among the broiler demand models (Table 4.27). The polynomial coefficient in these equations indicate first, that the demand curve for broilers is becoming increasingly flatter, as is indeed evident from the plot of Figure 4.4., and second, that the slope on income is becoming smaller (i.e., steeper curve). Also with some exceptions, the quantity-price ratio has risen steadily since the 1950s in response to falling real prices and rising levels of consumption per person. The real price/real income ratio has also risen strongly over this period. As a result the direct and income flexibilities have shown a strong upward movement over time (Table 4.32). It is not possible to directly compare relative magnitudes of income flexibilities across meat categories because, for example, of some underestimation in the beef categories. Nevertheless, the comparatively strong upward trend is unmistakable. With respect to the income flexibility, this may indicate continued strong long-term growth prospects for the broiler industry. However, against this conclusion are indications that the market for chicken is reaching saturation.

Of particular interest in the broiler model are the cross-flexibilities presented in Table 4.33. The cross-product coefficients on the polynomial terms in the broiler equation in Table 4.27 are not statistically significant, however, in each case they have a negative sign. This indicates an increasing cross-effect, ceteris paribus. However, the relative size of the cross-quantity flexibilities depend also on the cross-quantity/own-price ratio. Not unexpectedly, therefore, table beef has the strongest cross flexibility of demand. The cross effect of pork on broiler prices is greater than hamburger beef quantities on broiler prices. Chavas' results indicate an ambiguous rise in price elasticities, the opposite effect of a rise in direct flexibilities, a decreasing cross-elasticity for beef and a sharply decreasing cross-elasticity for pork.

4.8 Concluding Summary

In this chapter a number of estimating techniques and statistical models were applied to an analysis of structural change in the U.S. retail demand for meats, namely, table beef, hamburger beef, pork and broilers. Each of these approaches is characterized by estimation coefficients which were permitted, to a greater or lesser degree, to vary through time. This is a direct contrast to the constant coefficient models of classical demand relationships. The following were the objectives of research undertaken in this chapter: (a) to test the hypothesis of no parameter variation in the estimated demand relationships, i.e., to accept the classical model of constant coefficients of demand; (b) where parameter variation is identified, to establish if there is any systematic behavior contained in that variation over time; and (c) to relate systematic variation in terms of estimating slope coefficients and flexibilities of demand to structural changes in retail meat demand which have occurred over the historical period.

With graphical analyses as a guide, structural changes were identified and quantified using qualitative shift variables, linear and cubic splines functions within a discontinuous time-varying switching model, and Legendre polynomials within a continuous time-varying parameter model. Annual models of market demand for meats were specified as price dependent on the assumption that supplies available for consumption determine retail prices. This assumption is less satisfactory for broiler demand, however, for overall model consistency and compatibility within the Michigan State University Agricultural Model (MSUAM), all meat demand equations were price dependent market demand models. Flexibilities, therefore, are the appropriate measures of demand responsiveness.

Linear and log-linear functional forms were used in ordinary least squares estimation of retail demand parameters for each of the four retail meats. Alternative estimation procedures were tested and rejected because of inferior fit and unexpected signs on some cross-effects of pork. To investigate structural changes in demand, a long series of annual data was used; 33 observations from 1950 to 1982.

Preceding the parameter variation analysis were two related analyses of structural change in U.S. meat demand. The first, a price adjustment model was estimated and differences in short-run and long-run flexibilities were examined. The short-run direct flexibility was found to be smaller than the long-run flexibility. The impact of imperfect knowledge and institutional delays in the short-run prevent complete and instantaneous adjustment of market prices to clear the market. Only after some time has elaspsed in subsequent periods do final adjustments in prices take place. Arguments are provided as to why this result does not contradict the traditional notion of Marshallian short and long-run demand curves. In the second analysis the influence on meat demand of changes in the age composition of the population and of the trend towards increased eating away from home were investigated. Away-from-home purchases of food showed no significant influence on retail beef prices. The retail price series, for example, for hamburger beef may be an inappropriate price when considering the influence of institutional (fast food restaurants) purchases. The growth in the 5 to 24 age cohort, a result of the 'baby boom' of the 1950s, has been a significant factor in augmenting demand for hamburger beef, whereas a significant negative relationship was identified between older age cohorts and hamburger beef demand.

Graphical analyses, involving plots of retail prices and domestic consumption per person of individual meats, indicate substantial changes in price-quantity relationships over time. Using time-quantity interaction variables it is evident that over the past several years direct flexibilities for table beef and broilers have risen; for hamburger beef they have declined while for pork they have remained comparatively unchanged. The lower the direct flexibility, the greater the exent to which increases in quantities available per person are absorbed by demand and hence the smaller the adjustment of price to clear the market. Given supplies made available to consumers, this implies that, recently, quantities of hamburger beef have been more readily absorbed by demand than have table beef or poultry meats. Relatively speaking, the preference for hamburger beef has been growing vis-à-vis other meats. From this preliminary analysis it is apparent that considerable change in the structure of U.S. demand for meats, especially of beef and broilers, has occurred over the past several decades.

An attempt was made to relate in a general way the observations of economic structural change in meat markets to the estimated changes in flexibilities over time. One testable hypothesis explaining systematic changes in the structure of meat demand is the hypothesis of irreversibility of demand. The general hypothesis was that direct flexibilities will tend to be more flexible during decreasing consumption phases and less flexible (inflexible) during increasing consumption phases. The differences in the estimated direct flexibilities were quite small, nevertheless, the pattern of change in their values agrees with the hypothesis of irreversibility of demand. Most conclusive results were obtained by using changes in the cattle cycle as the underlying cause of these systematic changes in direct flexibilities of demand.

Linear and cubic spline functions were employed within a time-varying switching regression model. This model, an extension of those tested earlier, permitted slope parameters to change over some periods and remain constant over others. These periods of change were modelled in a continuous fashion. With the notable exception of pork, the null hypothesis of no variation in the regression coefficients of the own-quality was rejected at the one percent level. For example, the log-linear spline model of broiler price indicates that the direct flexibility is not constant. It has been increasing linearly over time although the rate of increase has slowed since the middle 1960s. This result is consistent with the observations that the market for chicken is becoming saturated and that the impact of gains from technology in the broiler industry, which have kept real prices down, may be slowing. More significantly, the competitive advantage of price enjoyed by chicken over beef may be steadily becoming diluted.

Compared to splines, Legendre polynomials provided continuous time-varying parameter estimation and had the particular advantage over other polynomials of the property of finality of coefficients. The orthogonal nature of these polynomial functions provides independence among the coefficients of each polynomial term added. The same degree polynomial is not required for each explanatory variable while for others the assumption of a constant value may be justified. There is considerable flexibility in its use in providing a time-varying character to regression coefficients and, hence, estimated flexibilities were obtainable for each period. Limitations of this estimation approach include problems associated with usual regression analysis: in particular, specification of the degree of polynomial must be based on economic reasoning.

Continuous time-varying parameter specification was found to make a significant contribution, beyond the classical model of fixed regression coefficients. Again the notable and consistent exception was in the pork demand model. The direct and income flexibilities of all-beef demand were generally greater than unity. This indicates first, that the beef market has been subject to larger price variations as supply fluctuates, and second, that increases in real disposable income per person have had a more than proportional impact on market prices. The level of income responsiveness for beef has declined relatively over the past several years. This decrease in income flexibilities (absolute from 1977 to 1979 and relatively to 1982) occurred in both table beef and hamburger beef markets. Nonetheless, the steady upward progression of income flexibilities since 1979 should not be overlooked. Income flexibilities have continued strongly upward for broilers.

A consistent result throughout has been the recently rising direct flexibilities for table beef and broilers and a declining direct flexibility for hamburger beef. This latter trend is consistent with the increasing price competitiveness of hamburger beef with table beef, a situation reminiscent of the high beef price period of the early 1970s. Ground beef appears to have become a closer substitute with table beef.

Chapter 5

EMPIRICAL EVALUATION OF THE IMPACT OF STRUCTURAL CHANGE ON RETAIL MEAT DEMAND AND U.S. BEEF IMPORTS

In the previous chapter various specifications of retail demands for meats, namely, table beef, hamburger beef, pork and broilers, were estimated and results were presented. In the latter section of that chapter, continuous time-varying parameter models were estimated over 1950-1982. These were considered to be a substantial improvement over fixed parameter models estimated over the same period. The notable exception was pork demand.

In this chapter, these preferred demand equations are integrated into the Michigan State University Agricultural Model (MSUAM). The MSUAM is an econometric simulation model of the U.S. livestock and grains sectors and world wheat and feed grains regions. Equations linking the retail meat demand component with the MSUAM are derived or estimated.

The benefits of including the retail meat demand component into a model like the MSUAM derive from the systematic insights into and assessments of meat demand within a U.S. national and international context. This assessment is greatly enriched by the comprehensiveness of the MSUAM. The analysis proceeds by simulations of the model under varying policy and economic scenarios of national and world agricultural markets. Scenarios selected reflect specific structural changes potentially impacting either directly the U.S. demand for meats via the estimated demand relationships or indirectly via related national and international agricultural sector markets.

Of particular interest in this research is the market for non-fed beef in the U.S. As noted earlier, a substantial portion of non-fed beef consumed in the U.S. is imported, predominantly from Australia. In each model simulation, and hence scenario presented, the impacts of structural change on the level of non-fed beef imports are examined.

Scenarios examined over the 1983-1991 period include:

(a) model sensitivity to one year and medium term shocks arising from changes in the levels of retail meat demand or U.S. real disposable income per person;

(b) the sensitivity of key livestock and meat market variables to a one-year or medium-term increase or decrease in U.S. non-fed beef imports;

(c) the impact on non-fed beef supply and hence, on farms and retail meat prices of a dairy PIK (payment in kind) program and the implied slaughter of dairy cows to bring into balance supply and demand in the U.S. dairy market;

(d) the effect of sustained economic growth or decline in developing market and communist economies on their feed grain imports and hence on the U.S. fed beef market; and

(e) the ramifications of changing structural relationships, own-quantity, cross-quantity, and income effects, in retail meat demand as characterized by parameter variation over time.

In a number of these scenarios, where appropriate, the differential impacts of the structural change under conditions of a strong (excess demand) feed grain market and a weak (excess supply) feed grain market are investigated.

Before reporting the results of these various policy and economic scenarios, an overview of the MSUAM and its structure is given. This is followed by details of the U.S. retail meat demand component and of its integration into the existing feed-livestock component of the entire model. The linkage equations and their specifications are discussed. Assumptions made regarding projections of exogenous variables, base projections of endogenous variables generated by the augmented MSUAM and validation of key market variables are also presented.

5.1 Overview of the Michigan State University Agricultural Model

The MSUAM is an annual econometric model comprising a detailed U.S. agricultural model and a nine region world grain model (Figure 5.1). This multi-commodity, non-optimizing simulation model follows a systems methodology of being essentially problem solving. It is designed primarily for intermediate and long term analyses. To date the model's strengths have been in addressing questions of trade levels, trade policies, domestic grain policies and long-term trends in U.S. and world grains. A primary objective of this research, particularly in this chapter, is to develop an integrated U.S. retail meat demand component for analysis of the four major meat categories, table beef, hamburger beef, pork and broilers.

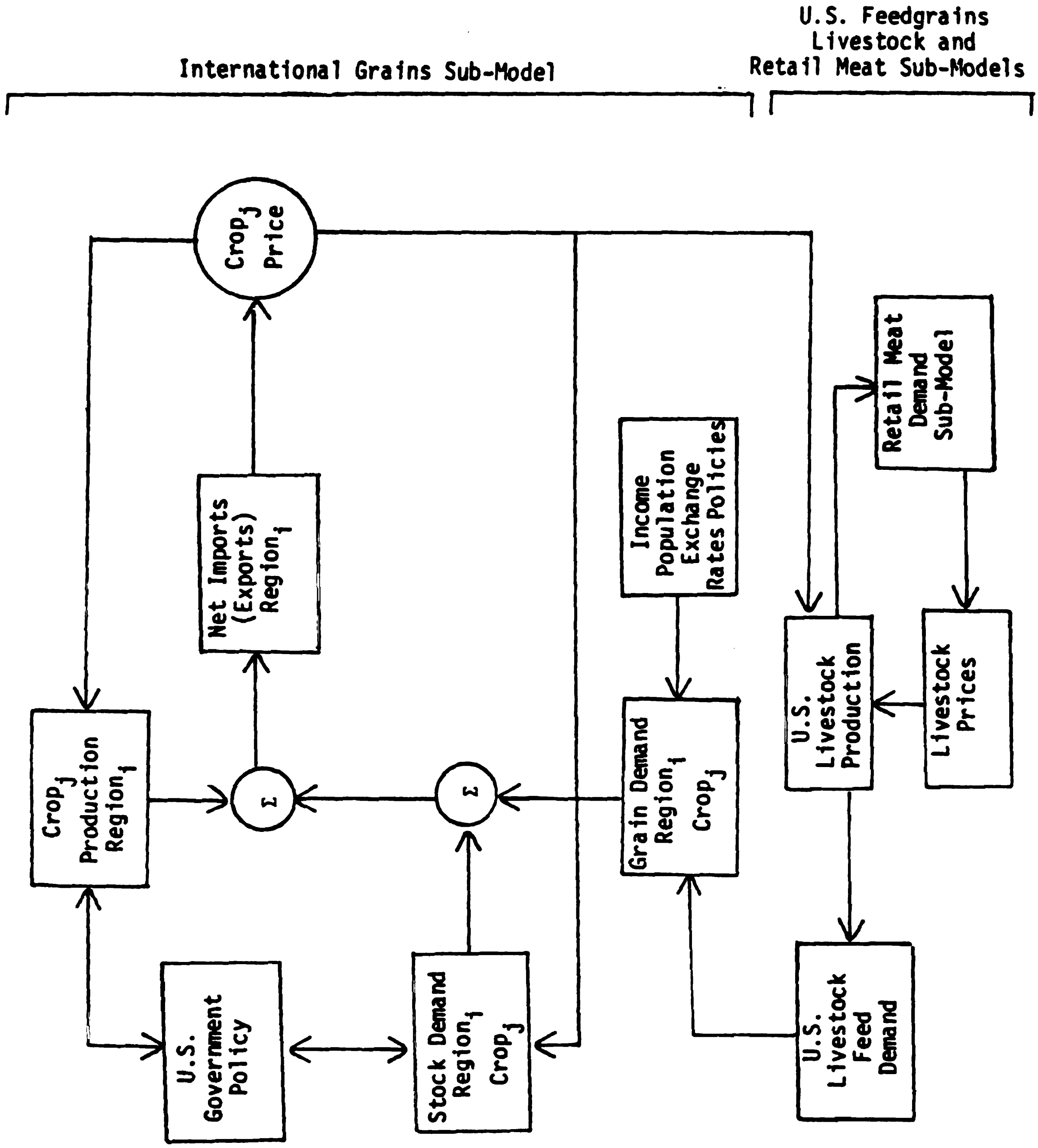

Figure 5.1 Flowchart of Major Components of MSU Agricultural Model

The agricultural model as originally developed by Hondai (1975) and Trapp (1976) contained three basic components: (a) a domestic supply component of wheat, feedgrains (corn, sorghum, barley and oats), oilseeds, fed beef, non-fed beef, pork, poultry and dairy products; (b) a domestic demand component for each of the above commodities; and (c) an international trade component of U.S. exports of wheat, feed grains and oilseeds. Later, Baker (1978) independently developed an econometric and financial projections model of the U.S. farm sector. This model contains a farm cost sector, flow of funds, and an income accounting and balance sheet framework. This component has been used to provide intermediate and long-term forecasts of the farm sector's financial position for use in strategic planning by producers, input suppliers and government policy analysts.

Wailes (1983) further developed the overall model through re-estimation and respecification, and integrated the financial model into the MSUAM. His major contribution was to develop a U.S. agricultural policy component and to set the whole model into a stochastic simulation framework. The U.S. policy component comprises both supply and demand management policy interactions. Supply management recognizes the role of loan rates, target prices, set-asides, national program acreage, diversion payments and recommended voluntary diversion. Demand management recognizes the Commodity Credit Corporation (CCC) stocks and farmer-owned reserve stocks rules and their relationship to the supply control variables. This policy component is a departure from other U.S. agricultural sector models. In essence the farm program is endogenized in the model. Indeed this is consistent with the considerable discretionary authority given to the U.S. Secretary of Agriculture and suggests that the policy process be modeled to interact endogenously with the supply and demand forecasts of the MSUAM.

However, since government policies have historically related to the grain market and not to livestock production, no explicit policy framework exists for the livestock sector. Nevertheless, government grain policies can be expected to have a significant indirect effect on the livestock sector, an effect which would be captured in this model.

The domestic-international linkage was based on export supply available from domestic production, and farm grain prices are derived from export prices. Subsequently, Mitchell (1982) added the nine region world wheat and coarse grains model. This endogenized world wheat and coarse grain prices. The world and U.S. soybean model was added by Christensen (1979)[1].

Therefore, the U.S. domestic component provides estimates of production, feed and food usage, prices, stocks and exports of all major grains, soybeans and livestock. Livestock numbers and production are estimated for fed beef, non-fed beef, dairy, pork, broilers, turkey and eggs. These commodities, overall, account for some 80 percent of U.S. farm income. Grain and livestock sectors are linked by feed utilization (grain consuming animal units) equations. More will be detailed on the livestock sector, later in this chapter.

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[1]The initial project began under the direction of Vern Sorenson and John Ferris, although other major contributors include J. Roy Black and John Ross.

The world agricultural component estimates production, consumption and trade of wheat, coarse grains (corn, oats, barley, sorghum, rye) and soybeans for four exporting countries (Canada, Australia, Argentina, Brazil) and five importing regions (Soviet Bloc--USSR and Eastern Europe, Developed Markets, Less Developed Markets, China, and Undesignated--trade type cannot be assigned). International and U.S. models are simultaneously solved to provide net wheat, coarse grain and soybean trade by region and world prices. Hence export quantities and prices are endogenously determined. Specific interregional flows are not identified.[2]

The model is dynamic in the sense that the solution in period t+1 is determined by the solution in period t. No explicit or extensive treatment of risk, uncertainty, investment, or disinvestment is contained in the model specification. Certain specifications attempt to proxy various aspects of these notions of model dynamics. For instance, the hypothesized relationships of the role of price or profit expectations and partial adjustment due to information, institutional or technical lags contribute somewhat to the dynamic specification of the model.

No explicit attempt is made to include information on detailed resource use or on factors of production. Moreover, the model is not specified to analyze issues of long-run resource requirements, input

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[2]The international component is the driving force for the overall agricultural model and reflects the importance of world trade to U.S. agriculture. In contrast to the more commonly used spatial equilibrium models which allocate trade according to transportation costs, world demand in the MSUAM is allocated among exporting countries according to a trade hierarchy. This hierarchy is dependent upon grain available for export and upon marketing behavior.

usage, technological change, investment or environment. The extent of aggregation of the endogenous variables will always be of concern to the modeler in some analyses but not in others.

Interaction with the general economy is not modelled explicitly in the MSUAM although there is one aspect of the model which permits some feedback in this regard. The author developed a subroutine which determines endogenously the consumer price index for food (CPIFOOD).[3] Using a market basket approach, farm values and market spreads are econometrically estimated for each component of the food basket. Retail prices or retail values are then calculated to obtain a retail price weighted index of food. The programming subroutine is contained in Appendix B. Changes in government policies and other economic shocks can then be analyzed with respect to their impact of the CPI for food, and hence their commensurate inflationary impact on the general economy.

Overall, the MSUAM may be viewed as a set of integrated commodity models with three important sets of linkages; (a) feed grain--livestock, (b) crop supply and demand and policy management, and (c) domestic-international grain markets.

5.1.1 Model Estimation Procedure

The MSUAM, including the U.S. retail meat demand component contains some 215 endogenous variables and 210 exogenous variables. There are approximately 90 endogenous equations estimated by ordinary least squares using data from 1960 to years ranging between 1976 and 1982

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[3]The contribution of John Ferris is acknowledged.

depending on the equation, available data and when it was last estimated. The shortcomings of the OLS estimation method are recognized as are its strengths. The MSUAM is in large part recursive, though not completely so. Supply is predetermined while demand responds to current information, including quantities supplied. To the extent that model components are recursive, single equation biasness and inconsistency in parameter estimates will be minimized. OLS has been shown in Monte Carlo studies to maintain the Gauss-Markov property of minimum variance. Variants of the limited and full information techniques would place a prohibitive burden on degrees of freedom in a systems model as large as the MSUAM. This problem of the undersized sample was also discussed by Labys (1973, p. 138) who noted the necessary trade-off between biasness and efficiency of OLS estimates.[4] (Thiel, 1971). Moreover, as Wailes (1983) observed, various researchers have found that OLS tends to improve relative to limited information estimates as the model size increases. Finally, a very significant justification for this estimation procedure is its relative computational simplicity and inexpensiveness.

5.1.2 Solution Algorithm

Simulations described in this study were carried out using the GSIM program (Wolf, 1983) developed in the Agricultural Economics Department at Michigan State University. GSIM employs the Gauss-Seidal method of

[4] For a discussion of some of these problems as they relate specifically to the application of models like the MSUAM, see Cromoco (1982, pp. 26-30).

iteration to obtain a solution to a set of simultaneous equations.[5] This is a straightforward numerical method for the solution of systems of equations and is used widely in large, complex economic models.

A particular advantage of the simulation approach to agricultural sector modeling is that constituent agricultural commodities may be analyzed simultaneously. Important cross-commodity effects may be considered. For some analyses of the effects of policy changes a simulation model of this kind has advantages over the alternative multiplier analysis (Labys, 1973, p. 199). For instance, analysts may consider in a simulation analysis varying rates of change in an exogenous variable or varying levels of several exogenous variables together. This flexibility provides a considerable advantage in the evaluation of different policy and economic scenarios in agriculture.

5.2 U.S. Domestic Livestock Model

Beyond the detail of the previous description of the MSUAM, there is neither sufficient space nor time to detail the entire model used in simulations to be presented later. Recent presentations of the component submodels are given in Wailes (1983) and Mitchell (1982). Details of the U.S. retail meat demand component will be covered in much greater detail since this is an addition to the existing model. To do this, however, it seems necessary to provide at least a brief outline of

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[5] GSIM is based on the General Analytical Simulation Solution Program (GASSP) developed originally at the USDA.

the U.S. livestock model into which the retail meat model is being integrated.

As stated earlier, the livestock sector includes beef (fed and non-fed), dairy, pork and poultry (chicken, turkey and eggs). The livestock sector is based on a calendar year and crops are based on their respective marketing year. At the farm level interactions between livestock types are limited. Interactions of dairy steers in fed beef production and dairy cow inventory as a determinant of non-fed beef production are examples.

5.2.1 Beef Supply

Figure 5.2 gives a diagrammatric representation of the U.S. beef supply, and dairy supply and demand as estimated in the MSUAM. Submodels linking these equations with other livestock and feedgrain equations are shown.[6]

The specifications of equations of the beef supply model provide aggregate supplies of all steer and heifer slaughter, which is classified as fed-beef production, and of cow and bull slaughter, which is classified as non-fed beef production. With the introduction of the retail meat demand model, estimated marketing margin equations provide the link to fed beef and non-fed beef prices at the farm level. Transmission equations provide the linkage between fed and non-fed beef

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[6]Rectangular boxes indicate stock variables and product flows, while circles represent other variables of influence.

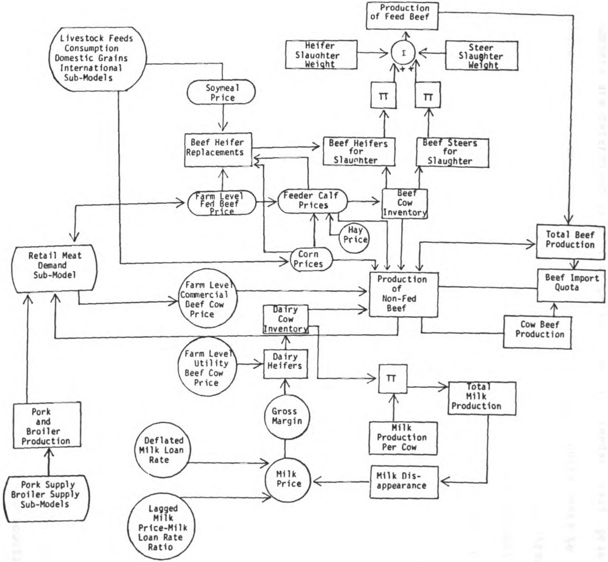

Figure 5.2: Flowchart of U.S. Beef Supply and Dairy Supply and Demand

quantities and table and hamburger beef quantities consumed at the retail level, respectively.

Both producer decision variables and biological response variables characterize the types of relationships in the beef model. Beef cow numbers are determined by a five-period lag in feeder calf prices, change in consumer price index to reflect the opportunity costs to the enterprise of carrying a cow, lagged beef cow numbers and a time trend. A notable feature of this specification is the asymmetric contraction and expansion phase specified into the five-period lag in feeder calf prices.

The steer and heifer slaughter behavioral equation was initially specified to explicitly recognize these biological and decision processes. However, due to the biological inconsistencies of this equation with beef cattle inventories, an alternative model was specified. In order to impose consistency with the inventory of beef carried into the slaughter period, fed beef produced was derived using estimated slaughter numbers and slaughter weights. This alternative model required explicit information on calving rates, calf survival rates, replacement rates, veal slaughter, feedlot survival rates, and dressed weights. The trade-off of the additional estimations and information required was greater consistency between projection of the breeding herd and the slaughter volume. An expense of this formulation is the short-run impact of changes in corn and soymeal prices on fed-beef production. For medium-term simulations, however, this cost may not be great.

Note also that in the original MSUAM, fed beef production included the slaughter of all steers and heifers and non-fed beef slaughter comprised cow and bull slaughter only. To the extent that steers and heifers are grass fed before slaughter, fed-beef production will be overestimated and non-fed beef will be underestimated. Adjustment for this bias is made in the retail demand model equations which are estimated using the more accurate definition of fed and non-fed production, discussed in Chapter 4.

Cow and bull slaughter is estimated as being determined by lagged beef and dairy cow inventories, lagged corn and feeder calf prices, current-period hay price and a three year polynomial lag on the Omaha commercial low price. Estimated results appear to reflect the important influences of the culling decision.

Import quotas govern the quantity of manufacturing quality beef allowed into the U.S. Since 1980, the countercyclical meat import formula has been used to determine U.S. beef imports (Conable, 1980). The formula is computed as:

$$\text{Annual Quota} = \begin{array}{c}\text{Average}\\ \text{Annual}\\ \text{imports}\\ \text{1968-77}\end{array} \cdot \frac{\text{3 yr. Moving Average of Domestic Production}}{\text{10 yr. Average of Domestic Production, 1968-77}} \cdot \frac{\text{5 yr. Moving Average of Per Caput Domestic Cow Beef Production}}{\text{2 yr. Moving Average of Per Caput Domestic Cow Beef Production}} \tag{5.1}$$

The countercyclical import law is designed to permit greater imports of meat when domestic supplies are low and consumer prices are high, putting downward pressure on rising beef prices. Conversely, it is intended to reduce meat imports when domestic supplies are large and consumer prices low, hence moderating the downside in beef prices.

The average annual level of imports for 1968-77 has been officially determined at 1204.6 million pounds, product weight, or as used in the model, 1646.4 million pounds, carcass weight.[7]

The 10-year average of domestic production of quota meats for 1968-77 is 23,184 million pounds, carcass weight. From this quantity, 220 million pounds for average total carcass weight of live cattle imports, is subtracted for that period. This gives 22,964 million pounds, carcass weight. In the MSUAM the domestic production of beef cows is aggregated into estimated non-fed beef (cows and bulls) production, although historical data on beef cow production is available. Therefore, a simple transmission equation was econometrically estimated with beef cow production (QCW) as a function of non-fed been production (NFBFQT).[8]

These calculations for the import quota give the adjusted base quantity of imports for a particular year. However, the key point of reference for imports estimates is the 'trigger' level, which is 110 percent of the adjusted base quantity. It is only when imports are expected to exceed the 110 percent level that the President must

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[7]The conversion from product weight to carcass weight is estimated from data in USDA (1982a, p. 155).

[8]The transmission equation is

$$\underset{}{QCW} = \underset{(2.40)}{239.275} + \underset{(36.35)}{\cdot 8498}\ NFBFQT$$

$\hat{\sigma}/m = .021$ $\bar{R}^2 = \cdot 989$ DW $= \cdot 98$ no turning point errors 1964-79 restrict total imports to the adjusted base quantity level, but to not less than 1250 million pounds, product weight.

In the model the endogenously estimated non-fed beef imports are measured and determined by the beef import quota. That is, non-fed beef imports are assumed to be equal to the beef import quota as determined by the counter-cyclical meat import formula. Actual imports may be greater or less than the quota or the trigger level depending upon political circumstances in the U.S. and/or economic conditions of beef supply in major beef exporting countries (Table 5.1).

No attempt has been made to estimate these factors nor project their possible impacts on the actual level of non-fed beef imported by the U.S. It is therefore assumed that beef export supply from beef exporting countries is completely elastic. This implies that exporters to the U.S. will always try to maximize profits by exporting quantities of beef up to the maximum levels allowed under the countercyclical meat import law.

Table 5.1, on the operation of the beef quota, indicates that except for three years (1973, 1978-79), of the past ten, and five of the past 18 years, beef imports have been less than or approximately equal to the trigger level of the quota. In five of the past 18 years actual imports have been less than the base import quota.

This suggests that the specification of U.S. beef imports to equal the adjusted base quantity may tend to slightly underestimate, on average, actual beef imports. The results of a recent study (Harris and Dewbre, 1983) suggest that trigger level import restrictions are

Table 5.1

Operation of U.S. Meat Import Law[a] on Imports of Beef: 1965-1983

	Adjusted Base Quantity (ABQ)	Trigger Level	Actual Imports	Ratio of Actual Imports to ABQ	Comments on Import Program
	Million Pounds (Carcass Weight)[b]			Units	
1965	1141.6	1255.8	822.0	.72	No restrictions
1966	1197.3	1317.0	1101.5	.92	No restrictions
1967	1216.8	1338.5	1192.5	.98	No restrictions
1968	1278.2	1406.0	1342.1	1.05	VRA's with Australia and New Zealand
1969	1328.9	1461.8	1461.8	1.10	VRA's, except Canada and United Kingdom
1970	1343.5	1477.9	1571.9	1.17	VRA's below trigger, quotas imposed then suspended
1971	1373.2	1510.5	1510.5	1.10	Quotas imposed then suspended
1972	1405.0	1545.5	1826.5	1.30	VRA's; then suspended
1973	1414.2	1555.6	1824.3	1.29	Quotas imposed then suspended, no restrictions
1974	1389.2	1528.1	1430.9	1.03	Quotas imposed then suspended; no restrictions
1975	1456.2	1601.8	1645.5	1.13	VRA's
1976	1584.4	1742.8	1742.8	1.10	VRA's, then quotas imposed
1977	1637.7	1801.5	1752.3	1.07	VRA's
1978	1659.9	1825.9	2074.9	1.25	VRA's, then quotas imposed, then suspended
1979	1583.6	1742.0	2153.7	1.35	Quotas imposed then suspended, VRA's above trigger
1980[c]	2040.1	2244.1	1917.7	.94	No restrictions
1981	1743.8	1918.2	1639.2	.94	No restrictions
1982	1566.0	1722.6	1753.9	1.12	No restrictions, then VRA's Australia, N.Z., Canada
1983	1482.7	1631.0	d	d	VRA's, likely at below trigger levels

[a]P.L. 88-482 from 1965, replaced by P.L. 96-177 in 1980; VRA's are voluntary restraint agreements.

[b]Converted from product to carcass weight using USDA (1982a, Table 184, p. 155).

[c]Countercyclical law (P.L. 96-177) in effect from hereafter.

[d]Actual imports in 1983 and likely to be close to the trigger level in that year.

Source: Obtained from USDA, Commodity Programs, FAS; derived from official files, U.S. Bureau of Census statistics.

unlikely to be imposed during the 1980s and that a free market will prevail largely because of the limited ability of suppliers to meet the quota levels. Results of the sensitivity of this assumption is Appendix Table A3.

5.2.2 Dairy Supply and Demand

As specified by Wailes (1983) four behavioral equations make up the dairy model. The decision process in the model focused primarily on the dairy heifer equation (Figure 5.2). This equation is determined by a gross margin variable reflecting the profitability (or opportunity cost) of the dairy enterprise, cull cow (Omaha utility cow) price, and dairy heifer numbers lagged one period. Dairy cow inventory is determined by lagged dairy cow numbers and a five-period polynomial distributed lag on dairy heifer numbers. This lag assumes that the age structure of cows in the herd follows a fixed pattern and changes over time only in terms of changes in the dairy heifer inventory. Milk production per cow is estimated exogenously to the model and is multiplied by dairy cow numbers to generate total milk production. The highly aggregate demand component is completely described by a single milk price equation. This equation is determined primarily by milk disappearance, the ratio of lagged milk price to the milk loan rate, and the deflated milk loan rate.

5.2.3 Pork Supply

Figure 5.3 presents a flowchart of the pork supply relationships as estimated. Also shown in this figure are broiler supply, and egg and

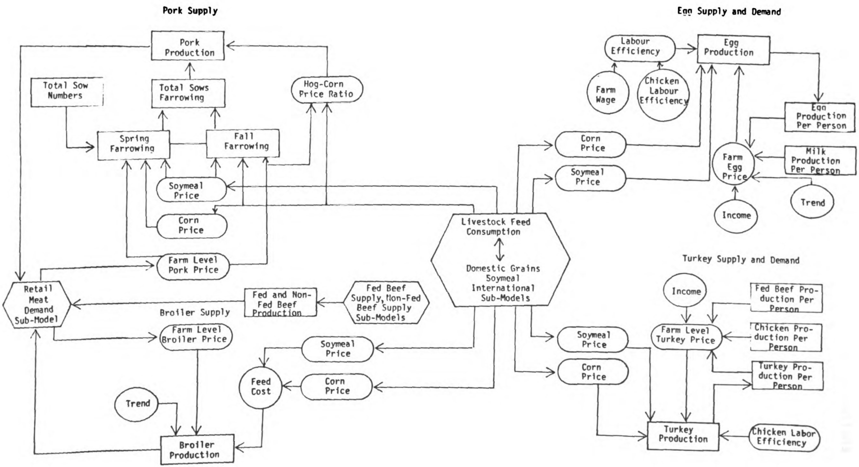

Figure 5.3 Flowchart of U.S. Pork and Broiler Supply and Turkey Egg Supply and Demand

turkey supply and demand. The submodels linking these equations with other segments of the model are shown.

Production of pork is determined by the size of the pig crop and the weights to which they can be economically fed for slaughter. Separate equations are used to represent fall farrowings and spring farrowings. Fixed technical coefficients are used to obtain litter sizes per sow. Pork production is then the product of slaughter weights and hogs slaughtered.

The spring sow farrowing equation is recursively determined by lagged sow numbers, corn price, soymeal price and the pork price. Fall sow farrowings are determined by a similar equation. Included into these specifications is the asymmetric response of hog prices during the contraction and expansion phases of the hog cycle. Pork production is estimated as a function of lagged pork production, last fall and this spring's farrowing, and the change in the hog-corn price ratio.

5.2.4 Poultry Supply

Separate turkey, broiler and egg production equations are estimated in the poultry sector model (Figure 5.3). The model does not capture the complexity or rapid structural change that has occurred in this sector over the last 20 years or so. The primary reason, at least initially, for including poultry in the model was to identify feed consumption by this sector. This has been achieved reasonably well. Despite the annual specification of a sector, where supply turns over more than once a year, year to year variation is explained very well.

5.2.5 Livestock Feed Consumption

Figure 5.4 illustrates the economic relationship among wheat and coarse grains fed to livestock and the relevant linking submodels. The livestock-feed relationships link the livestock sector to the crop sector. Feed consumption is estimated for feed grains (corn, sorghum, barley, oats), soymeal and wheat. Wheat fed to livestock is estimated directly whereas feed grains and soybean fed are based on grain or meal consumed per standardized animal unit. Wheat comprises a relatively small share of livestock feed in the U.S., where the amount of wheat fed depends primarily on availability and the price relationship between wheat and feed grains.

The number of grain consuming animal units is derived from numbers of livestock in each category, weighted by feed consumption per animal type. The feed weights were obtained from USDA sources. Grain consumption per animal unit is estimated from livestock and feed prices. Total feed grain consumption is then obtained as the product of feed grain consumed per grain consuming animal unit and the number of grain consuming units. Soybean meal consumption is obtained in the same way as feed grain consumption.

Clearly, some aggregation bias is likely to occur in estimates from this simplified feed consumption model. Feeding rates are not fixed in reality but differ across livestock classes. To date, development of a more disaggregated model has been prevented by an absence of historical data identifying feed consumption by livestock type or feed. Feeding rates and hence grain consumption also differ across time for given animal types. Livestock and feed price relationships do not capture the

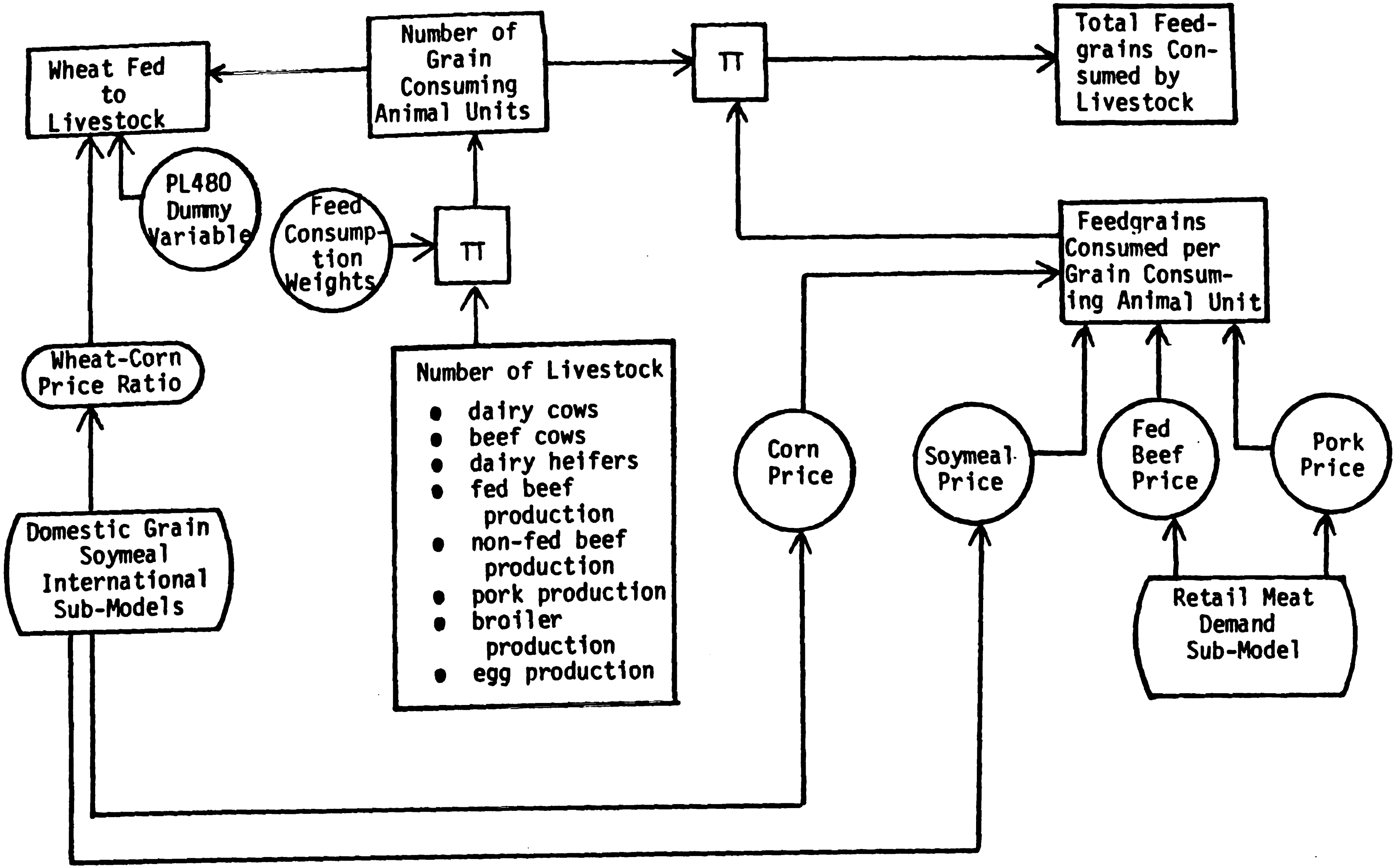

Figure 5.4 Flowchart of Wheat and Feedgrains Consumption by U.S. Livestock Sector

total variation in feed consumption caused by cycles in livestock production. Much of this variation in feed grain consumption is of a short term nature. Therefore, the above method of estimation should capture satisfactorily long-term variation in feed grain consumption.

Because livestock estimates are on a calendar year and the crop sector is on a crop marketing year, synchronization of the interface of the two sectors was necessary. To achieve this, livestock numbers in t+1 were estimated. Since all explanatory variables for livestock supply are predetermined, they can be led forward over a period.

5.3 Model of U.S. Retail Meat Demand

In the foregoing sections an overview of the MSUAM was presented. Model components of U.S. livestock and livestock feed consumption were also outlined since these submodels form an integral link with the retail demand for meat. In this section the retail meat demand model is described in detail.

In Figure 5.5 a block diagram of the U.S. retail meat demand model is presented. A block diagram embodies a complete model description and has a one-to-one relationship with the set of equations describing the mathematical model. All relationships among variables are shown either as a summation, Σ, or multiplication, π, except where a function is generated. In this case, each functional equation is symbolized and denoted by F_i for i = 1, 2, ...,11. As in previous diagrams in this chapter, flow or stock variables are shown in rectangles, while circles represent other variables and influences. The FORTRAN coded version of this block diagram is contained in Appendix B.

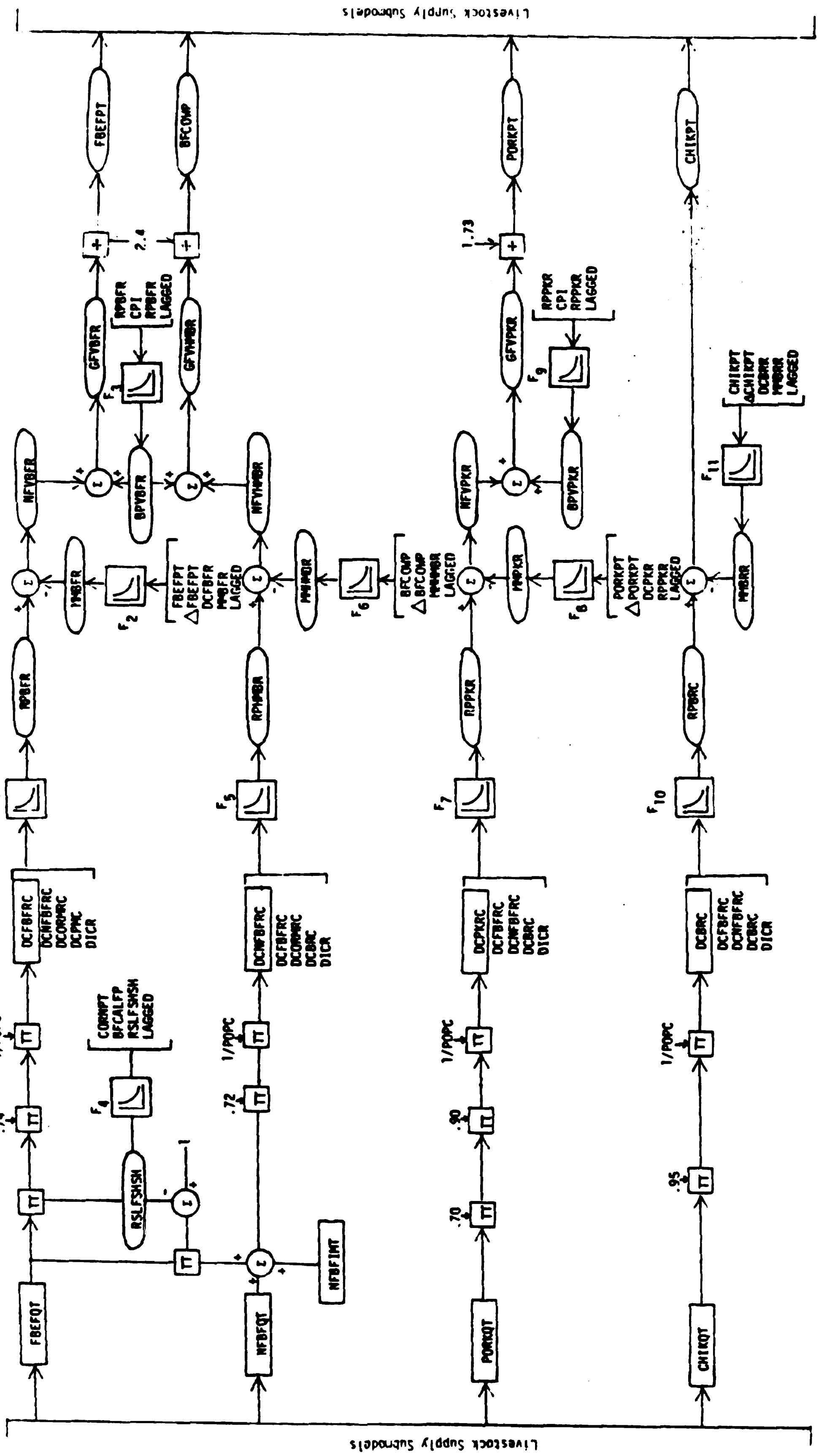

Figure 5.5 Block Diagram of U.S. Retail Demand for Meats

The retail demand model contains 11 behavioral equations each of which have been estimated by ordinary least squares techniques. Four of these are price dependent demand equations, each of table beef, hamburger beef, pork and broilers. These were estimated in the previous Chapter 4. With one exception, the other estimated equations are marketing margin or by-product value equations, which provide the transmission between retail and farm level product prices. The exception is an equation which estimates the ratio of slaughter of fed steers and heifers to all steer and heifer slaughter. Its purpose is to provide a more accurate determination of the quantities of fed and non-fed beef production.

In addition to these estimated equations, there are ten linkage identities which either transform farm product quantities produced (carcass weight) to retail product quantities consumed (retail weight) or transform retail prices to farm prices. Variable codes and units of measure of variables used in Figure 5.5 and in specifying the retail meat demand model are presented in Table 5.2. Some of these variables have been defined elsewhere, however, to facilitate the following discussion, these are included here.

A shortcoming of the specification of fed and non-fed beef production in the original MSUAM, was the aggregation of all steer and heifer slaughter as fed beef. Discussion in the previous two chapters highlighted some of the problems arising from this aggregation.[9] A portion of steers and heifers is raised primarily on grass and not in

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[9]The nature of this aggregation bias was the subject of a recent paper by Martin (1983).

Table 5.2

Variable Codes and Units of Measurement Used in Specifying the U.S. Retail Meat Demand Model

Variable Code	Variable Name	Unit of Measure
BCALFP	Kansas City feeder calf price, medium no. 1 steers, real	$/cwt
BFCOWP	Beef cow price, Omaha commercial, real	$/cwt
BPVBFR	By-product value beef choice yield, grade 3, retail, real	¢/lb
BPVPKR	By-product value pork, retail, real	¢/lb
CHIKQT	Chicken production, broilers on ready-to-cook basis	million lbs.
CHIKPT	Chicken price, farm level, real	¢/lb
CHNGBRR	Change in chicken price, farm level, real	%
CHGBCP	Change in beef cow price, Omaha commercial, real	%
CHGFBPT	Change in choice Omaha steer price, real	%
CHGPKP	Change in pork price, farm level, real	%
CORNPT	Price of corn, No. 2 yellow corn at Chicago market, real	¢/bu.
CPI	Consumer price index	index
DCBRR	Domestic consumption broilers, retail weight	million lbs.
DCFBFR	Domestic consumption fed beef (choice), retail weight	million lbs.
DCPKR	Domestic consumption pork, retail weight	million lbs.
DCBRC	Domestic consumption broilers, retail weight, per person	lbs.
DCFBFRC	Domestic consumption fed beef, retail weight, per person (table beef)	lbs.
DCNFBFRC	Domestic consumption non-fed beef, R.W., per person (hamburger beef)	lbs.
DCORMRC	Domestic consumption other red meat, R.W. per person (pork, veal, lamb)	lbs.
DCPMC	Domestic consumption poultry meat, R.W., per person (chicken, turkey)	lbs.
DCPKRC	Domestic consumption pork, retail weight, per person	lbs.
DICR	Disposable income per person, real	$
FBEFQT	Fed beef production, steers and heifers, dressed weight	million lbs.
FBEFPT	Fed beef price, choice Omaha steers	$/cwt.
GFVBFR	Gross farm value, beef choice yield, grade 3, retail weight, real	¢/lb.
GFVHMBR	Gross farm value, commercial beef cow, retail weight, real	¢/lb.
GFVPKR	Gross farm value, pork, retail weight, real	¢/lb.
MMBRR	Marketing margin, broilers, retail weight, real	¢/lb.

Table 5.2 (Continued)

Variable Code	Variable Name	Unit of Measure
MMBFR	Marketing margin, fed beef, retail weight real	¢/lb.
MMHMBR	Marketing margin, commercial beef cow, retail weight, real	¢/lb.
MMPKR	Marketing margin, pork, retail weight, real	¢/lb.
NFBFIMT	Non-fed beef imports, carcass weight equivalent	thousand tons
NFBFQT	Non-fed beef production, cows and bull slaughter, dressed weight	million lbs.
NFVBFR	Net farm value, choice beef, retail weights, real	¢/lb.
NFVHMBR	Net farm value, commercial cow, retail weights, real	¢/lb.
NFVPKR	Net farm value, pork, retail weights, real	¢/lb.
PORKQT	Pork production, liveweight, marketing year, Dec.-Nov.	million lbs.
PORKPT	Pork price, 7 markets, barrows and gilts real	$/cwt.
RPBFR	Retail price, table beef (choice grade), real	¢/lb.
RPBRR	Retail price, broilers, (young chicken), 4 region average, real	¢/lb.
RPHMBR	Retail price, hamburger beef, real	¢/lb.
RPPKR	Retail price, pork, real	¢/lb.
RSLFSHSH	Ratio slaughter, fed steers and heifers to all steers and heifers	ratio

feedlots. Such aggregation, therefore, is likely to result in a substantial underestimation on non-fed beef production. It was also recognized that although range-fed cattle typically contribute some cuts of table beef, fed steers and heifers contribute significantly to processed/ground beef production directly, or by supplying fat trimmings for mixing with lean ground beef.

Ryan (1980) reported that 23.2 percent of all steer and heifer carcasses are of processing quality.[10] Although the general order of magnitude of this percentage appears to be in the correct "ballpark", the degree of accuracy of this figure appears spurious. This percentage can be expected to vary with changes in both input and output prices faced by the cattle feeder, and to vary with movements in the cattle cycle, grading changes, and with various shifts in retail meat demand.

In Appendix Table A2 is contained the derivation of the data series of fed and non-fed beef supply and of table and hamburger beef consumption used in estimation of retail beef demand in Chapter 4. In essence, the quantity of all steer and heifer beef (federally inspected and other) is adjusted by the ratio of slaughter of fed steers and heifers to all steers and heifers (RSLFSHSH). This ratio, RSLFSHSH, is equal to the number of marketings of cattle on feed in 23 states (MRCF23)[11]

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[10]Using this figure, Martin (1983) estimated that over the 1961-1979 period, fed steers and heifers contributed an annual average of 3414.4 million pounds of lower quality beef compared with 1675.2 million pounds a year of high quality cuts produced by non-fed steers and heifers. It is not stated if this is carcass or retail weight. Nevertheless, the potential bias of including all steers and heifers in the fed beef category may be only half as great as if it were excluded. A bias occurs whether non-fed steers and heifers are included or not into fed beef production. However, the bias is greater when it is included.

divided by the number of all steers and heifers slaughtered (SLSR + SLHF). Therefore, the quantity of fed steer and heifer beef was reduced by the ratio and non-fed beef production was augmented by the non-fed steer and heifer beef residual. Therefore, to bring estimates of fed and non-fed beef production provided by the original MSUAM into line with the more complete estimates of table and hamburger beef production/consumption in the retail demand equations, RSLFSHSH was econometrically estimated as a behavioral equation (see function F_4 in Figure 5.5).[12]

A priori, the ratio of the slaughter of fed steers and heifers is determined primarily by the prices of inputs to the fed beef production process, i.e., mainly feed costs and feeder cattle, and the relative prices of outputs, namely choice beef and beef cow prices. Structural capacity of feedlots may be captured by lagged production or some other proxy variable for capacity. Two versions of this ratio equation are shown below in equations (5.2) and (5.3).

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[11] Data on MRCF23 (USDA, 1982a) has been discontinued and replaced by data on marketings of cattle on feed in 13 states.

[12] Because of the manner in which fed beef production, FBEFQT, is estimated in the MSUAM (i.e., slaughter weights times numbers) and because of FBEFQT's limited involvement in other estimated equations, the adjustment achieved by this steer and heifer ratio equation, in large part, overcomes the biasedness inherent in the original MSUAM specifications.

$$RSLFSHSH = \cdot 418 - \cdot 075\ CORNPT_{t-1} - \cdot 004\ BFCALFP_{t-1} \qquad (5.2)$$
$$\qquad (7\cdot 35)\quad (4\cdot 34) \qquad\qquad (6\cdot 67)$$

$$- \cdot 102 \frac{FBEFPT}{BFLOWP} + \cdot 960\ RSLFSHSH_{t-1}$$
$$(3\cdot 17) \qquad\qquad (20\cdot 08)$$

$$\hat{\sigma}/m = \cdot 020 \qquad \bar{R}^2 = \cdot 96 \qquad DW = 2\cdot 66 \qquad 1960\text{–}82$$

$$RSLFSHSH = \cdot 276 - \cdot 113\ CORNPT - \cdot 004\ BFCALFP_{t-1} + 1\cdot 00\ FSLFSHSH_{t-1}$$

$$\hat{\sigma}/m = \cdot 025 \qquad \bar{R}^2 = \cdot 94 \qquad DW = 2\cdot 46 \qquad 1960\text{–}82 \qquad (5.3)$$

In the estimated model, corn prices, CORNPT, and beef feeder calf prices, BFCALFP, were chosen to measure input costs in the previous period. Current corn prices would capture the short-run impact of changing input costs, however, the long-run impact is more closely reflected by corn prices lagged one period.[13] A positive sign is expected on the $RSLFSHSH_{t-1}$, as a reflection of the longer term growth trend in fed beef production. The ratio of fed beef price to non-fed beef price, lagged one period was included to reflect output prices. As the price of choice beef rises, the profitability of fed beef production increases, and hence the steer-heifer ratio variable can be expected to rise. Therefore, the expected sign of this variable is positive. However, a negative sign was obtained in each formulation of this equation

[13] The coefficient on current period corn prices in equation (5.2) is also negative although smaller in magnitude and with a smaller t value.

(5.2).[14] For this reason, this output-price ratio variable was dropped and equation (5.3) was used in the retail meats model. This equation performs an important role in the retail demand model. Essentially it endogenises the substantial impact of changes in fed beef production, at the margin, on non-fed beef production during periods of expansion and contraction in the beef cow herd.

Following the equation for RSLFSHSH, six identities are estimated. Those identities provide values for the domestic consumption, retail per person, of each explanatory quantity variable used in the price dependent retail demand equations. Although it is not shown specifically in Figure 5.5 each of these consumption variables is solved simultaneously in the overall simulation model. Details of the factors used to make conversions[15] of product from live to retail weight are contained in the FORTRAN program presented in Appendix B.

Hence table beef, hamburger beef, pork and broiler consumption are simulated endogenously and are estimated directly from the simulation model. Domestic consumption of red meat, DCORMRC, and of poultry meat DCPMC, are only partially endogenously simulated in the model. In other red meat, pork is endogenous, but veal and lamb are not, at least at the retail level. Veal and lamb consumption are set at a constant average level of 1973-1982. For poultry meat consumption, other chicken meat is

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[14]Simultaneity bias between fed beef prices and the steer-heifer slaughter ratio may be partly responsible, i.e., an error in variables problem.

[15]These conversion factors were obtained either directly from USDA (1979) or have been indirectly estimated from data in USDA (1982a).

not determined by the model and likewise it is set at the constant average level of 1973-1982. Turkey consumption is endogenously determined by the model at the farm level, although not at the retail level in the MSUAM. Therefore, turkey production was converted to retail weight and to a per person basis for inclusion in the poultry meat consumption variable, DCPMC.

The retail price dependent demand equations are central to this retail component of the MSUAM. These estimated equations were presented, along with test statistics, in Chapter 4. For convenience of exposition, however, they are presented again in Table 5.3. The table beef price equation is specified with a second degree Legendre polynomial in own-quantities consumed. The hamburger price and broiler price equations each have first degree Legendre polynomials in own-quantities and disposable income per person. The preferred pork equation is a traditional fixed-coefficient model: the null hypothesis of fixed parameter coefficients could not be rejected. Justification of the specifications and estimation of these equations is contained in Chapter 4.

The two other types of behavioral equations contained in the retail meat demand component are the marketing margin equations for each retail product and the by-product value equations for beef and pork. Estimated equations for the meat market margins, the difference between the retail price of a particular meat and its farm value, are presented in Table 5.4. These equations allow for the absolute margin via the current farm price variables and allow for the percentage margin via the annual percentage change in the farm price variable. The current farm price variable can be expected to have a positive sign on its coefficient as

Table 5.3
Retail Meat Price Equations in the U.S. Meat Demand Model

Dependent Variable	Estimated Equations[a,b]	Summary Statistics $\hat{\alpha}/m$	$\bar{R}^2$	D.W.
Table Beef Price	RPBFR = 248.211 − 2.245 DCFBFRC + 1.280 PT1FB − .751 PT2FB (5.07) (5.68) (2.78) (3.06) − 1.990 DCNFBFRC − .196 DCORMRC − 2.097 DCPMC + 0.33 DICR (9.74) (.96) (5.54) (2.32)	.043	.78	1.61
Hamburger Beef Price	RPHMBR = 84.802 − 1.326 DCFBFRC − 1.812 DCNFBFRC + .618 PT1NF (2.59) (4.54) (10.92) (3.40) − .059 DCORMRC − 1.017 DCBRC + .046 DICR − .007 PT1DI (.29) (3.01) (3.74) (1.93)	.064	.84	1.79
Pork Price	RPPKR = 92.059 − .334 DCFBFRC − .351 DCNFBFRC − 1.0448 DCPKRC (6.19) (1.61) (1.81) (5.88) − 1.521 DCBRC + .041 DICR (5.38) (5.07)	.043	.86	2.37
Broiler Price	RPBRR = 65.232 − .382 DCFBFRC − .401 DCNFBFRC − .202 DCPKRC (3.74) (2.80) (4.29) (2.11) − 2.085 DCBRC + .693 PT1BR + .030 DICR − .008 PT1DI (9.94) (3.88) (5.01) (1.95)	.038	.99	2.24

[a]The table beef, hamburger beef and broiler equations were estimated for the period 1950-1982 and are contained in Tables 4.24, 4.25 and 4.27, respectively. The pork equation was estimated for the period 1960-1982 and may be compared with the pork equation in Table 4.3, estimated from 1950-1982.

[b]Variable code definitions are given in Table 5.1 and footnote (a) of Table 4.23.

Table 5.4
Estimated Farm-Retail Price Margins Equations: 1960-1982

Dependent Variable		Explanatory Variables														
		Current Farm Price				Change in Farm Price					Throughput					
	Constant	FBEFPT	BFCOWP	PORKPT	CHIKPT	ΔFBEFPT	ΔBFCOWP	ΔPORKPT	ΔCHIKPT	Lagged Margin	DCFBFR	DCPKR	DCBRR	$\hat{\sigma}/m$	$\bar{R}^2$	D.W.
Fed Beef Margin (MMBFR)	-.767	.388				-.107				.517	.006			.053	.67	2.15
	(.13)	(2.33)				(2.42)				(3.73)	(3.20)					
Non-Fed Beef Margin (MMHMBR)	-7.408		.902				-.175			.593				.091	.73	1.84
	(1.29)		(4.20)				(5.89)			(4.40)						
Pork Margin (MMKPR)	10.776			.501				-.094		.136		.004		.043	.74	2.30
	(2.77)			(5.83)				(4.75)		(.97)		(1.85)				
Broiler Margin (MMBRR)	9.305				.152				.069	.636			-.004	.035	.95	2.41
	(1.34)				(.98)				(2.81)	(2.66)			(1.37)			

margins tend to adjust over time with trends in farm level prices. A negative sign is expected on the change in the current farm price, since short-run increases in farm prices tend to decrease the margin, reflecting the hypothesis of price leveling or smoothing practiced by retailers. Lagged margin is included to reflect the longer term growth trend in the real cost of providing retailing and wholesaling services and to reflect the upward trend in value added in these services; hence a positive sign is expected. Some studies use real wage rates to capture this variation in margins, however, lagged margins would appear to have greater dynamic content and are therefore preferred.

Two conflicting hypotheses may be proposed for the coefficient sign on throughput, as an explanator of margins. One hypothesis is that margins decrease with increasing throughput as overheads are spread (Reeves, 1979). This is the cost-side explanation. Alternatively, increases in throughput are associated with demand-pull pressures. As demand strengthened, more livestock are slaughtered (following the initial stock retention phase), and margins widen in response to increased profitability in the subsector. Therefore, a positive relationship exists between throughput and margins. Some cost gains are achieved with greater throughput, however, the stronger influence toward widening margins is the increased throughput being drawn into slaughter plants. In the non-fed beef margin equation, throughput was not included. It has a positive sign but was not significantly different to zero. In slaughter plants, both economies of size and the throughput related variation in margins is more likely to be related to their primary function of fed beef slaughter. In many respects non-fed beef slaughter will more likely fill a residual role in slaughter plants.

The above hypothesized pattern of signs on regression coefficients is revealed in each of the estimated equations, except for broilers. The broiler subsector, unlike the beef and pork subsectors, is very highly coordinated and concentrated. Moreover, price levelling is not expected to be important in such an industrialized subsector where the same participants often control production, distribution and marketing (Reimund, Martin and Moore, 1981). Therefore, a positive sign on prices and changes in prices of broilers would reflect the ability of producer-wholesalers to influence their 'profit margin' positively with own-prices. Throughout in this equation reflects the increasing economies of size experienced in this subsector over time.

By-product value equations were estimated for beef and pork to provide the transmission between farm and retail prices. In years of strong product demand by-product value is a more important component, in absolute terms, of the total livestock carcass. By-products are, therefore, estimated as a function of current and past retail prices and the CPI. The same by-product value equation was used for fed and non-fed beef prices. The estimated equations for beef, BPVBFR, and pork, BPVPKR, are presented below in equations (5.4) and (5.5).

$$\underset{}{BPVBFR} = \underset{(1{\cdot}86)}{-4{\cdot}931} + \underset{(6{\cdot}70)}{{\cdot}198\ RPBFR} - \underset{(2{\cdot}58)}{{\cdot}080\ RPBFR_{t-1}} - \underset{(1{\cdot}70)}{{\cdot}465\ CPI} \qquad (5.4)$$

$\hat{\sigma}/m = {\cdot}118$ $\bar{R}^2 = {\cdot}68$ DW $= 1{\cdot}65$ 1960–82

$$BPVPKR + \underset{({\cdot}20)}{{\cdot}200} + \underset{(5{\cdot}36)}{{\cdot}079\ RPPKR} - \underset{(1{\cdot}65)}{{\cdot}024\ RPPKR_{t-1}} - \underset{(3{\cdot}39)}{{\cdot}517\ CPI} \qquad (5.5)$$

$\hat{\sigma}/m = {\cdot}139$ $\bar{R}^2 = {\cdot}68$ DW $= 1{\cdot}56$ 1960–82

To complete the integration of the U.S. retail meat demand model with the farm level components of the MSUAM, price transmission identities were required for each of the four retail products. Hence, farm product price is equal to the retail price less the marketing margin plus the by-product value (in the case of beef and pork) divided by a factor for converting retail weight equivalents to farm product equivalents (except for broilers which is already on a ready-to-cook basis).

5.4 Projections of Key Exogenous Variables

Simulations of economic and policy scenarios regarding the livestock subsector in the U.S. are dependent upon the assumption underlying projections of certain key exogenous variables. In this section the future trajectories of these variables in the model are given. Assumptions made about these key variables are drawn from those made in Michigan State University's 1983 Spring Report on the long-term forecast of U.S. and world agriculture (MSU, 1983). Details of these assumptions and the source of the projections are not repeated here. Nevertheless, some aspects of these projections are given.

Table 5.5 contains actual and projected values of U.S. population, inflation, interest rates and real disposable income per person. The forecast on inflation reflects the low inflationary growth expected over the next few years. Inflation is expected to increase gradually from 5.5 percent to 7.0 percent for the 1986-1991 period. Steady real disposable income growth is assumed over the medium-term.

Table 5.5

Actual and Projected Values of U.S. Population, Inflation, Interest Rates and Disposable Income: 1975-1991

Year	Civilian Population POPC Millions	Consumer Price Index CPI 1967=1.00	Prime Interest Rate PIR %	Real Interest Rate RIR %	Disposable Income Per Person, Real DICR $/Person	Rates of Change: Population %	Rates of Change: CPI %	Rates of Change: Disposable Income %
1975	213.8	1.61	6.29	3.91	3180	1.04	9.14	- .44
1976	215.9	1.71	5.19	3.04	3245	.98	5.77	2.02
1977	218.1	1.82	5.59	3.07	3313	1.02	6.45	2.12
1978	220.5	1.95	8.11	4.16	3395	1.10	7.66	2.48
1979	223.0	2.17	11.04	5.09	3386	1.13	11.33	- .27
1980	225.6	2.47	12.79	5.18	3272	1.17	13.50	-3.38
1981	227.7	2.72	15.31	5.63	3271	.93	10.40	- .01
1982	229.8	2.89	12.80	4.43	3270	.92	6.13	- .03
1983	232.0	3.00	10.80	3.60	3340	.96	3.80	2.20
1984	234.2	3.12	8.50	2.72	3430	.96	4.00	2.75
1985	236.5	3.26	8.50	2.61	3540	.96	4.50	3.00
1986	238.8	3.44	10.50	3.05	3660	.96	5.50	3.50
1987	241.0	3.65	10.00	2.74	3790	.96	6.00	3.50
1988	243.4	3.88	10.50	2.71	3920	.96	6.50	3.50
1989	245.7	4.16	11.00	2.64	4060	.96	7.00	3.50
1990	248.1	4.45	11.00	2.47	4200	.96	7.00	3.50
1991	250.4	4.76	11.00	2.31	4350	.96	7.00	3.50

Source: MSU (1983)

International income growth assumptions are presented in Table 5.6 for the major grain exporting and importing countries or regions. Growth is expected until 1987 when long-term growth rates are assumed to be achieved. The lower near-term growth rate is to reflect a slow recovery from the current recession. Medium population estimates based upon fertility rates, mortality rates, and immigration patterns affect a gradually declining population growth rate throughout the world (Table 5.7).

The 1983 base yields and growth rates are reported in Table 5.8. Yield assumptions are obtained from historical trends, USDA projections and from observations by agents in the field. The 1983 base yields are the trend value for 1983. Expected yields for 1983 are substantially higher for the U.S. due to the PIK program. Yields are also expected to be higher in Australia following the recovery from a drought in that country. Except for the U.S., total cropland used for wheat and coarse grain production is exogenously determined in the world component of the MSUAM (Table 5.9). Growth rates in the cropland base are based on historical trends and authoritative opinion.[16]

5.5 Validation of Model

Validation of the MSUAM has been conducted elsewhere and will not be repeated here.[17] In this section model validation will focus on the

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[16] Further explanation on the nature of these and other general assumptions in simulations of the MSUAM, especially in the grains component, see Schmitz, McCalla, Mitchell and Carter (1981, pp. 229-238).

[17] See Wailes (1983), Schmitz, McCalla, Mitchell and Carter (1981, pp. 227-229), and various MSU Agricultural Model Quarterly Reports.

Table 5.6

International Income Growth Assumptions: 1975-1991

Region	Real Growth Rates[a]				
	1975-81	1982	1983-84	1985-86	1987-91
	% per year				
Canada	3.60	-1.75	1.55	3.25	3.70
Australia	2.80	3.00	2.82	3.25	3.70
Argentina	2.80	-4.50	1.80	2.50	4.00
Brazil	7.90	0	.70	4.00	5.00
Soviet Bloc	2.80	3.00	3.00	3.00	3.00
Developed Markets	3.90	1.50	2.76	2.90	3.15
Less Developed Markets	5.30	1.60	3.63	4.20	5.00
Mainland China	3.08	3.50	3.25	3.00	3.00

Source: MSU (1983, p. 142)

[a]Index of GNP, 1970=100.

Table 5.7

Population Estimates for 1982 with
Projected Growth Rates for 1983-1991

Region	1982 Population	% Growth Per Year
United States	229.80	.96
Canada	24.60	1.33
Australia	14.80	1.08
Argentina	27.70	1.08
Brazil	135.00	2.19
Soviet Bloc	382.20	.71
Developed Markets	532.00	.50
Less Developed Markets[a]	2340.00	1.93

Source: MSU (1983, p. 143)

[a]Includes Brazil.

Table 5.8

Wheat, Coarse Grains, and Soybean
Yield Assumptions: 1983-1991

Commodity Region	1983 Base Yields[a]	Bushels/Acre Growth/Year
Wheat		
United States	38.00 (34.80)	.60
Canada	29.25	.45
Australia	19.65	.15
Argentina	25.60	.30
Soviet Bloc	28.72	.32
Developed Markets	54.99	1.19
Less Developed Markets	21.85	.45
Coarse Grains[a]		
United States		
Corn	118.00 (105.35)	2.35
Oats	55.40 (54.60)	.40
Barley	49.30 (49.80)	.80
Sorghum	60.30 (59.40)	.90
Canada	45.18	.88
Australia	21.90	.20
Argentina	49.92	1.32
Soviet Bloc	32.38	.48
Developed Markets	58.04	1.04
Less Developed Markets	19.57	.27
Soybeans		
United States	32.50 (31.10)	.30
Brazil	26.20	.30

Source: MSU (1983, p. 144).

[a]Coarse grain yields are based on a 56 pound bushel.

[b]1983 base yields are trend yields, not expected yields, except for the U.S. Base yields for the U.S. are expected to be higher due to the PIK program. U.S. trend yields are in brackets.

Table 5.9

Actual and Projected Cropland Harvested Area
of Wheat and Coarse Grains: 1975-1991

Year	United States[a]	Canada	Aus-tralia	Argen-tina	Soviet Bloc	De-veloped Mar-kets	Less De-veloped Mar-kets
	mpa[b]	--------------million harvested hectares---------------					
1975	261	17.3	12.5	11.2	146.2	47.8	155.5
1976	271	19.0	12.9	13.0	146.2	48.0	162.0
1977	277	18.0	14.3	9.8	148.0	46.8	159.0
1978	267	17.8	14.9	10.8	147.0	47.5	160.0
1979	275	17.0	15.3	9.4	144.0	48.2	162.0
1980	287	19.0	15.8	11.4	145.0	48.2	163.0
1981	296	20.5	16.2	11.1	145.0	48.2	165.0
1982	296	20.6	16.6	11.2	143.0	48.2	166.0
1983	272	21.4	17.0	11.3	144.0	48.2	168.0
1984	265	21.0	17.3	11.4	145.0	48.2	170.0
1985	277	21.1	17.6	11.5	145.0	48.2	172.0
1986	282	21.2	17.9	11.5	146.0	48.2	173.0
1987	288	21.3	18.2	11.6	147.0	48.2	175.0
1988	290	21.4	18.5	11.7	147.0	48.2	177.0
1989	293	21.5	18.9	11.8	148.0	48.2	178.0
1990	295	21.6	19.3	11.9	149.0	48.2	180.0
1991	299	21.7	19.8	12.0	150.0	48.2	182.0

Source: MSU (1983, p. 145).

[a]Includes soybean and cotton area.

[b]million planted acres

retail meat demand component and on farm livestock product prices which are estimated by the retail model.

Table 5.10 compares the predictive accuracy of (a) the individual equations when simulated as single regression models, (b) a dynamic simulation of the model when actual lagged endogenous variables are used, and (c) a dynamic simulation of the model when lagged endogenous variables are produced by the model. These dynamic model results are generated by the full simulation model when all equations are allowed to interact, in contrast to (a) above when equation performance is viewed in isolation.

The criteria of performance used in validation of the model are Thiel's inequality U-coefficient and the root mean squared percentage error. The U-coefficient takes values such that $0 \leq U \leq 1$, where a value of zero implies a perfect forecast and a value of one implies a complete lack of relationship between the predicted and actual values.[18] Coefficients presented in Table 5.10 for each model indicate that the equations may be used to project changes with a reasonable degree of confidence. The root mean square error percentage is the root mean

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[18] The coefficient is calculated from the formula

$$U = \sqrt{\frac{\Sigma(P_i - A_i)^2}{n}} \Bigg/ \sqrt{\frac{\Sigma(A_i)^2}{n}} + \sqrt{\frac{\Sigma(P_i)^2}{n}}$$

where P_i = projected value, A_i = actual value, and n = number of observations.

Table 5.10

Model Validation: Thiel's U and Root Mean Squared Error as a Percengage of the Mean: 1975-1982

	Individual Equations		Dynamic Model			
			Act. Lagged Endog.		Pred. Lagged Endog.	
	Thiel's U	RMS/ Mean %	Thiel's U	RMS/ Mean %	Thiel's U	RMS/ Error %
RSLFSHSH	.0125	.00	.0157	.03	.0111	.00
DCFBFRC	.0036	.14	.0284	8.33	.0207	.91
DCNFBFRC	.0110	.63	.0292	4.33	.0179	.04
DCPKRC	.0117	.52	.0230	6.29	.0190	4.69
DCBRC	.0131	.00	.0131	.00	.0131	.00
RPBFRC	.0248	.00	.0550	1.38	.0536	1.10
MMBFR	.0231	.99	.0364	.04	.0231	1.61
BPVBFR	.0591	.25	.1634	.11	.0146	.51
RPHMBR	.0361	.03	.0648	4.17	.0636	2.93
MMHMBR	.0437	2.04	.0750	1.42	.0757	.05
RPPKR	.0194	.04	.0431	9.48	.0402	7.21
MMPKR	.0210	1.34	.0189	1.14	.0139	.20
BPVPK	.0536	.43	.0847	3.54	.0808	2.33
RPBRR	.0204	.06	.0545	1.10	.0529	.72
MMBRR	.0191	.30	.0475	5.15	.0431	1.04
CORNPT	.0510	.48	.0991	2.20	.0918	1.79
PORKPT	.0108	.02	.0708	17.02	.0614	10.30
FBEFPT	.0017	.00	.1091	.83	.0955	3.95
BFCOWP	.0000	.00	.1258	2.20	.1251	2.67
CHIKPT	.0000	.00	.0699	8.06	.0715	6.91

square error divided by the mean of the actual values over the period, expressed as a percentage. This measures how well the model equations, on average, are tracking historical values. The results of greatest interest in Table 5.10 are those of the dynamic model simulations. Except for the farm price of pork, all variables display a percentage error of less than 10 percent, with most variables having a percentage error much less than five percent. Surprisingly, the model using predicted lagged endogenous variables performed better for most variables than the model using actual lagged endogenous variables. In later simulations, however, i.e., beyond the historical period, actual lagged endogenous variables are used while they exist.

Validation was conducted over the relatively recent historical period, 1975-82 because of the importance of a model's ability to track the most recent years of history. Overall, the model performed well with respect to their criteria, especially given the market volatility of these years and the fact that most of these behavioral equations were estimated using data over the 1950-82 period. The model can be expected to provide a reasonable representation of the behavior of retail meat demand for use in policy analysis.

Of course, model testing is not complete with dynamic within-sample simulation and the calculation of certain performance criteria, above. At this point a model is only conditionally accepted. The model must also perform satisfactorily and coherently with respect to impacts of specific changes in key exogenous (and endogenous) variables. That is, variable responses to such impacts must have coherence and correspondence with reality. This sensitivity analysis is conducted in the following section.

5.6 Base Level Projections of Endogenous Variables: Actual and Simulated Results

In Figure 5.6, simulated values for key endogenous variables in the MSUAM are shown for the period 1975-91, along with actual values from 1975 to 1982. The projections are conditional upon several assumptions regarding the nature of future changes in population, income, crop yields and other key factors. Also, this simulation represents the base model run for what is considered a most likely scenario of future market conditions. Results from the base model take into account the 1983 Payment-In-Kind (PIK) program for wheat and corn in the U.S.[19] Hence, the base model reflects a relatively weak grain market, especially for corn, with low prices and high yields. The impact of the coarse grains market on the livestock subsector will be discussed below.

In general the behavior of the model was satisfactory. Simulated values of the ratio of slaughtered fed steers and heifers to all steers and heifers slaughtered, tracked closely the actual series of data from 1975 to 1982. The behavior of simulated values of fed beef production also approximated actual values reasonably well. Note that beef cow numbers, non-fed beef, pork and broiler production have been exogenized

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[19] An analysis of this program using the MSUAM is contained in Ferris et al., (1983).

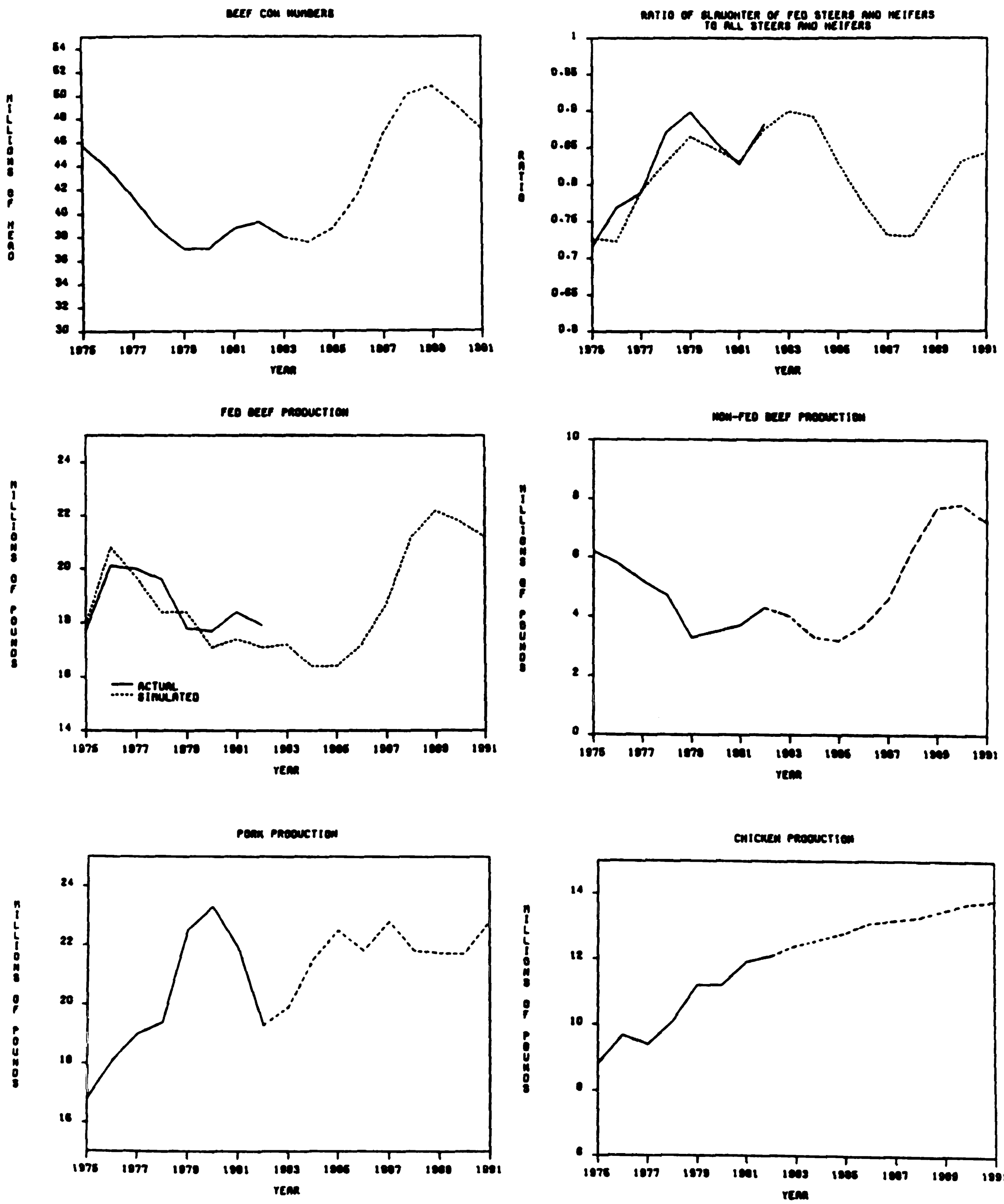

Figure 5.6

Base Level Projections: Actual and Simulated Results

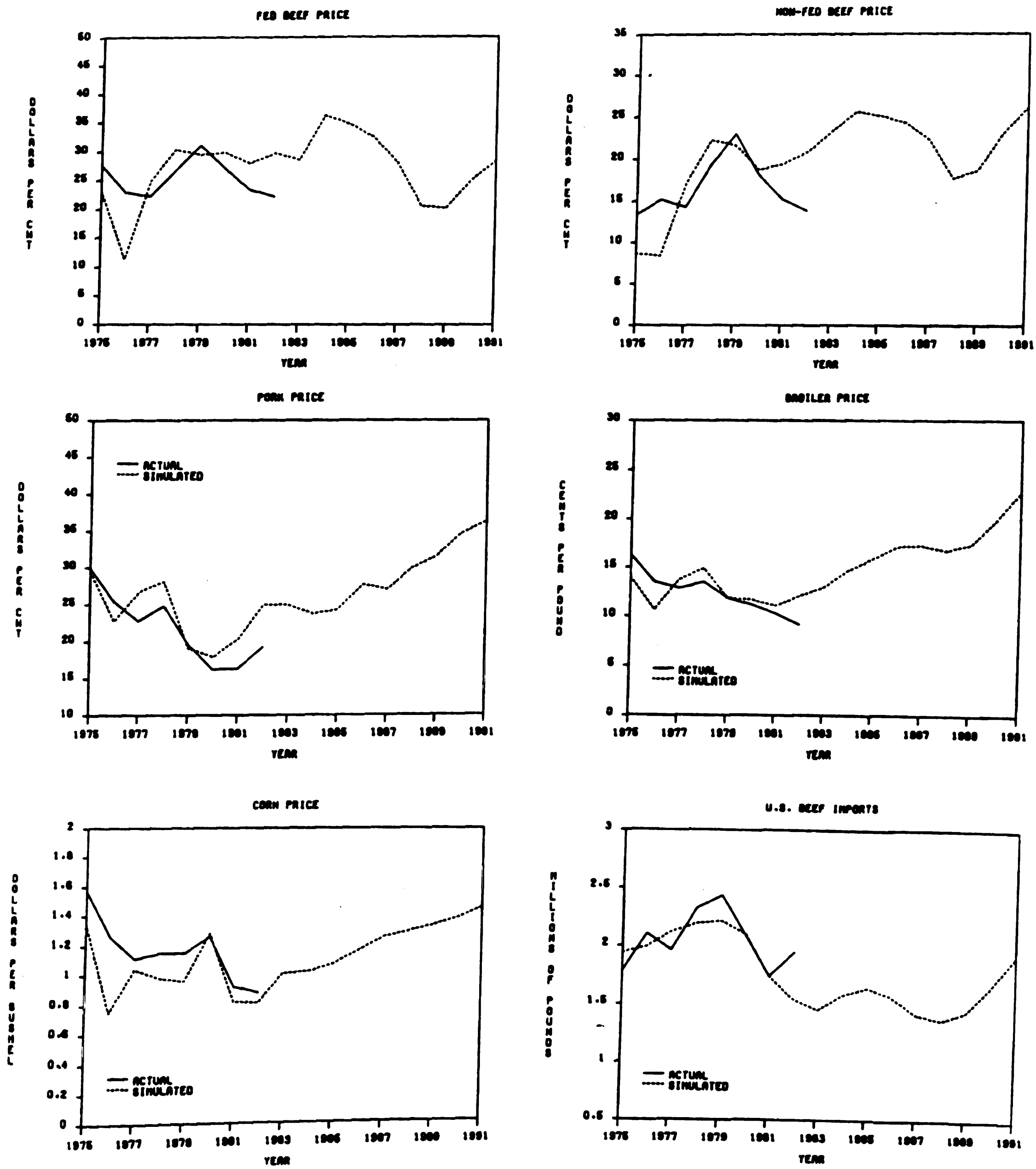

Figure 5.6 (continued)

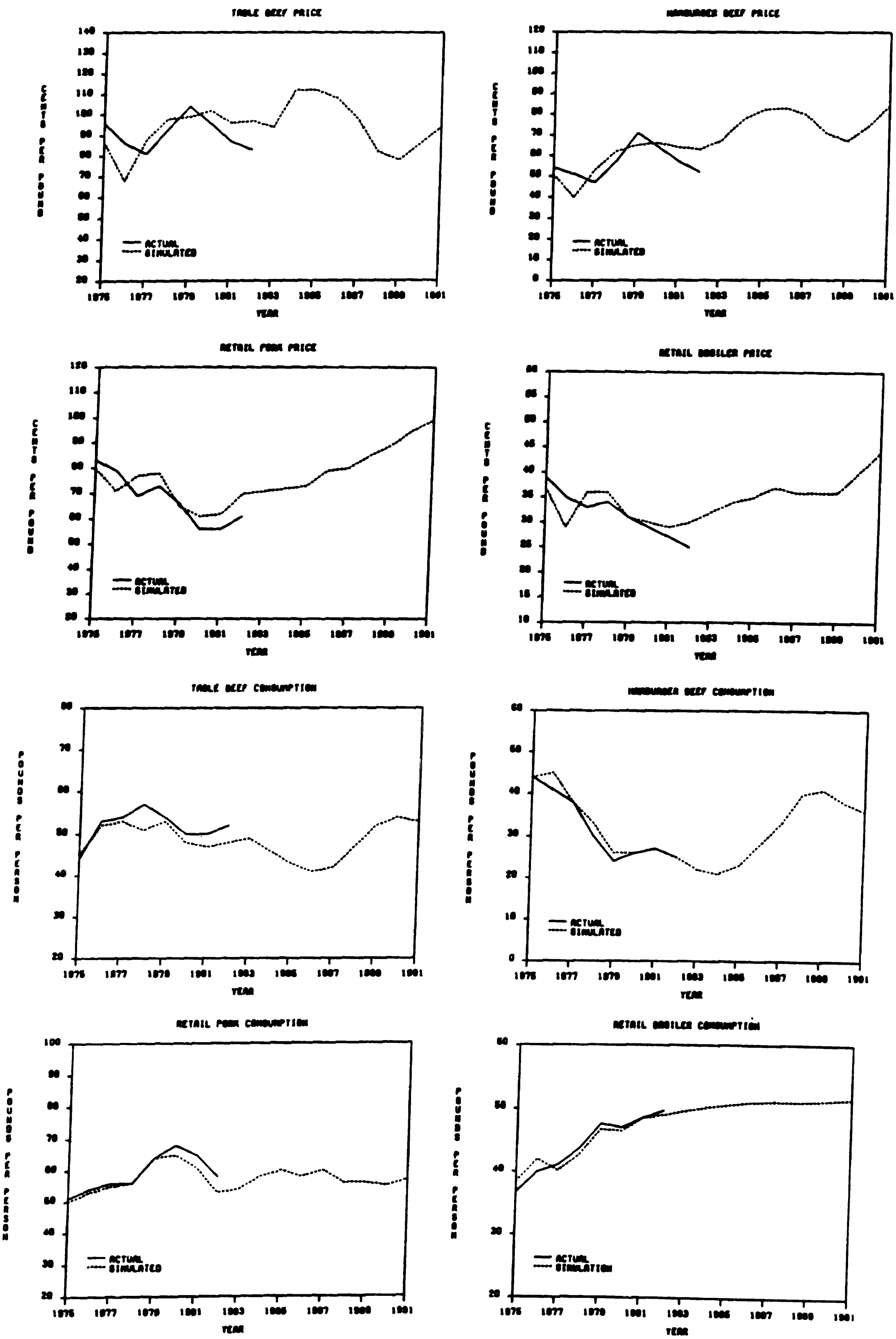

Figure 5.6 (continued)

over the historical period.[20] Nevertheless, the projected values over 1983-91 are endogenously determined by the dynamic interaction among all equations in the model.

The simulated series of farm product prices tracked reasonably well over the historical period, although there were some problems with underestimation of fed beef price in 1976 and overestimation in the last two years of this period for fed and non-fed beef prices. Most of the overestimation problems have been carried over from a similar overestimation in retail beef prices, table beef and hamburger beef. The likely cause of these problems is the estimated relationships for farm product quantities, namely, fed and non-fed beef production, which as evidenced in fed beef production, is also overestimated in the late years of the historical period.[21] Otherwise the tracking and direction of simulated values of retail prices are reasonable.

As noted earlier, results of non-fed beef imports presented in simulations represent the estimated adjusted base quota level of beef imports under the countercyclical formula. The assumptions underlying the use of this level to represent U.S. beef imports are (a) that the elasticity of the supply of beef exports is completely elastic, and (b) that the level of U.S. beef imports will continue to follow historical levels of actual imports which have fallen between adjusted base quota

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[20]In large models of this type it has sometimes been necessary to exogenize equations during the historical period in order to achieve satisfactory model convergence. Convergence is achieved when the change between iterations is less than .1 percent.

[21]This would indicate a need for some re-estimation and respecification of these weaker parts of the original model.

and the 10 percent higher trigger level (Table 5.1). Hence, model estimates of non-fed beef imports are more representative of long-term import levels. An analysis of the sensitivity of this assumption is presented later.

The estimated retail prices determine to a large degree the level of farm prices and therefore a similarity in the behavior of these two price series emerges. Simulated retail prices track quite closely actual values with exceptions in some years. As with farm prices, there is an overestimation in the last two years of the historical series. Simulations of retail consumption per person represent a close approximation to actual observations, especially in the case of hamburger beef, pork and broiler consumption.

For the projection period to 1991, the results indicate a continued decline in beef cow numbers to 1984 and thereafter an increasing trend in numbers peaking at 50 million in 1989. After this year the down phase of the cycle is evident. Because of the derivation of fed-beef production specified in the MSUAM, fed beef production follows a similar cyclical path. Non-fed beef production is also determined by cow numbers, although it more directly responds to changes in the prices of corn, feeder calves and hay.

Growth in fed beef production and the increased supplies of beef available for consumption depress retail beef prices and cause a subsequent decline in the farm price of fed beef. With this decline in fed beef prices the ratio of the slaughter of fed steers and heifers and all steers and heifers slaughtered declines until 1988 and thereafter increases. Projected beef imports follow a cyclical pattern at levels generally below the historical period. This is because beef cow numbers and overall beef production are rising for much of the projection period. Therefore, according to the countercyclical formula for beef imports and the rising phase in the U.S. beef cattle cycle, the adjusted base quota is relatively low until 1990. If the recent past levels of actual exports of beef to the U.S. are continued, then this suggests that for most of the 1980s, either voluntary restraint agreements (VRA) are likely to be imposed on countries exporting beef to the U.S. or more restrictively, the quota levels will be applied. On the other hand, if available supplies of beef from exporting countries are low, as predicted by Harris and Dewbre (1983), then U.S. quotas levels may not be prohibitive. Beef import quotas turn upwards after 1988 as U.S. beef cow production and total beef production turn downwards.

Projected retail prices of table beef reveal considerable fluctuation over the 1980s, reaching 95 cents (1967 dollars) per pound in 1991. This compares with 84 cents per pound in 1982. Retail prices of pork and broilers are projected to rise above historical levels to the seemingly overestimated level for pork of 99 cents per pound and 44 cents per pound for broilers in 1991. These rising real levels of retail broiler prices represents a significant turn around in the historical decline in real broiler prices. This would indicate a declining comparative advantage of broilers over beef at the retail level. The loss in advantage is illustrated by the levelling of retail broiler consumption per person and the steady upward trend in table and hamburger beef consumption. Retail pork consumption, by contrast, is projected to oscillate around the 1982 level. Overall, the interactive response among endogenous variables seems plausible and consistent with a priori expectations.

5.7 Sensitivity Analyses

A further test of the coherence (logic) of an economic simulation model may be made by conducting sensitivity analyses on certain key variables. Two analyses of particular interest are (a) the effect of a short livestock feed supply caused by a one-period reduction of 20 percent in feed grain and soybean yields, and (b) the impact of a one-period increase in non-fed beef imports[22] of 700 million pounds and a permanent increase in imports of 400 million pounds. These simulations, examined below, are compared with the results of the base level simulation.

5.7.1 Impact of a Short Livestock Feed Supply

In terms of the livestock feed markets in 1983, the base level simulation reflects the planted acreage and yield expected to arise under the newly instigated PIK program. Strong participation in the program reduced planted acres and increased average yields, since producers nominated, under the program, their lowest yielding land. A reduction of total grain supplies is expected to follow. Hence, the program will strengthen grain prices, for example, from .882 dollars to 1.008 dollars per bushel for corn between 1982 and 1983. Soybean prices will indirectly benefit from this strengthening of grain prices. However-

[22] All beef imports are assumed to be of non-fed beef.

ever, the PIK program is anticipated to maintain prices and reduce somewhat the grain surpluses rather than to cause a tight grain market and high grain prices. Besides farmer participation in the scheme, weather conditions remain an important factor in determining the final level of prices and the condition of the feed market.

Livestock producers have benefitted from the surplus condition of the feedgrains and soybean markets. Because of low feed costs, livestock producers have been shielded from the full ramifications of low real prices and a soft demand for their livestock products. To some extent the PIK program has reduced this shield. Nonetheless, grain markets still could not be characterized as tight while U.S. stocks of wheat and feedgrains remain at relatively high levels, historically (MSU 1983, pp. 147-148). Certainly a tight market would result if the effects of PIK were compounded by drought conditions in major feedgrain and soybean producing areas in the U.S. or by major U.S. grain trades internationally.

To simulate such a tight livestock feed market, U.S. yields of soybeans, sorghum and corn were reduced to around the levels of 1980, a year of excess demand for livestock feeds.[23] Base model yields in 1983 were reduced from 32.5 bushels per acre to 27.0 bushels per acre for soybeans, 60.3 to 47.0 bushels per acre for sorghum and from 118.0 to 94.9 bushels per acre for corn. This represents about a 20 percent reduction in overall yields. The effect of these yield reductions when simulated in the model was to increase corn prices from 1.01 to 1.14

[23]These three livestock feeds comprise the large bulk of livestock feeds.

dollars a bushel (13 percent), and to increase soymeal prices from 3.86 to 6.03 dollars per bushel (56 percent) in 1983. Wheat prices also rose, due to indirect effects, from 1.36 to 1.39 dollars per bushel (2.2 percent). The 1983 drought in the major grain and soybean producting areas of the U.S. was forecast by observers at the time of writing to reduce yields by almost double the yield reduction simulated in this analysis. Nevertheless, the nature of the impact of this drought should be clear from the scenario presented here.

Table 5.11 and Figure 5.7 present the short and long-run effects of these yield reductions on key farm and retail level variables. Because of the lagged specifications in many of the estimated equations often no immediate impact is felt. In this discussion, the <u>immediate impact</u> refers to 1983, the year the change was made; the <u>short-run impact</u> relates to 1984 and the <u>long-run impact</u> occurs in 1991.[24]

The short-run impact at the farm level of an overall 20 percent reduction in soybean and feedgrain yields is to increase the price of soybean and feedgrains in both the short and longer terms. This reduces the short-run production of fed beef[25], pork and broilers, each of which relies on livestock feeds. Non-fed beef production, by contrast, being predominantly pasture and range fed, does not depend on grain-based livestock feeds. Hence, the higher feed costs cause a shift of beef production from feedlot produced beef towards range fed beef.

[24]This is not a total multiplier although one could easily be calculated.

[25]Because fed beef production is specified to change primarily in response to beef and dairy cattle numbers short-term responses are reduced.

Table 5.11

Effect of a 20 Percent Decrease in Feedgrain Yields[a] (Strong Feed Market): One-Period Impact in 1983

		1982	1983		1984		Average 1985-91		1991	
Response Variables	Units	Actual	Base Level	Low Yields: Change From Base Level	Base Level	Low Yields: Change From Base Level	Base Level	Low Yields: Change From Base Level	Base Level	Low Yields: Change From Base Level
Beef Cow Numbers[b]	Millions	39.3	38.1	0	37.6	-1	46.3	0	47.1	-.7
Ratio Steer-Heifer Slaughter	Ratio	.882	.900	0	.893	-.010	.789	.030	.843	-.017
Farm Production[c]										
Fed Beef	Bil. lbs.	18.0	17.2	0	16.4	-0	19.9	2.5	21.3	.4
Non-fed Beef	Bil. lbs.	4.4	4.0	0	3.4	.2	5.8	.1	7.2	.2
Pork	Bil. lbs.	19.4	20.0	0	21.5	-.9	23.5	-.2	22.8	-.2
Broilers	Bil. lbs.	12.1	12.4	0	12.6	-.3	13.4	0	13.9	0
Farm Prices (1967 Dollars)										
Fed Beef	$/cwt.	22.2	28.7	0	36.3	.6	27.1	1.2	28.3	-.7
Non-fed Beef	$/cwt.	14.0	23.3	0	25.6	.4	22.5	-.2	26.1	-.4
Pork	$/cwt.	19.2	24.9	0	23.7	2.5	30.2	.6	36.3	.1
Broilers	$/cwt.	9.2	13.1	0	14.8	1.1	18.2	.1	22.8	-.3
U.S. Beef Imports	Bil. lbs.	1.566	1.453	0	1.580	-.022	1.578	.009	1.922	.036
Corn Price	$/bushel	.82	1.01	.13	1.03	.09	1.28	.2	1.45	.01
U.S. Net Exports Feedgrains	Mil. m. tns.	56.9	60.3	-2.8	63.5	-5.0	81.7	-.7	97.9	-.1

[a]See text for discussion of yield levels.

[b]1983 is an actual level

[c]Farm production and beef imports are in carcass weights except pork, which is in live weight.

[d]This is the actual level of the adjusted base quota. Actual imports of beef in 1982 were 1.939 million tons.

Table 5.11 (continued)

		1982	1983		1984		Average 1985-91		1991	
Response Variables	Units	Actual	Base Level	Low Yields: Change From Base Level	Base Level	Low Yields: Change From Base Level	Base Level	Low Yields: Change From Base Level	Base Level	Low Yields: Change From Base Level
Retail Prices (1967 Dollars)										
Table Beef	¢/lb.	83.9	94.5	0	112.1	1.3	94.5	-1.2	94.5	-2.6
Hamburger Beef	¢/lb.	51.9	68.0	0	76.7	.7	77.3	-.4	83.7	-1.9
Pork	¢/lb.	60.7	71.1	0	71.9	4.1	85.8	1.2	99.7	.2
Broilers	¢/lb.	24.8	31.6	0	34.0	1.9	37.9	.2	43.8	-.4
Consumption Per Person[b]										
Table Beef	Lbs.	51.9	49.4	0	46.4	-.6	47.6	-1.4	52.9	0
Hamburger Beef	Lbs.	25.4	22.3	0	20.7	1.2	34.2	2.1	36.0	1.7
Pork	Lbs.	58.4	54.2	0	57.8	-2.4	57.5	-1.1	57.4	.5
Broilers	Lbs.	49.7	49.7	0	50.2	-1.2	51.2	-.2	51.6	-.1

[a]See text for discussion of yield levels.

[b]Retail weight.

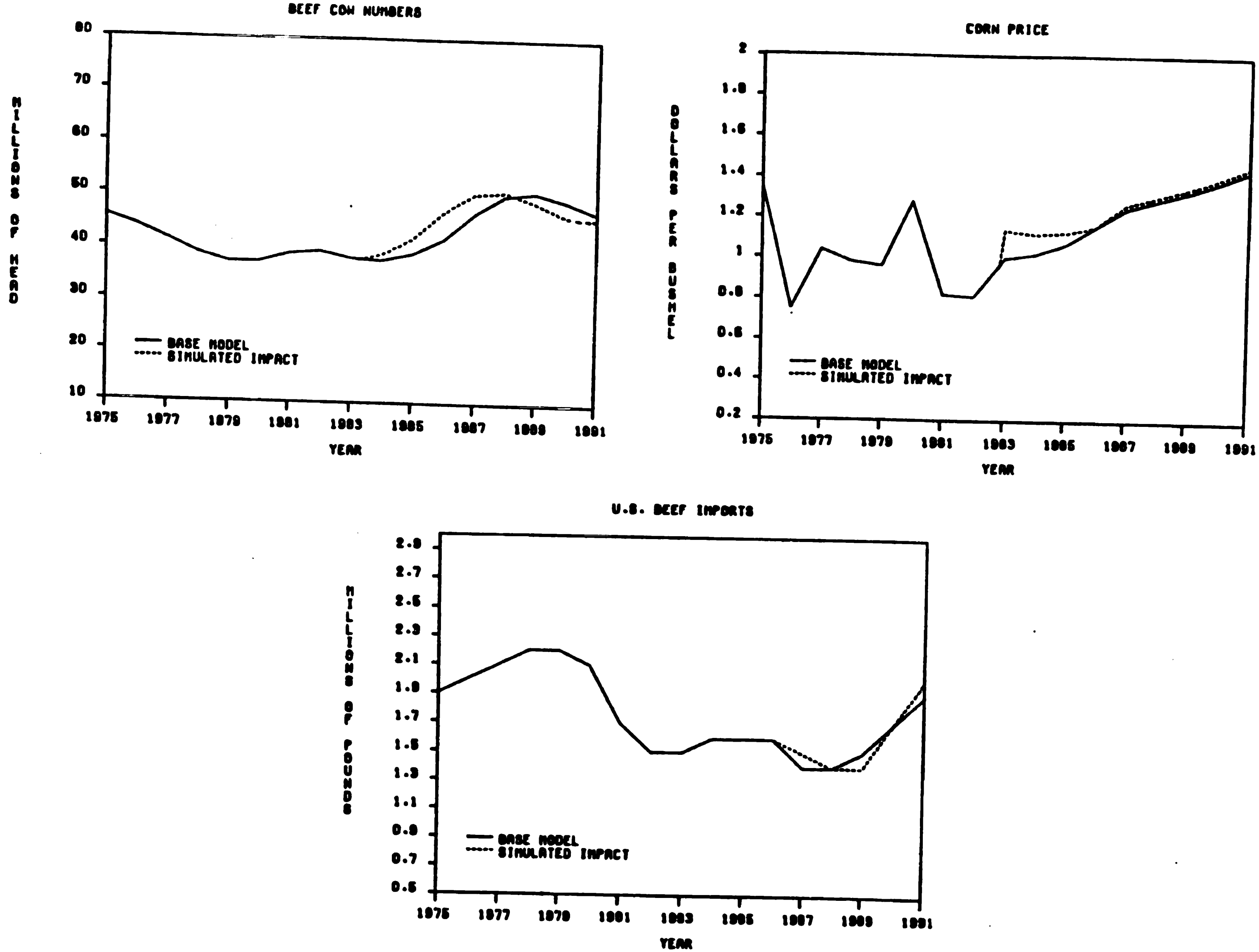

Figure 5.7 - Effect of 20 Percent Reduction in Feed Grain Yields: One-Period Impact in 1983.

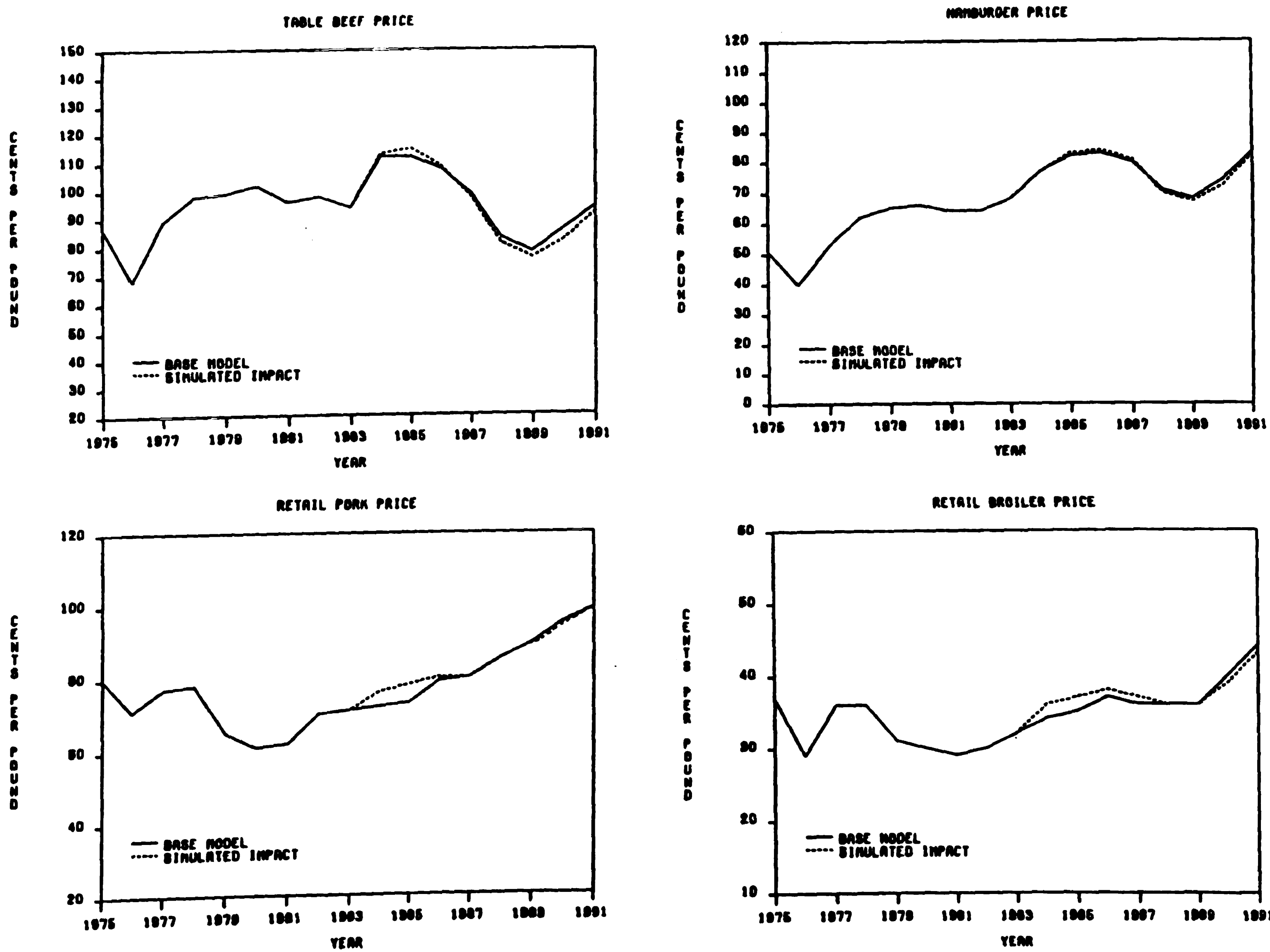

Figure 5.7 (continued)

Associated with this shift is a decline in the proportion of fed steers and heifers slaughtered. Beef cow numbers decline in response to two factors. First, since fed beef production is the driving factor in profitability in the U.S. beef cattle industry, beef cows are slaughtered and total numbers decline. Second, with the shift towards non-fed beef production, which increases in the short and longer runs, more cows are slaughtered. This increased beef cow slaughter brings about a reduction, albeit small, in the short-run level of U.S. beef imports. Since the reduction in feed grains and soybean yields is a one-period impact, this reduction occurs only in the short run.

An expected result of reduced soybean and feedgrain yields is a reduction in U.S. net exports of feed grains. The immediate impact is a 4.6 percent reduction in feedgrain exports. In the next period the reduction rises to 7.9 percent and then returns over the longer term to the base model levels.

The effect of these yield changes on retail consumption and prices is also shown in Table 5.11. The 20 percent decline in yields in the first period causes no immediate impact since farm production, and hence retail consumption, is predetermined with respect to retail prices. The short-run impact in the second period, however, is a 1.3 percent fall in retail consumption of table beef per person. Pork and broiler consumption also fall, by 4.2 percent and 2.4 percent, respectively. By contrast, hamburger beef consumption rises by 5.8 percent in 1984. The impact on table beef consumption is greater in subsequent periods, rising by 2-9 percent over 1985-91.

Retail prices rise for each product. Table beef prices increase by 1.2 percent in 1984, compared to less than one percent for hamburger beef, 5-7 percent for pork and 5.6 percent for broilers. Interestingly, the increased supply availability of hamburger beef per person might at first be thought to decrease its retail price. However, the reduced supplies of competing livestock products result in a net rise in hamburger prices. At the farm level, estimates in Table 5.11 indicate that a 20 percent reduction in soybean, sorghum and corn yields results in a 1.7 percent increase in fed beef prices, and a 1.6 percent increase in non-fed beef prices. Pork and broiler prices rise by 10.5 percent and 7.4 percent respectively in the short run. Note that, as expected, the price responsiveness of fed beef is greater than non-fed beef, and the responsiveness of farm prices is greater than retail prices. Over the longer term, at both farm and retail levels, production adjusts to these price increases to bring about market adjusting price declines.

5.7.2 Effect of Changes in U.S. Beef Imports

Several simulations were conducted to assess the effects of changes in U.S. beef imports. In the first simulation, beef imports were increased by 700 million pounds in one period, thereafter reverting back to the level of the adjusted base quota on imports. The choice of this increase of nearly 50 percent of base level imports and of almost 20 percent of base level non-fed beef production was not purely arbitrary. This scenario is illustrative of the effects of a substantial relaxation of the beef import quota in one year. It also allows for comparison with other studies using similar levels of change. Results of these effects on farm and retail prices and quantities are examined relative to the base model and are presented in Table 5.12.

The immediate impact of an increase in imports on the U.S. beef subsector is the lower farm prices for livestock and feedgrains. In the short run, non-fed beef production increases as female stock are slaughtered. The lower prices of fed beef, pork and broilers cause a decrease in production. After several periods non-fed beef production returns to the base level and the differences in prices become less apparent. Over the longer term, the aberrations, caused by the one-shot increase in imports, dampen and farm prices and quantities return more or less to the base model levels. Note the decrease in beef imports to levels below the base quantities following the initial impact of augmented imports.

A significantly greater impact is evident at the retail level. Overall, however, given the nearly 50 percent increase in the 1983 U.S. adjusted beef import quota the impact is relatively small. The increase represents approximately 40 percent of actual beef imports in 1982. In Table 5.13, a comparison is made of the effect on farm and retail prices of this 700 million pound increase in one year with a 400 million pound increase either as a once-and-for-all increase or as a permanent increase over the whole projections period, 1983-91.

An immediate impact of the 700 million pound increase in beef imports is to decrease table beef prices by 4.6 percent and fed beef prices by 7.3 percent. For the same increase in the level of imports, Freebairn and Raussar (1975, p. 687) obtained smaller decreases of 3.0 percent and 5.5 percent in respective prices. This seems consistent

Table 5.12

Effect of a 700 Million Pound[a] Increase in U.S. Beef Imports: One Period Impact in 1983

Response Variables	Units	1982 Actual	1983 Base Level	1983 Increased Imports: Change From Base Level	1984 Base Level	1984 Increased Imports: Change From Base Level	Average 1985-91 Base Level	Average 1985-91 Increased Imports: Change From Base Level	1991 Base Level	1991 Increased Imports: Change From Base Level
Beef Cow Numbers[b]	Millions	39.3	38.1	0	37.6	-.2	46.3	0	47.1	.1
Ratio Steer-Heifer Slaughter	Ratio	.882	.900	0	.893	.010	.789	.004	.843	.008
Farm Production[c]										
Fed Beef	Bil. lbs.	18.0	17.2	0	16.4	-0	19.9	-.1	21.3	.1
Non-fed Beef	Bil. lbs.	4.4	4.0	0	3.4	.3	5.8	0	7.2	.1
Pork	Bil. lbs.	19.4	20.0	0	21.5	-.1	23.5	-1.2	22.8	0
Broilers	Bil. lbs.	12.1	12.4	0	12.6	-0	13.4	0	13.9	0
Farm Prices (1967 Dollars)										
Fed Beef	$/cwt.	22.2	28.7	-2.1	36.3	.1	27.1	.1	28.3	-.2
Non-fed Beef	$/cwt.	14.0	23.3	-1.1	25.6	.2	22.5	0	26.1	-.1
Pork	$/cwt.	19.2	24.9	-.4	23.7	.2	30.2	0	36.3	0
Broilers	$/cwt.	9.2	13.1	-.6	14.8	-.2	18.2	0	22.8	-.2
U.S. Beef Imports	Bil. lbs.	1.566[d]	1.453	.700	1.580	-.024	1.578	.004	1.922	-.012
Corn Price	$/bushel	.82	1.01	-.01	1.03	-.01	1.28	0	1.45	0
U.S. Net Exports Feedgrains	Mil. m. tns.	56.9	60.3	-.1	63.5	.1	81.7	.1	81.7	0

[a]Approximately 50 percent of the 1982 adjusted base quota level and 40 percent of actual U.S. beef imports in 1982.

[b]See table 5.11

[c]See table 5.11

[d]See table 5.11

Table 5.12 (continued)

		1982	1983		1984		Average 1985-91		1991	
Response Variables	Units	Actual	Base Level	Increased Imports: Change From Base Level	Base Level	Increased Imports: Change From Base Level	Base Level	Increased Imports Change From Base Level	Base Level	Increased Imports Change From Base Level
Retail Prices (1967 Dollars										
Table Beef	¢/lb.	83.9	94.5	-4.3	112.1	-.5	94.5	.5	94.5	-.6
Hamburger Beef	¢/lb.	51.9	68.0	-2.6	76.7	-.9	77.3	.2	83.7	-.9
Pork	¢/lb.	60.7	71.1	-.7	71.9	-.1	85.8	0	99.7	-.1
Broilers	¢/lb.	24.8	31.6	-.9	34.0	-.2	37.9	0	43.8	-.2
Consumption Per Person [a]										
Table Beef	Lbs.	51.9	49.4	0	46.4	.8	47.6	.1	52.9	.9
Hamburger Beef	Lbs.	25.4	22.3	2.2	20.7	-.1	34.2	-.4	36.0	-.2
Pork	Lbs.	58.4	54.2	0	57.8	-.2	57.5	.1	57.4	-.1
Broilers	Lbs.	49.7	49.7	0	50.2	-0	51.2	0	51.6	-0

a Retail weight

Table 5.13

Effect of a One-Period and a Permanent Increase in U.S. Beef Imports

Response Variables[a]	Base Level 1983	One-Period Increase in U.S. Beef Imports (mill. lbs.): 700 — Immediate Impact 1983	One-Period Increase in U.S. Beef Imports (mill. lbs.): 400 — Immediate Impact 1983	Permanent Increase of 400 Million Pounds in U.S. Beef Imports: Maximum Response	Permanent Increase of 400 Million Pounds in U.S. Beef Imports: Long-Term Response 1991
		---Change from Base Levels------------			
Retail Prices (¢/lb.)					
Table beef	94.5	-4.3	-2.5	-2.7 (1)[b]	-1.0
Hamburger beef	68.0	-2.6	-1.5	-2.0 (1)	- .9
Pork	71.1	- .7	- .4	- .6 (8)	- .6
Broilers	31.6	- .9	- .5	- .6 (1)	- .4
Farm Prices ($/cwt.)					
Fed beef	28.7	-2.1	-1.2	-1.2 (0)	- .6
Non-fed beef	23.3	-1.1	- .7	- .7 (0)	- .4
Pork	24.9	- .4	- .2	- .3 (8)	- .3
Broilers	13.1	- .6	- .3	- .4 (0)	- .3
Corn Prices ($/bu.)	1.01	- .01	0	- .02 (4)	- .01
U.S. Beef Imports (mill. lbs.)	1453	700	400	417 (4)	354[c]
U.S. Net Exports feed Grains (mill. tons)	60.3	- .1	- .1	- .5 (5)	- .3

[a]Real prices are in 1967 dollars.

[b]The number in parenthesis is the delay of the maximum response in years.

[c]Minimum response to 400 million pounds permanent increase.

with this study's results since in their study, the 700 million pound increase was only 35 percent of actual imports. However, a significant departure of the results of this study from their results is in the effect on non-fed beef prices. In the present study the estimated decrease in hamburger beef prices is 3.8 percent and for non-fed beef prices the decrease is 4.7 percent. Not only are these responses substantially lower than their estimates of 5.2 percent and 13.1 percent, respectively, but the impact on non-fed prices is less than on fed beef prices. An economic explanation of this result is that beef imports are more closely substitutable with fed beef than they are with non-fed beef. However, neither the available evidence nor the model specification support this conclusion.

In subsequent periods, however, the results from both a one-period impact and a permanent increase show a larger effect on hamburger beef prices than on table beef prices. This suggests a more likely explanation for this departure. That is, the long-run specification of fed beef production, which responds primarily to changes in cattle inventories, causes an apparent underestimation of fed beef production and hence an overestimation on the short-run price response. This in turn would cause an underestimation in the hamburger beef price response.

The immediate effect of this one-shot increase of beef imports on retail and farm prices of pork and broilers is smaller than for beef products. There is a high degree of compatibility between the percentage changes of these estimates and those obtained by Freebairn and Raussar (1975, p. 687). The effect at the retail level was a decrease in pork prices of less than one percent, and a 2.8 percent decrease in broiler prices. At the farm level, the immediate impact is larger; pork prices fell by 1.6 percent and broiler prices fell by 4.6 percent. This result reflects a greater degree of substitution between hamburger/non-fed beef and broilers than between hamburger/non-fed beef and pork.

Also presented in Table 5.13 are the results of a one-period increase of 400 million pounds in U.S. non-fed beef imports. As expected the immediate impact is a little over half that described in the previous analysis. However, a 400 million pound or 28 percent increase in the 1983 quota level is a more realistic level to examine in terms of a permanent increase in beef imports.[26] As expected, the major impact is in the first or second periods. Also as expected, a permanent increase in beef imports gives a decrease in farm and retail prices in the long run. Nevertheless, changes in non-fed beef imports have a small long-run effect on retail and farm prices of meat products. As in other studies, this is due to the long-run response of domestic beef supply to price (Arzac and Wilkinson, 1979, p. 305).

5.8 Economic and Policy Simulation Analysis

In this section, results of specific economic and policy simulations are presented. These simulations illustrate the following direct impacts on retail demands for meats: (a) a sustained increase in demand for individual meats; (b) a sustained increase in real disposable incomes; (c) an analysis of time-varying parameter changes in demand; (d) a proposed reduction of the dairy cow herd to bring in to balance

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[26]See Appendix Table A3 for the results of a 10 percent increase in each year.

demand and supply in the dairy market; and (e) changing economic growth in major grain importing regions in the world.

5.8.1 Sustained Increase in Retail Meat Demand

A sustained increase of 10 percent in demand for each retail meat was simulated (Table 5.14). This increase represents a continuous shifting out of the demand curve over the projection period and reflects various scenarios of these retail products. In the case of table beef such a continuous increase in demand may be due to one or a combination of potential factors. These include a favorable shift in tastes and preferences towards table cuts of beef; the steady shift of the 'baby boom' group into older age cohorts, traditionally characterized as heavy consumers of table beef (steaks, roasts); or a successful advertising campaign aimed at increasing demand for table beef.

The sustained growth in demand for hamburger beef may also reflect a steady shift in tastes and preferences toward leaner meat or the effect of meat grade changes and changes in product specifications which more accurately reflect, at reasonable prices, the qualities of leaness and taste desired by consumers. Similar factors may also explain such shifts in pork and broilers. In the case of broilers, however, the individual growth in demand may follow from a continued preference for white meat and the alleged health factors associated with its consumption.

The initial impact of an increase in the demand for each product is an increase in farm and retail prices, since quantities are predetermined in the current period. The associated immediate rise in prices of

Table 5.14

Effect of a Sustained Increase of 10 Percent in the Retail Demand for Meats: Demand Increases Applied Individually

		Table Beef Demand			Hamburger Beef Demand			Pork Demand			Broiler Demand		
Response Variable[a]	Units	Short-Run Impact[b]	Maximum Response[c]	Long-Run Response[d]	Short-Run Impact	Maximum Response	Long-Run Response	Short-Run Impact	Maximum Response	Long Run Response	Short-Run Impact	Maximum Response	Long Run Response
		percentage change from base level											
Retail Prices:	¢/lb.												
Table beef		11.1	15.1 (4)	.3	-1.1	-1.1 (1)	- .2	- .5	.8 (5)	- .6	-1.2	-1.9 (2)	-1.1
Hamburger beef		3.7	-14.6 (6)[e]	-9.2	8.0	10.5 (6)	7.9	- .3	1.0 (6)	.2	- .4	2.8 (6)	1.2
Pork		1.1	- .7 (5)[e]	1.0	- .3	- .3 (1)	- .2	5.8	7.0 (3)	5.3	- .5	- .5 (1)	- .1
Broilers		2.6	- 7.5 (5)	-3.2	- .6	- .8 (2)	- .4	-1.5	-1.5 (2)	- .5	8.3	9.2 (6)	7.0
Farm Prices:	¢/lb.												
Fed beef		15.3	13.8 (5)	2.8	-1.4	-1.4 (1)	- .4	- .8	1.9 (5)	- .4	-1.7	4.2 (6)	-1.8
Non-fed beef		5.9	-23.0 (5)	-3.4	5.3	10.1 (5)	5.0	- .4	1.6 (5)	- .1	- .8	3.8 (6)	0
Pork		2.1	- .7 (3)	1.7	- .4	- .4 (1)	- .3	5.6	9.0 (3)	6.3	- .8	- .8 (1)	- .2
Broilers		3.4	-10.7 (5)	- .5	-1.0	-1.3 (2)	- .3	-2.2	-2.2 (1)	- .7	13.7	14.4 (6)	10.1
Beef Cow Numbers	millions	4.4	9.2 (3)	2.3	- .2	- .8 (4)	- .4	- .2	- .5 (8)	- .5	- .2	-1.8 (4)	-1.2
Corn Price		1.1	4.8 (6)	3.1	- .1	- .6 (4)	- .3	2.0	3.1 (3)	2.1	.4	.6 (2)	.2
U.S. Net Exports Feedgrains	mill. m. tons	0	-1.7 (4)	-1.1	0	.1 (3)	.1	- .2	-1.5 (3)	- .7	0	- .3 (2)	- .1
U.S. Beef Imports	mill. lbs.	5.0	-5.1 (4)[e]	12.1	-1.2	-3.4 (2)	- .1	- .1	- .7 (3)	- .4	0	-1.5 (3)	-1.4

[a] Real prices in 1967 dollars.

[b] Since the only immediate impact (in 1983) was the 10 percent increase in demand of the particular equation in question, the short-run impact (in 1984) is of greater interest.

[c] The number in parenthesis is the delay of the maximum response in years.

[d] The long-run response refers to 1991.

[e] Maximum negative response.

competing products following the increase in table beef demand is caused by a series of effects at the farm level. The rise in fed beef prices increases the corn price and feeder calf price which subsequently dampens fed beef slaughter and supplies available for consumption. With lower quantities available, retail prices of competing products rise temporarily. The following short-run response is a decline in competing product prices. Beef imports rise in the initial period following an increase in demand for table beef. This rise is associated with an inventory build-up in response to higher fed beef prices. In later years the sustained increase in table beef demand appears to have a negative influence on the level of beef imports. It is the rising beef cow inventory and the associated rise in the supply of cow beef which, according to the countercyclical formula, reduces the level of non-fed beef imports. Also, the increasing quantities of fed steer and heifer beef increases the supply of processing quality beef obtained from the lower quality cuts from these carcasses (Martin 1983, p. 6).

Note also that the corn price increases and U.S. net exports of feedgrains decrease when the level of demand increases for high grain consuming livestock products. As expected, the opposite effect occurs when hamburger beef demand increases.

5.8.2 Sustained Increase in Real Disposable Income Per Person

Real income growth projections contained in this model reflect the recent turnaround and expected growth in the U.S. economy. However, these base model rates of growth in real disposable income per person were increased by two percent in each year. As expected, this increase has a substantial positive effect on retail and farm prices for meats, the percentage increase more or less reflecting the income responsiveness among meat categories. The impact was greater in later periods.

U.S. corn prices responded in an upward direction while U.S. net exports of feedgrains declined in each period. With rising beef demand beef cow numbers increase as producers hold breeding stock from slaughter in expectation of greater returns in the future. As a result, beef production, especially non-fed beef production decline in the short-run. This reduction in non-fed beef production, and indeed total beef production impacts directly on the countercyclical formula for U.S. beef imports and augments the level of beef imports permitted under the quota. Over the long term, as producers begin to release cattle for slaughter, both fed and non-fed beef production increases. The latter increases both from the non-fed steer portion of the herd and from cull cows and bulls. In turn, cow beef and total beef production increase and hence imports are reduced.

5.8.3 Structural Changes in Demand Parameters

In the previous Chapter 4, estimates derived from time-varying parameter models indicated considerable variation in the flexibilities of retail demand for meat. Following from this result, three broad developments may be identified for further investigation.

First, over the past several years own-quantity flexibilities of all beef, and in particular, table beef, were shown to rise. This rise indicates a weakening of demand for table beef. That is, relatively large price adjustments in the market price are required to clear the market in response to small changes in quantities supplied. This recent trend has been explained in other studies by the negative quality changes which have led to a substitution of poultry meat for red meats. Second, among red meats, hamburger beef, because of its attributes of leaness and convenience in preparation, has been noted both in earlier discussion and in other studies, to have achieved greater preference among many consumers. Hence, hamburger beef appears to have become a stronger substitute for table beef. Third, income flexibilities for both table beef and hamburger beef, although rising steadily since 1979, have shown a relative decline since 1977. This down trend may suggest a decrease in the long-term growth rate of the U.S. beef industry.

These three scenarios, of certainly many possible ones, are presented below. The choice of these simulations was based primarily on the desire to investigate the effect on the U.S. beef subsector of a continuation of recent trends and development in the structure of retail meat demand.

(a) Continuous Increase in Own-Quantity Slope Coefficients

The prime objective of increasing the slope of the table beef demand relationship, i.e., making it steeper, was to investigate the effect of increasing the own-quantity flexibility for table beef on the beef subsector (Table 5.15 and Figure 5.8). This represents a continuation of recent trends. The coefficient for table beef quantity was increased linearly by one percent such that the original coefficient, , becomes .01 T for time, T = 1, 2,...,9, over the projection period 1983 to 1991.

Table 5.15

Effect of a Continuous Increase[a] in Own-Quantity Slope Coefficients in Retail Meal Demand Curves: Slope Changes Applied Individually

Response Variable[b]	Units	Table Beef Demand: Immediate Impact[c]	Table Beef Demand: Short-Run Response	Table Beef Demand: Long-Run Response[d]	Hamburger Beef Demand: Immediate Impact	Hamburger Beef Demand: Short-Run Response	Hamburger Beef Demand: Long Run Response	Broiler Demand: Immediate Impact	Broiler Demand: Short-Run Response	Broiler Demand: Long-Run Response
		percentage change from base level								
Retail Prices:	¢/lb.									
Table beef		- .9	-1.7	-3.2	0	0	- .1	0	.4	1.3
Hamburger beef		0	- .3	3.5	- .4	- .6	-4.6	0	.1	-2.2
Pork		0	- .1	- .2	0	0	0	0	.1	- .1
Broilers		0	- .2	1.5	0	0	.1	-2.2	-3.9	-14.6
Farm Prices:	¢/lb.									
Fed beef		-1.4	-2.2	-3.9	0	.1	- .2	0	.5	1.6
Non-fed beef		- .3	- .7	2.5	- .4	- .5	-3.4	0	.2	-1.8
Pork		0	- .2	- .4	0	0	.1	0	.2	- .2
Broilers		0	- .3	2.3	0	0	.1	-3.4	-6.0	-20.6
Beef Cow Numbers	millions	0	- .1	-4.7	0	0	.3	0	0	3.1
U.S. Corn Price	$/bu.	0	- .1	-2.1	0	0	.1	- .1	- .2	- .3
U.S. Net Exports Feedgrains	mill. m. tons	0	0	.8	0	0	0	0	0	.2
U.S. Beef Imports	mill. lbs.	0	- .4	-2.3	0	.1	.2	0	0	.7

[a]One percent linear increase.

[b]Real prices in 1967 dollars.

[c]See Table 5.14.

[d]See Table 5.14.

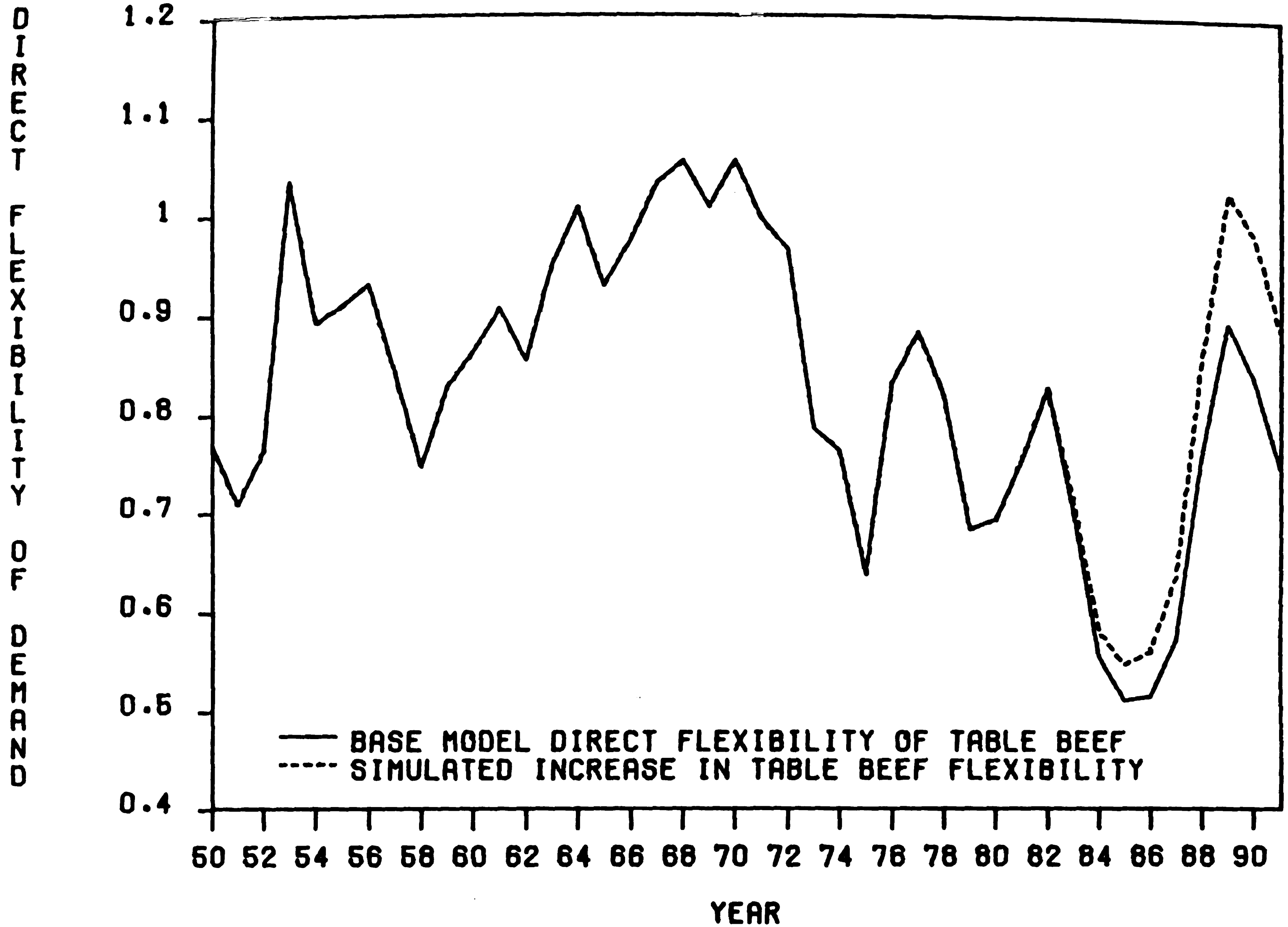

Figure 5.8 Simulated Increase in Table Beef Flexibility of Demand

The simulated results agree with a priori expectations. The continuous time-varying increase in the own-quantity coefficient increase the effect of a given quantity of table beef on the table beef price, decreasing the retail price in each period. The immediate impact of this one percent structural change is a .9 percent decrease in table beef price. In the short run, i.e., the next period, the higher relative prices of substitute products brings further increases in supply availability of those products, causing downward pressure on all other retail and farm level prices. The effect of this structural change is greater at the farm level. Lower fed beef prices result in reduced feeder calf and corn prices. Beef cow numbers are reduced in response to both the declining profitability of cattle production and the increased slaughter of breeding stock. As a result non-fed beef production is increased and U.S. beef imports reduced.

In the longer run with the continued run-down of the beef cow herd, non-fed beef production decreases. With fed and non-fed beef production falling below base model levels U.S. beef imports would be expected to increase. Somewhat surprisingly, however, imports continue below base levels. A likely explanation, given the components of the countercyclical formula in equation (5.1), is that the three-year moving average of production is falling faster than the ratio of the five-year to two-year moving averages for per person domestic cow-beef production is increasing. This apparent disfunction of the countercyclical formula was reported in another analysis (Simpson, 1982). In this analysis an opposite case was observed, where the trigger level, and hence the adjusted base quota level continued to increase even though production was increasing. This being so, the beef import formula appears to be ineffectual in achieving its purported countercyclical function.

(b) Continuous Decrease in Income Slope Coefficients

Using the same method, the coefficient of disposable income per person was allowed to decrease linearly over the projection period. Separate experiments were conducted for table beef and hamburger beef with the decrease being one percent in each case (Table 5.16). Since the result of this structural change is to increase prices for the given changes in income the overall effect is to cause decreasing income flexibilities over time. This declining income responsiveness of consumers operating at the market level implies a declining long-term growth in demand for the particular product in question.

In the case of table beef, for example, the immediate impact of a continuous decline in income responsiveness of one percent annually, is to reduce retail prices by 1-2 percent and farm prices by 1.7 percent. This percentage decline increases over time. As in the previous experiment of coefficient change, the decline in profitability of fed beef production leads to a steady reduction in beef cow numbers, an increase in non-fed beef production and to an associated decline in non-fed beef imports.

(c) Continuous Increase in Substitution Effects

Evidence presented here and in other studies indicate an adverse shift of consumer preferences and tastes away from table beef. Factors cited have included alleged, undesirable health attributes of table

Table 5.16

Effect of a Continuous Decrease[a] in Income Slope Coefficients in Retail Meat Demand Curves: Slope Changes Applied Individually

		Table Beef Demand			Hamburger Beef Demand		
Response Variable[b]	Units	Immediate Impact[c]	Short-Run Response[d]	Long-Run Response[e]	Immediate Impact	Short-Run Response	Long-Run Response
		percentage change from base level					
Retail Prices:	¢/lb.						
Table beef		-1.2	-2.7	-4.4	0	.2	.1
Hamburger beef		0	- .5	6.0	-1.9	-3.3	-13.0
Pork		0	- .4	- .6	0	.1	.2
Broilers		0	- .6	-2.3	0	.1	.2
Farm Prices:	¢/lb.						
Fed beef		-1.7	-3.3	-6.4	0	.3	-0
Non-fed beef		-1.4	- .8	4.2	-2.0	-3.0	-13.9
Pork		0	- .4	-1.1	0	.1	.2
Broilers		0	-1.4	3.5	0	.2	.3
Beef cow numbers	millions	0	- .3	-7.2	0	0	1.0
U.S. corn prices	$/bu.	0	-1.0	-3.4	0	0	.6
U.S. net exports feed grains	mill. tons	0	- .3	1.0	0	0	- .1
U.S. beef imports	mill. lbs.	0	- .6	-3.1		.3	- .3

[a]One percent linear increase.

[b]Real prices in 1967 dollars.

[c]1983.

[d]1984.

[e]1991.

beef, a general preference for lean meats, the effect of official government reports citing the desirability of eating white meats or fish, or the convenience and strong promotion of certain fast foods such as hamburger beef and chicken pieces. Following the period of high beef prices, especially of table beef, during the middle 1970s, changes in consumption habits of traditional and heavy consumers of table beef, also contributed to the substitution of the other meats, and indeed non-meats, for table beef (see Chapter 2).

The simulations presented in Table 5.17 reflect some of the quantitative effects of these types of structural changes occurring in the retail meat market over the past decade. In the first experiment, the coefficient of substitute product, hamburger beef, is increased only in other red meat demand relationships (table beef and pork) by one percent linearly over the projected period. The immediate impact of this structural change on table beef and pork prices is a decrease of .5 percent and .1 percent respectively. In the next period the impact is a .9 percent and .2 percent, respectively. Over the longer term, the impact lessens for table beef but increases for pork. Two forces account for this diminished long-term effect on table beef prices. The first is the increased competitiveness of hamburger beef associated with rising real hamburger prices. The second is the effect of lower corn prices and feeder calf prices in moderating the decline in fed steer and heifer slaughter. Farm prices reflect these changes. As expected fed beef production falls along with beef cow numbers. Similar to previous simulations, the slaughter of breeding stock and lower feeder calf and corn prices, augment non-fed beef production, forcing down U.S. beef imports under the countercyclical policy.

Table 5.17

Effect of a Continuous Increase[a] in the Substitution Effect of Hamburger Beef on Other Red Meat Demand and of Broilers on all Other Meat Demand: Substitution Effects Applied Individually

Response Variable[b]	Increase in Hamburger Beef Coefficients in Other Red Meat Equations			Increase in Broiler Coefficient in all Other Red Meat Equations		
	Immediate Impact[c]	Short-Run Response[d]	Long-Run Response[e]	Immediate Impact	Short-Run Response	Long-Run Response
	------------percentage change from base level-----------					
Retail Prices:						
Table beef	- .5	- .9	- .1	-1.4	-2.6	-3.9
Hamburger beef	0	- .2	3.9	- .7	-1.8	.8
Pork	0	- .2	- .7	-1.1	-1.8	-5.6
Broilers	0	- .1	2.0	0	- .2	3.4
Farm Prices:						
Fed beef	- .7	-1.1	.2	-2.2	-3.5	-5.8
Non-fed beef	- .1	- .4	3.7	-1.2	-2.3	.1
Pork	- .2	- .3	- .9	-1.7	-2.8	-7.1
Broilers	0	- .2	2.9	0	- .2	5.0
Beef cow numbers	0	- .7	-4.3	0	- .2	-7.0
U.S. corn price	0	- .1	-2.0	- .2	- .6	-5.0
U.S. net exports feed grains	0	0	.7	0	0	.3
U.S. beef imports	0	- .2	-1.0	0	- .5	-3.5

[a]One percent linear increase.

[b]Real prices in 1967 dollars.

[c]1983.

[d]1984.

[e]1991.

This case of the effect of changes in the structural relationship of hamburger quantities on other red meats may be usefully juxtaposed with the case of increasing structural competition of broiler consumption on retail prices of all other meats. This scenario attempts to recreate, or perhaps more precisely, extrapolate an existing development in retail meat demand in the U.S. To date retail broiler prices have exhibited a strong downward trend in association with a consistent growth in levels of broiler consumption. Evidence of growing consumer preferences and tastes underscore this trend. For various reasons, only some of which can be fully substantiated, chicken has been promoted as a more healthful form of meat protein. It has been credited with a lower fat content although its production involves the extensive use of growth additives and antibiotics in feedstuffs (see Chapter 2). Convenience in preparation and purchasing as a ready-to-eat food have also contributed to its increasing share in the consumer meat budget and in overall meat consumption. The factors appear to have strongly influenced the structure of the demand for other meats considered in this study.

The immediate impacts of the one percent continuous increase in the broiler-quantity coefficient on table beef, hamburger beef and pork demands are a 1.4 percent, .7 percent and 1.1 percent decline in their respective prices. The short-run impact is approximately double these percentage reductions in price. Farm level declines are greater in each case. U.S. corn price and beef imports decline both in the short and long runs. Compared to the impact of the similar structural change considered for hamburger or other red meats, the impact of the rising cross-effect of chicken meat on other meats is substantially greater. This is to be expected, first, because the impact is widespread and, second, because of the large cross-coefficients of broilers versus hamburger.

In each of the simulations of structural change in retail meat demand in the U.S., the underlying scenario has been similar in impact although viewed from different perspectives. The recent history of the demand for table beef has been projected in terms of the implications of a rising own-quantity flexibility, declining income flexibility, and increasing cross-quantity flexibilities. In each case the result has been lower retail and farm prices for all products in the short-run but also in the long-run for table beef, lower corn prices, beef cow numbers, and generally, lower U.S. beef imports.

5.8.4 Impacts of a Proposed Dairy Herd Reduction Program

Legislation was tabled in 1983 in the U.S. House of Representatives to implement a dairy cow herd reduction program. The objective broadly is to achieve a balance in the U.S. dairy market and hence reduce the large and growing annual cost of the current price support program. Details of the herd reduction program are not yet firm, however, in essence it is to provide incentives to producers to undertake dairy cow culling in order to decrease numbers more in line with effective demand. The presently proposed legislation provides for this program to be undertaken within one year. There is an amendment to this proposal, supported by the National Cattlemen's Association and others, proposing to postpone the program's implementation until 1984, to avoid the seasonal peak in cow and hog slaughter, and to temporarily suspend the incentive if total federally inspected cow slaughter exceeds certain initial levels on a weekly basis.

Certainly, the achievement of dairy market balance in the immediate term, 1983, can be expected to have a greater impact on the beef cattle market than if dairy herd reduction was carried out over a number of years. In terms of goals of market stability, there is strong reason to minimize the disruption of the beef and beef cattle markets by permitting the increase in dairy cow slaughter to be gradually absorbed into regular red meat supplies. A more obvious area where a one-year dairy cow slaughter program would be felt is U.S. beef imports. Most, if not all, dairy cow beef would compete directly with these imports, but would also be expected to bring about a direct reduction in the level of imports through the operation of the countercyclical beef import formula.

In this section these two broad alternatives, namely to achieve dairy cow herd reduction in one year versus over several years, are examined. This analysis is by necessity, somewhat aggregative although the general order of magnitude of the impacts of the two policy alternatives should be obtained.

In January 1, 1983 dairy cow numbers were 11,066 thousand head. The Spring 1983 report of the MSUAM (MSU 1983, p. 61) contains a 1983 estimate of milk produced per dairy cow of 1,250 pounds, giving U.S. milk production of 138,500 million pounds. Total supply including beginning commercial stocks and imports is estimated at 147,400 million pounds in 1983. Domestic consumption (utilization) is estimated at 127,300 million pounds including 2300 million pounds consumed on farms.

Supply is therefore some 14.5 percent or 18,500 million pounds in excess of demand in 1983.

In terms of the annual average level of milk production per cow, this excess 18,500 million pounds represents 1,480 thousand dairy cows or 13.37 percent of the 1983 dairy cows herd. If it is assumed that all dairy cows produce the average amount of milk per cow, the slaughter of this excess number of dairy cows would bring supply into balance with demand, ceteris paribus. This assumption, however, may be quite unrealistic as it is likely that farmers would slaughter their less productive cows before others. A distribution of the national dairy cow herd by productivity per cow would enable a more realistic assumption to be made. However, neither national nor useful regional distribution data are readily available.

In a somewhat arbitrary fashion, therefore, the lower bound on the number of dairy cows slaughter needed to bring supply into balance with demand was the rounded figure of 13 percent.[27] The upper bound on dairy cow slaughter was even more arbitrarily chosen at 2,213 thousand cows or 20 percent of the 1983 dairy cow herd. This percentage implies an average productivity of culled cows of 8,360 pounds per cow or culled cows approximately two-thirds as productive as the national average for 1983 estimated in the MSUAM. In summary, a 13 percent and 20 percent dairy cow herd reduction implies the slaughter of 1,439 thousand and 2,213

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[27]This is most certainly a lower bound. Nevertheless, a more detailed analysis may enter into the calculations, a producer participation factor. In this study, a 100 percent participation is implicitly assumed.

thousand cows, respectively. This slaughter may be carried out in one year or over a three-year period, 1983-85.

To arrive at dairy cow beef production the number of dairy cows slaughtered were multiplied by the weighted average dressed weight of bulls and steers in 1981 (Table 5.18).[28] When dairy cows are slaughtered and dairy cow beef enters the beef market over a three-year period, production is assumed to flow into the market in three equal portions. In terms of the mechanics of simulating the impact of this additional non-fed beef coming into the U.S. beef market, quantities were exogenously added to total non-fed beef production in the appropriate years.

The one-year slaughter program can be expected to have a substantial immediate impact on the U.S. beef subsector (Table 5.19). The three-year slaughter program, as expected, is considerably less disruptive in the first year. However, over the longer term a much greater affect on retail and farm prices would be felt. The simulations of a one-year slaughter program, assuming a 13-20 percent dairy cow herd reduction, indicates a 4-6 percent reduction of table beef prices in the immediate term. Hamburger prices fall by 3-5 percent, with smaller declines in retail pork and broiler prices. With this one-year shock, the demand effects of available supply reductions in the following year, cause a sharp increase in product prices. When the slaughter program is operated over a three-year period, the immediate decrease in retail table beef and hamburger beef prices ranges between 1-4 percent and 1-3

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[28]1981 was the latest available data (USDA, 1982a).

Table 5.18

Production and Allocation of Dairy Cow Beef Under Alternative Dairy Cow Herd Reduction Policies

	Units	Percentage of Dairy Cow Herd Slaughtered	
		13	20
Number of Dairy Cows Slaughtered[a]	thousands	1439	2213
Weighted Average Dressed Weight of Cows, Bulls, Stags[b]	lbs	537	537
Total Dairy Cow Beef Production:			
Slaughter in 1 year	'000 lbs	772.7	1188.4
Slaughter over 3 years	'000 lbs	257.8	396.3

[a]Base on January 1, 1983 dairy cow herd of 11,066 thousand head.

[b]Data contained in USDA (1982a).

Table 5.19

Potential Impact of Proposed U.S. Dairy Cow Herd Reduction Program

		Dairy Cow Slaughter Occuring Over:											
		One Year						Three Years					
		Percentage of Dairy Cow Herd Slaughtered to Achieve Dairy Market Balance:											
		13			20			13			20		
Response Variable[a]	Units	Imme-diate Impact[b]	Short-Run Re-sponse[c]	Long Run Re-sponse[d]	Imme-diate Impact	Short Run Re-sponse	Long Run Re-sponse	Imme-diate Impact	Short-Run Re-sponse	Long-Run Re-sponse	Imme-diate Impact	Short-Run Re-sponse	Long-Run Re-sponse
		--------percentage change from base level--------											
Retail Prices:	¢/lb.												
Table beef		-4.0	2.7	-.5	-6.1	3.6	-1.0	-1.4	- .9	-2.2	-3.5	-4.5	-5.5
Hamburger beef		-3.4	1.5	-1.7	-5.1	2.3	-2.3	-1.2	- .7	-2.4	-2.9	-5.0	-5.1
Pork		- .8	- .8	-1.6	-1.4	-1.3	-2.2	- .3	- .7	-1.9	- .7	-1.3	-3.0
Broilers		-2.5	0	-1.6	-3.8	.3	-2.3	-2.5	-2.1	-2.5	-2.2	-3.5	-4.3
Farm Prices:	¢/lb.												
Fed beef		-6.3	3.9	- .4	-9.8	6.1	- .7	-2.1	- .6	-3.2	-5.6	-5.5	-7.8
Non-fed beef		-4.7	4.3	- .4	-7.3	6.6	- .8	-1.7	0	-2.3	-4.3	-5.1	-5.7
Pork		-1.2	1.3	-1.9	-2.0	-1.7	-2.8	- .4	- .8	-2.5	-1.2	-1.7	-3.9
Broilers		-3.8	0	-2.2	-6.1	0	-3.1	-1.5	-1.4	-3.1	-3.1	-5.4	-5.7
Beef Cow Numbers	millions	0	- .5	2.5	0	- .8	4.0	0	- .3	3.4	0	- .5	5.9
U.S. Corn Prices	$/bu.	-5.9	-3.2	-3.4	-9.2	-4.6	-4.2	-1.5	-2.9	-2.8	0	-2.2	-4.1
U.S. Net Exports Feedgrains	mill. m. tons	.8	1.7	.8	1.7	3.0	1.3	0	0	.8	- .7	- .9	1.1
U.S. Beef Imports	mill. lbs.	-2.8	-3.2	-1.6	-4.1	-4.4	-2.1	- .7	-2.5	-3.1	-2.1	-6.3	-7.3

[a]Real prices in 1967 dollars.

[b]1983

[c]1984

[d]1991

percent, respectively. However, in the long-run, prices fall substantially more than long-run declines with the one-year program.

With the overall profitability of beef production reduced by the inflow of dairy cow beef onto the meat markets, beef cow numbers fall. The short-run impact is greater in the one-year program although, as expected, the long-run response is greater in the three-year program. Corn prices seem to fall more in the one-year program, both in the short and longer runs.

Perhaps the most consistent and substantial impact of this dairy cow herd reduction program falls on U.S. beef imports. Again the trade-off is between greater short-run declines in imports with the one-year slaughter program versus greater long-run declines with the three-year program. However, the disruption and market instability caused by the one-year program is likely to impose a greater cost on the subsector than when dairy cow slaughter is spread over a longer time period. Certainly in the latter case greater opportunity exist for market planning to cope with adverse long-run effects.

5.8.5 Effect of Changing Income Growth in World Markets

In recent years, the developing country markets, the Soviet Bloc and mainland China have accounted for almost all of net imports of world wheat, almost 60 percent of world coarse grains and up to 40 percent of soybean net imports. To this group of world markets, the U.S. provides around 50 percent of wheat, 75 percent of coarse grains and more than 60 percent of soybean net imports. In the short-run net imports are highly variable depending on production. In the long-run the income, population and productivity growth are the major determinants. When these regions are experiencing high economic growth their import demand for wheat and coarse grains rises. Depending on the level of U.S. livestock and livestock product prices, this import demand competes with the U.S. livestock subsectors for feedgrains. It may be expected, therefore, that changes in the rate of income growth of these grain-importing regions will influence economic conditions in the U.S. beef subsector.

Simulations of high and low income growth scenarios for developing markets, the Soviet Bloc and mainland China are presented in Table 5.20. Income growth rates for these regions were increased or decreased by three percent, relative to base level assumptions given earlier in Table 5.6, to give the high and low growth scenarios.

The short-run impact of low 'world' income growth on U.S. prices of meats is rather small, although the long-run decline in real prices becomes substantial. The impact is greatest for heavy feedstuff consuming industries, namely, pork and broilers. The greatest impact, logically, is on corn prices and U.S. net exports of feedgrains. For example, corn prices decline by one percent and 11 percent in the short and long runs, respectively, under the low income growth scenario. The low corn prices and reduced feedgrain exports reduce feed costs to U.S. livestock producers. Production increases in response to these incentives and hence prices fall. Notably, it appears that these changes in income growth in major world grain importing regions has a negligible impact on U.S. non-fed beef imports.

Table 5.20

Effect of Low Versus High Income Growth[a] in Developing Markets, Soviet Bloc and Mainland China

Response Variable[b]	Unit	Low Income Growth: Short-Run Impact	Low Income Growth: Long-Run Response	High Income Growth: Short-Run Impact	High Income Growth: Long-Run Response
		percentage change from base level			
Retail Prices:	¢/lb.				
Table beef		- 0	-1.1	0	.7
Hamburger beef		-.1	-1.8	0	1.9
Pork		-.3	-5.7	0	4.3
Broilers		-.3	-4.8	0	3.9
Farm Prices:	¢/lb.				
Fed beef		-.3	-2.5	0	2.1
Non-fed beef		0	-1.9	.4	1.9
Pork		-.4	-8.0	0	6.6
Broilers		-.7	-6.1	0	4.8
Beef Cow Numbers	millions	0	.2	0	-1.1
U.S. Corn Price	$/bu.	-1.0	-11.0	0	13.1
U.S. Net Exports Feedgrains	mill. m. tons	-2.7	-7.0	1.9	9.3
U.S. Beef Imports	mill. lbs.	0	-.5	0	0

[a] Income growth rates for these regions were increased and decreased by 3 percent, relative to base level assumptions given earlier in Table 5.6.

[b] Real prices in 1967 dollars.

5.9 Summary of Main Points

Preferred continuous time-varying parameter models of the four major retail meat categories, estimated in the previous chapter, were integrated into the retail meat demand component of the Michigan State University Agricultural Model (MSUAM). This U.S. retail meat model, together with other model components of the U.S. livestock and grains sector and world wheat and feedgrains regions, were used in simulations of various policy and economic scenarios of national and world agricultural markets. Scenarios chosen reflected specific structural changes which may potentially impact these markets. Particular emphasis was given in those simulations to the impact which these structural changes may have on U.S. imports of processing quality beef.

An overview of the MSUAM and its structure were given. Details of the retail meat demand component with its linking and transmission equations were also presented. Comparisons of actual values with simulated results for the endogenous variables over the 1975-82 period provide one method of validation of the estimated model. Validation also involved an assessment of dynamic simulation experiments of impacts on key model variables. Projections to 1991 suggest rising real prices for broilers at retail. This represents a significant turnaround in the historical decline in real broiler prices and indicates a declining comparative advantage of broilers relative to beef at retail. This loss in advantage is illustrated by the stabilizing of retail broiler consumption per person and the upward trend in table beef and hamburger beef consumption through the late 1980's.

Structured into the base model projections are reduced planted acreage and above average grain yields to reflect the newly instigated Payment-In-Kind (PIK) Program. Contrasting these base model results were simulated drought effects on U.S. feedgrain yields, 20 percent lower in 1983. This raised corn prices 13 percent in that year. Higher feed costs led to a shift from feedlot produced beef towards range and pasture produced beef. Beef cow numbers decline in response to the declining profitability of beef cattle production and in response to the increased slaughter of cows. The one-year impact from 20 percent lower feedgrain yields, causing increased cow slaughter and increased production of processing quality beef, brought about only a small reduction in U.S. beef imports. Retail prices increased in the short-run, especially for feed grain and soymeal intensive products, pork and broilers, and then decreased in later periods.

The impact of a 50 percent one-year increase in the 1983 adjusted beef import quota was relatively small. A similar conclusion was reached in other studies. The immediate impact is to decrease table beef prices by 4.6 percent and fed beef prices by 7.3 percent. Hamburger prices fell by 3.8 percent while non-fed beef prices fell by 4.7 percent in the initial year of impact. In the following years, the results from both a one-period impact and a permanent increase in beef imports show a larger price effect on processing quality beef prices than on table beef prices. The long-run specification of fed beef production, which responds primarily to changes in cattle inventories, causes an apparent underestimation of fed beef production and hence an overestimation of the short-run price response.

A sustained 10 percent increase, in retail demand for meats, applied on an individual product demand basis, increased prices in the immediate term given fixed supplies available. Retail prices of competing products also rise, temporarily. For example, the rise in fed beef prices increases the corn price and feeder calf price which subsequently dampens fed beef slaughter and supplies available for consumption. With lower quantities available, retail prices of competing products also rise. The short-run response is a decline in competing products. An increase in table beef demand causes beef imports to rise initially then to decline over the longer term. An increase in demand for hamburger beef creates an opposite effect. A sustained increase in real disposable income also has a substantial positive effect on retail and farm prices for meats, the impact being greatest in latter periods. Imports rise initially as cow numbers are being increased, but then trend downward.

The effects of structural changes in the demand parameters of retail meats in the U.S. were characterized by three major directions of change. These structural changes followed from results contained in the previous chapter and in large part reflect a continuation of present trends in structural change in retail demand. These developments are first, a rising direct flexibility of demand for beef, in particular table beef; second, a down trend in income flexibilities for all beef; and third, an increasing cross-effect on other red-meats from hamburger beef demand and an increasing cross-effect on all other meats from broiler demand. In each case the result has been similar although the effect has been viewed from different perspectives. The result has been lower retail and farm prices for all products in the short-run but also in the long run for table beef, lower corn prices and beef cow numbers, and generally, lower U.S. beef imports.

An analysis is presented of the effects on the livestock sector of a dairy cow slaughter program to achieve balance in the dairy market in one year or over three years. The one-year program is in the immediate term substantially more market destabilizing than the three-year program. However, over the longer term a much greater effect from the three-year program on retail and farm prices would be felt. Assuming a 13-20 percent dairy cow herd reduction, the one-year program causes a 4-6 percent reduction of table beef prices in the immediate term. Hamburger prices fall by 3-5 percent, with smaller declines in retail pork and broiler prices. Hamburger beef prices continue to fall in later years also. The program operated over a three-year period results in immediate decreases in retail table beef and hamburger beef prices of 1-4 percent and 1-3 percent, respectively. However, in the long run, prices fall substantially more with the one-year program. Perhaps the largest impact falls on U.S. beef imports. With the one-year program beef imports fall in the first couple of years by between 2-5 percent. With the three-year program beef imports fall by between 3-7 percent in the longer run.

Finally, simulations were made of high and low income growth scenarios for developing markets, the Soviet Bloc and Mainland China. The short-run impact, for example, of low 'world' income growth on U.S. meat prices is rather small, although the long-run decline in real prices becomes substantial. The largest impact logically is on corn prices and U.S. net exports of feed grains. A negligible effect was felt by U.S. non-fed beef imports.

CHAPTER 6

CONCLUSIONS

The U.S. beef market and indeed the market for other major meats, pork and poultry, have been subject to substantial structural change over the past several decades. These changes have occurred in nearly all segments of the beef subsector. For example, the development of a hybrid corn industry and other developments such as price support program in grain markets placed downward pressure on feedgrain prices and encouraged a large-scale grain-fed beef production system. Developments such as boxed beef have not changed the consumer product but have facilitated major changes in the way much of the beef is distributed and marketed. At retail, changes in consumer lifestyles and habits and in consumer attitudes to health and convenience of foods, and the growth in fast food outlets each have had their impact on the demand for meats. Traditional methods of marketing of meats have come increasingly under pressure to develop or adapt to accommodate these transitions. Moreover, the strong downturn in beef consumption since 1976 record levels has emphasized the need for greater scrutiny of these marketing methods.

Against this trend is the continued strong upward trend in the consumption of poultry meats, particularly broilers. During 1976-82 these gains in market share were largely at the expense of red meats. The steady decline in real chicken prices has been achieved by substantial production and distribution efficiences in that subsector. Notably, however, the widening spread between beef prices and chicken prices has levelled off. Over the past several years retail broiler prices have remained at around 30 percent of retail beef prices, suggesting possibly that these efficiency gains in a highly industrialized broiler industry have begun to diminish. At least, the comparatively traditional beef industry should not continue to lose competitive ground to chicken in terms of relative prices, as it has for the past several decades.

With this background of considerable change in the U.S. markets for meats, structural models of retail demand were estimated. A central focus of these estimated models was the testing of the hypothesis of constant structural coefficients of retail meat demand. A major conclusion of this study, supported by considerable evidence, is that a constant parameter formulation for the retail demand functions for table beef, hamburger and broilers is not appropriate and is likely to result in misleading structural coefficients of retail demand. A notable and consistent exception throughout this analysis was aggregate pork demand for which the null hypothesis of fixed coefficients was accepted in each parameter variation model tested. It is possible that significant parameter variation has occurred for the individual heterogeneous pork products, such as bacon and sausage meats.

Structural changes in regression coefficients were identified and quantified using graphical analysis, qualitative shift and interaction variables, linear and cubic spline functions within a discontinuous time-varying switching regression model, and Legendre polynomials within a continuous time-varying parameter model. Annual models of retail market demand for table beef, hamburger beef, pork and broilers were specified as price dependent on the assumption that supplies available for consumption determine retail prices. This assumption within an annual model is less satisfactory for broiler demand. However, for overall model consistency and compatibility within the Michigan State University Agricultural Model (MSUAM), used in this study, all retail meat demand equations were estimated as price dependent market models. The appropriate measure of demand responsiveness, therefore, is flexibility of demand. Linear and log-linear forms were used in ordinary least squares estimation of demand parameters of each of the four retail meats over the data period 1950-82.

Considering the change which the retail market has undergone over the past several decades since 1950, it is perhaps not surprising that the same combination of traditional variables has not explained the at times complex and dynamic set of forces influencing retail prices over this period. It is less believable that the individual influences of these variables have remained constant throughout these years.

Compared to pre-1970 analyses of U.S. meat demand, the retail cross effects of hamburger beef consumption on table beef price is larger and the cross effect of table beef consumption on hamburger beef prices are smaller in this study. This means that hamburger beef has become a closer substitute with table beef and has achieved greater favor in many consumers' minds. Advertising, promotion and other forms of market and consumer education of substitute products, like hamburger beef, will make them even stronger substitutes. This will tend to make the direct flexibility of demand for table beef rise further. On the other hand, as seems the case for hamburger beef, successful attempts to product differentiate results in less substitutability, and hence, the direct flexibility of demand will tend to be lower.

The growth in the 5 to 24 age cohort, as a result of the baby boom of the 1950s, has been a significant factor in augmenting the demand for hamburger beef. A significant negative relationship was identified between the older age cohorts and hamburger beef demand. On the other hand, the increasing purchases of food away from home showed no significant influence on beef demand and hence retail beef prices. The data series, for example, for hamburger beef prices or for aggregate food expenditures away from home may have been inappropriate variables when considering the influence of institutional (fast food restaurant) purchases on hamburger beef demand.

The hypothesis of irreversibility of demand for beef is one testable hypothesis explaining systematic changes in the slopes of retail demand curves and in the derived flexibilities. This hypothesis, that direct flexibilities will tend to be more flexible during decreasing consumption phases and less flexible (inflexible) during increasing consumption phases, was accepted. Most conclusive results were obtained for all beef demand and for table and hamburger beef demands using changes in the cattle cycle as the underlying cause of these systematic changes in direct flexibilities of demand. Following from the close relationship between changes in the beef cattle inventory and retail consumption, this means that direct flexibilities of retail demand were higher during periods of beef cattle cycle or inventory upturns and lower in cycle downturns. The importance of managing beef cattle cycles is apparent since the greater the cycle amplitude, especially during the upswing, the more volatile retail prices will be in response to changing quantities of beef supplied. It was this volatility that had much to do with price induced shift in consumer preferences during the middle and late 1970s. The resultant changes in habits then had their impact on other consumption behavior patterns causing parameter shifts in other explanatory variables.

The hypothesis that income responsiveness has been declining steadily over time, was not supported in this study. Income flexibilities fluctuated, albeit systematically, over the 33 year period. For instance, the income flexibilities of table beef and hamburger beef declined from 1977 to 1979, but have since shown a steady upward progression. In recent years, the flexibility on income was higher during periods when incomes were decreasing. This agrees with the hypothesis that consumers (and retailers) are more responsive to decreases in incomes because of the tighter budgetary constraint imposed. Income flexibilities for broilers, however, have risen steadily over the period.

Regression coefficients and hence flexibilities of demand were also shown to vary significantly between the short run and the long run. Estimation of a price adjustment model indicated a smaller direct flexibility in the short run than in the long run. The impact of imperfect knowledge and institutional delays in the short run prevent complete and instantaneous adjustment of market prices to clear the market. Only after some time has elapsed in subsequent period do final adjustments in prices take place. It is argued in some detail that this result does not contradict the traditional notion of Marshallian short and long-run demand curves.

Models discussed above permitted regression coefficients to change a small number of times and, therefore, allowed for a similar number of changes in structure over that time series. The applications of linear and cubic spline functions and of Legendre polynomials permit the coefficients to vary more continuously over time. An important property of Legendre polynomials is the finality of coefficients property. This is a special property of orthogonal functions which in this case essentially means that the coefficient terms of the polynomial are independent of each higher-order term of the polynomial added when estimating higher degree models.

Time varying parameter specifications of both splines and the Legendre polynomials were found to make a significant contribution beyond the classical model of fixed regression coefficients. In reality shifts in demand from one structure to another are likely to be continuous and less likely to be abrupt. This continuity is more in accord with the inherent and psychic nature of people and more consistent with the role played by expectations in smoothing abrupt changes in market behavior. The notable and consistent exception to a time-varying parameter formulation was the pork demand, i.e., the slope of the pork demand curve has not changed significantly over time. This is not to say that increases and decreases in demand have not occurred, but that the demand for pork has responded almost entirely to the relative prices of substitutes. This gives support to the hypothesized residual role pork fills in the buying habits of consumers, responding largely to relative prices and not to changes in tastes or preferences. Hence slope changes are not significant.

It is perhaps not surprising that results indicate an integral relationship between variations in table beef and hamburger beef production and consumption on the one hand and direct flexibilities for beef on the other. In the continuous time varying models employing Legendre polynomials, the pattern of flexibilities of beef characterizes production cycles over the 33 year period. This is consistent with the notion of irreversibility in beef demand and the nature of cycle-induced structural changes in retail demand.

Over the past several years direct flexibilities for table beef have risen while for hamburger they have declined. The lower the direct flexibility, the greater the extent to which increases in quantities available per person are absorbed by demand and hence the smaller the price adjustment required to clear the market. This means that, recently, quantities of hamburger beef have been more readily absorbed by demand than have table beef or poultry meats. The implication is that the preference for hamburger beef has been growing vis-a-vis other meats. This position is reminiscent of the high beef price period of the early 1970s when ground beef became a closer substitute with table beef.

Rising direct flexibilities for table beef and broilers indicates a weakening of demand. That is, as quantities available for consumption increase, effective demand is insufficient to absorb the increased quantities causing relatively large price adjustments to clear the market. This result for chicken is consistent with the observations that the market for chicken is becoming saturated and that the impact of gains from technology in the broiler industry, which have helped keep real prices down, may be slowing. More significantly, the substantial price advantage enjoyed by chicken over beef may be eroding.

It has been shown in this research that it may be misleading to compute a single coefficient that purports to show the response of prices to changes in quantities and income over an extended time period. These findings have important implications for the analysis and forecast of meat demand. For example, an analysis of the cost of a public commodity program, may depend largely upon the elasticity or flexibility of demand for that commodity. The accuracy and validity of estimated regression coefficients in terms of the time over which that coefficient is relevant, may, therefore, bear upon the overall quality and effectiveness of that government program.

Preferred continuous time varying parameter models of the four major retail meat categories were integrated into a stochastic simulation model of U.S. livestock and feedgrains and world wheat and feedgrains markets. The historical analysis, indicating considerable systematic variation in the flexibilities of U.S. retail demand for meats, formed the basis of simulations of the effects of structural changes in demand parameters in the future. Simulated effects were characterized by three major directions of change, each of which represent a continuation of present trends in structural change in U.S. retail demand.

The first structural change simulated was a rising own-quantity flexibility for table beef. This trend indicates a weakening of demand resulting in relatively large price adjustments in the market price to small changes in quantities, and reflects the negative quality changes which have led to a substitution of poultry meat for red meats. Second, separate simulations are made of the increasing cross effect of hamburger beef and of broilers on other retail meats. Among red meats, hamburger beef, appears to have achieved greater preference among many consumers. This follows from its qualities of leaness and convenience in preparation. Hence, the hamburger beef quantity variable is simulated with an increasingly stronger substitution effect on the demand for other red meats. This scenario is juxtaposed with the case of increasing competition of broilers on the retail demand of all other meats. Third, income flexibilities for both table beef and hamburger beef have shown a relative decline since 1977. This downtrend is indicative of a decrease in the long-term growth rate of the U.S. industry. For each simulated change the coefficients in question were allowed to change linearly by one percent annually over the projection period 1983-91.

In each case the direction of impact on U.S. agriculture has been similar, although the magnitude of the impact has varied when viewed from these different perspectives of structural change in retail demand. The result was lower retail and farm prices for all products in the short run but also in the long run for table beef, lower corn prices and beef cow numbers, and generally lower U.S. beef imports. The greatest impact occurred in the scenario of a rising cross-effect of chicken meat on other retail meat demands. This was expected because the impact is widespread and because of the large cross-coefficients of broilers.

Other more general simulations were also conducted. Structured into base model projections was the newly created Payment-In-Kind (PIK) program and the concomitant reduction in planted acreage and above average yields. A simulated 20 percent decrease in feedgrain yields under this program in response to a one year drought in 1983 raised corn prices 13 percent in that year. Resources shift from fed beef production into range and pasture fed production in response to higher feed costs. The declining profitability of beef cattle production led to an increase in cow slaughter. This in turn brought about an increase in production of processing-quality beef but less than a 2 percent reduction in the U.S. beef import quota. This small response is not surprising given the long lags in the quota formula. Subsequent rebuilding of the beef cow herd results in a 2 percent increase in imports over the longer term.

A sustained 10 percent increase in retail demand for meats, applied on an individual product demand basis substantially increased prices in the immediate term, given fixed available supplies. Retail prices of competing products also rise, temporarily. The rise in fed beef prices, for example, increases corn prices and feeder calf prices which subsequently dampen fed-beef slaughter and supplies available for consumption. With lower quantities available, retail prices of competing products also rise. An increase in table beef demand causes beef imports to rise initially then to decline over the longer term. An increase in demand for hamburger beef creates an opposite effect. A sustained increase in real disposable income also has a substantial positive effect on retail and farm prices for meats, the impact being greatest in latter periods. Imports rise initially as cow herds are rebuilt, but then trend downward.

The potential impacts of a proposed dairy herd reduction program have created considerable concern for some participants in the livestock markets of the U.S. The program's aim, ostensibly, is to achieve balance in the dairy market in one year or over three years. Instability in the livestock and feedgrain markets from the one-year program when implemented in 1983 was substantially greater in the immediate term than the three-year program. Over the longer term, however, there is a much greater effect on retail and farm prices. From the assumed 13-20 percent dairy cow herd reduction, the one-year program causes a 4-6 percent reduction of table beef prices in the immediate term. Hamburger prices fell by 3-5 percent with smaller declines in retail pork and broiler prices. Significantly, hamburger beef prices continue to fall also in later years. The three-year program results in immediate decreases in retail table beef and hamburger beef prices of 1-4 percent and 1-3 percent, respectively. However, in the long-run, prices fall substantially more with the one year program. Possibly the greatest impact falls on imports of beef into the U.S. With the one-year program beef imports fall in the first couple of years by some 2-5 percent. In the three-year program beef imports fall by 3-7 percent in the long run.

The potential contribution which time-varying parameter models make to the understanding of commodity markets seem substantial. Certainly, it is intuitively appealing to allow regression coefficients to vary in a manner more in accord with the actual nature of economic and, indeed, with many other relationships. Application of such an approach has been demonstrated although clearly much work remains to be done. The applications in forecasting and policy analysis seem extensive. Hence, the importance of undertaking such research should require less convincing.

A major emphasis given in this research is the role of beef imports into the U.S. The significance of this market remains of prime interest to major exporters such as Australia. It behooves policy analysts and decision makers in both the U.S. and, in particular, Australia to gain as complete an understanding as possible of inherent changes in the underlying structure of commodity markets. It is towards this understanding that this research has been directed.

APPENDICES

APPENDIX A

TABLES AND FIGURES

Appendix Table A1

Estimated Retail Demand Equations for Meat Using Zellner's Seemingly Unrelated Regression Method: Base Model Estimates Over the Period 1950-1982

Dependent Variable	Explanatory Variables										
		Domestic Consumption Per Person, Retail									
Deflated Retail Price	Constant	DCFBFRC	DCNFBFRC	DCORMRC	DCPKRC	DCPMC	DCBRC	DICR	$\hat{\sigma}/m$	$\bar{R}^2$	D.W.
Table Beef (RPBFR)	91.665	-1.380	-1.333	.095		-1.668		.062	.039	.69	1.54
	(4.12)	(5.45)	(5.72)	(.42)		(5.89)		(6.48)			
Hamburger Beef (RPHMBR)	51.314	-1.151	-1.353	.170			-1.522	.052	.054	.72	2.09
	(2.60)	(5.25)	(6.70)	(.86)			(5.32)	(5.92)			
Pork (RPPKR)	93.391	- .334	- .362		-1.063		-1.523	.041	.037	.90	2.36
	(7.33)	(1.90)	(2.19)		(7.00)		(6.44)	(6.05			
Broilers (RPBRR)	65.176	- .482	- .438		- .178		-1.493	.025	.034	.95	2.64
	(10.08)	(5.37)	(5.20)		(2.31)		(12.18)	(7.19)			

Notes: See Table 4.2 and 4.3.

Appendix Table A2

Generation Statements and Derived Data Series Used in Estimation of Fed and Non-Fed Beef Production and Table Beef and Hamburger Beef Consumption

```
GENR RSLFISCT=SLCT/FISLCT $
GENR SLSR=RSLFISCT*FISLS $
GENR SLHF=RSLFISCT*FISLH $
GENR SLCW=RSLFISCT*FISCW $
GENR SLBS=RSLFISCT*FISLBS $
GENR QSR=(SLSR*DWFIS)*.001 $
GENR QHF=(SLHF*DWFIH)*.001 $
GENR QCW=(SLCW*DWFICW)*.001 $
GENR QBS=(SLBS*DWFIBS)*.001 $
GENR RDWFICT=DWCT/DWFICT$
GENR QSHBF=(QSR+QHF)*RDWFICT $
GENR RBFRBF=DCBFR/DCBF $
GENR QSHBFR=QSHBF*RBFRBF $
GENR RSLFSHSH=MRCF23/(SLSR+SLHF) $
GENR QFBF=QSHBF*RSLFSHSH $
GENR DCFBFR=RBFRBF*QFBF $
GENR QNFSHBF=QSHBF-QFBF $
GENR QOBF=DCBF-QFBF-QNFSHBF $
GENR QNFSHBFR=QNFSHBF*RBFRBF $
GENR QOBFR=QOBF*RBFRBF $
GENR DCNFBFR=QNFSHBFR+QOBFR $
GENR DCFBFRC=DCFBFR/POPC $
GENR DCNFBFRC=DCNFBFR/POPC $
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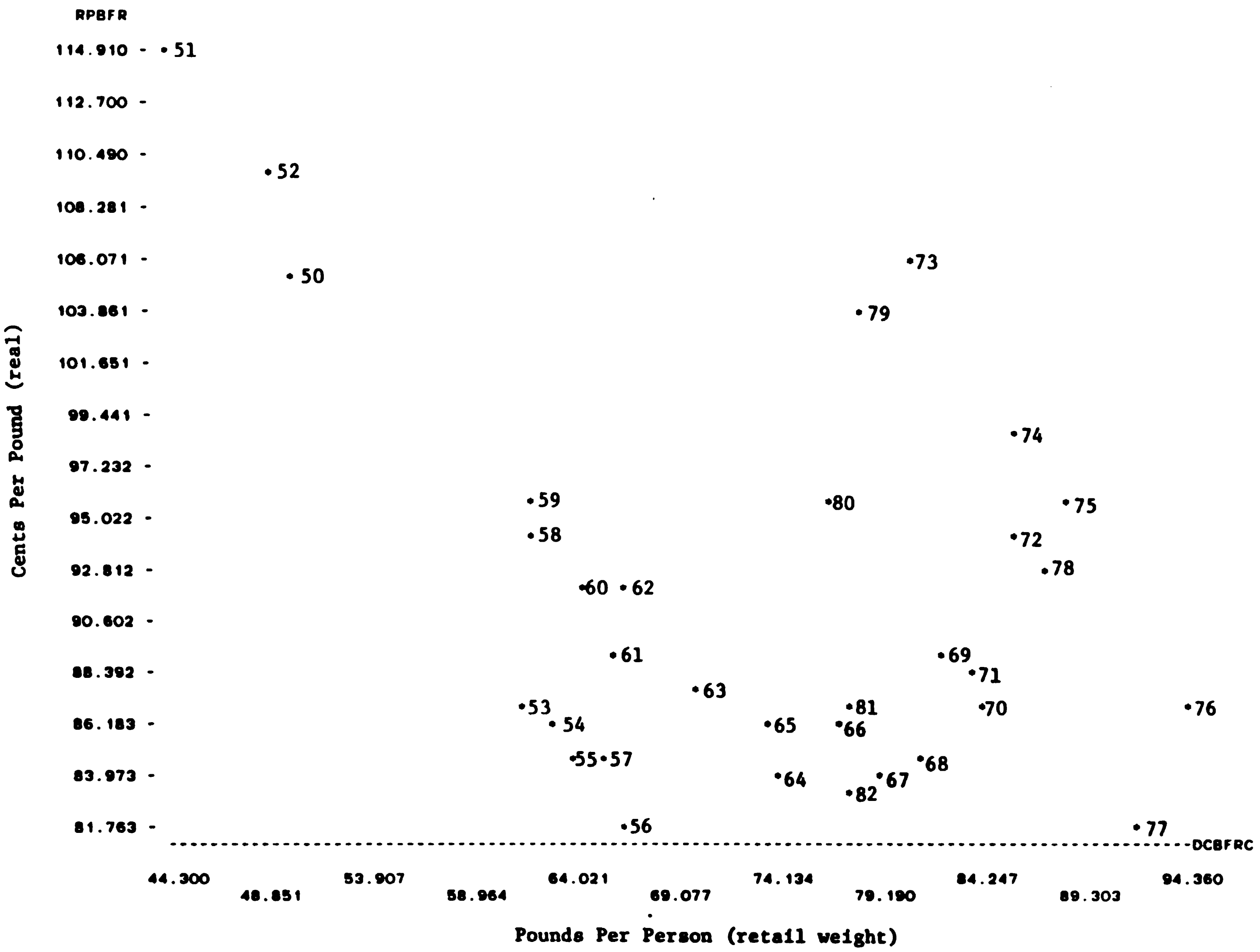
	RSLFISCT	SLSR	SLHF	SLCW	SLBS	QSR
1950	1.42059	9864.58	1974.62	6061.66	714.557	5534.03
1951	1.43817	8887.88	1724.36	5764.18	707.579	5048.32
1952	1.41474	10145.1	1991.95	5786.27	701.709	5802.98
1953	1.38777	13107.5	2843.54	7759.02	756.335	7366.41
1954	1.40122	13034.2	3463.82	8738.03	652.970	7207.90
1955	1.39528	12974.7	3730.97	9286.96	595.783	7343.67
1956	1.37496	14175.9	3900.77	9107.75	569.235	8193.65
1957	1.39138	13938.9	4146.33	8419.27	562.119	8042.74
1958	1.38125	13591.5	4076.07	6295.73	404.706	8032.57
1959	1.35880	13154.6	5028.93	5212.37	326.113	8511.01
1960	1.34212	14168.7	5534.89	5960.34	366.398	9294.68
1961	1.32567	14799.8	5993.36	5346.43	331.418	9871.46
1962	1.32312	15145.8	5848.20	5623.27	293.733	9829.62
1963	1.29582	16192.5	6229.00	5386.71	261.755	10816.6
1964	1.26041	18143.7	6463.41	6707.93	361.739	12011.1
1965	1.24637	16808.6	7560.51	8283.40	517.245	10858.4
1966	1.25089	17317.3	8674.91	7655.43	525.373	11446.7
1967	1.23459	18125.1	8856.97	6839.65	475.318	12089.4
1968	1.19688	18385.2	9558.26	6923.94	549.367	12263.0
1969	1.16491	18352.1	9652.48	6987.16	581.292	12222.5
1970	1.14818	19069.0	9534.51	6169.19	582.129	13043.2
1971	1.14278	19430.7	9403.94	6430.42	639.957	13154.6
1972	1.11984	19876.1	9557.87	6049.40	652.869	13575.4
1973	1.11733	18552.1	8541.98	6322.97	684.923	12782.4
1974	1.12107	19982.0	8923.73	7616.56	830.714	13987.4
1975	1.12356	18055.7	10584.0	11708.7	1119.07	12151.5
1976	1.10789	19127.8	12316.5	10751.0	1003.75	13293.8
1977	1.09464	19585.2	11894.3	9991.83	910.737	13396.3
1978	1.08179	18723.6	11879.1	8560.21	807.016	12807.0
1979	1.07939	17548.7	9835.37	5986.28	632.521	12266.5
1980	1.07822	17315.1	9682.41	6388.45	732.111	12259.1
1981	1.07453	17662.0	10117.8	6702.92	782.258	12522.4
1982	1.06545	17413.6	10475.5	7411.24	824.655	12137.3
	1	2	3	4	5	6

	QHF	QCW	QBS	RDWFICT	QSHBF	RBFRBF
1950	924.123	3176.31	500.190	.950092	6135.84	.792851
1951	824.246	2968.55	495.305	.954044	5602.68	.792715
1952	950.159	2939.43	491.196	.952381	6431.56	.791421
1953	1325.09	3863.99	529.434	.953096	8283.83	.792502
1954	1617.61	4369.01	457.079	.954373	8422.82	.788286
1955	1787.13	4699.20	417.048	.949721	8671.71	.783595
1956	1915.28	4617.63	398.464	.950730	9610.86	.778686
1957	2039.99	4302.25	393.484	.951087	9589.56	.772954
1958	2062.49	3336.74	283.294	.951304	9603.48	.769441
1959	2720.65	2611.40	228.279	.951747	10689.7	.764052
1960	3022.05	2986.13	256.478	.957770	11796.6	.756046
1961	3338.30	2667.87	231.992	.958609	12663.0	.749364
1962	3193.12	2794.77	204.438	.964467	12560.0	.744882
1963	3506.92	2698.74	184.014	.965461	13828.8	.740197
1964	3606.58	3226.51	244.897	.966833	15099.7	.739430
1965	4120.48	3942.90	354.830	.970740	14540.6	.739861
1966	4823.25	3705.23	367.761	.968067	15750.4	.740374
1967	4995.33	3406.14	333.674	.970346	16578.1	.740136
1968	5333.51	3427.35	387.853	.973554	17131.1	.740025
1969	5424.70	3507.55	410.392	.980198	17297.7	.739914
1970	5453.74	3146.29	411.565	.980769	18141.2	.739930
1971	5322.63	3279.52	454.369	.983845	18178.7	.740104
1972	5543.56	3139.64	475.289	.985692	18845.4	.739871
1973	5014.14	3250.00	510.267	.985804	17543.9	.740013
1974	5229.31	3739.73	582.331	.984127	18911.7	.739637
1975	5884.69	5561.61	763.205	.986395	17790.8	.739886
1976	7143.54	5235.74	694.596	.986885	20169.3	.739763
1977	6886.80	4726.14	627.498	.990083	20081.9	.739902
1978	6949.30	4185.94	583.472	.993485	19627.6	.739919
1979	5881.55	3106.88	468.698	.992175	18006.1	.739952
1980	5857.86	3270.88	549.083	.986003	17863.4	.740069
1981	6161.72	3431.89	588.258	.990683	18510.0	.739958
1982	6316.70	3764.91	619.316	.990491	18278.5	.739956
	1	2	3	4	5	6

	RSLFSHSH	QFBF	QNFSHBF	QOBF
1950	.648186	3977.16	2158:68	3393.16
1951	.746119	4180.27	1422.41	2869.32
1952	.714920	4598.05	1833.51	3116.44
1953	.633815	5250.41	3033.42	3829.17
1954	.569220	4794.44	3628.38	4320.18
1955	.598839	5192.96	3478.75	4641.29
1956	.574720	5523.55	4087.31	4510.14
1957	.576769	5530.96	4058.59	4652.44
1958	.612082	5878.12	3725.36	4182.52
1959	.675172	7217.39	3472.32	3512.29
1960	.650439	7672.97	4123.63	3350.40
1961	.662478	8388.96	4274.04	3239.00
1962	.693532	8710.76	3849.24	3766.00
1963	.709943	9817.66	4011.15	3783.19
1964	.705732	10656.3	4443.36	3799.31
1965	.735604	10696.1	3844.47	4519.45
1966	.751533	11837.0	3913.46	4389.57
1967	.776146	12867.0	3711.08	4214.88
1968	.810994	13893.2	3237.89	4495.90
1969	.852004	14737.7	2559.99	4767.28
1970	.869962	15782.2	2359.04	4784.76
1971	.876759	15938.3	2240.37	4905.30
1972	.912279	17192.2	1653.13	5116.62
1973	.933930	16384.8	1159.13	5268.07
1974	.807591	15272.9	3638.78	5577.33
1975	.715791	12734.5	5056.29	7606.24
1976	.768662	15503.4	4665.93	7369.67
1977	.789497	15854.6	4227.30	6966.06
1978	.871326	17102.0	2525.55	6370.44
1979	.899246	16191.9	1814.18	5515.93
1980	.859672	15356.6	2506.74	5456.62
1981	.828443	15334.5	3175.53	5245.96
1982	.881778	16117.6	2160.93	5721.46
	1	2	3	4



Appendix Figure A1 - Plot of Retail Prices and Domestic Consumption of All Beef

Appendix Table A3

Implications of the Assumption of Adjusted Base Level of U.S. Beef Imports vs. the Trigger Level of U.S. Beef Imports

Response Variables	Units	1982	1983		1984		Average 1985-91		1991	
		Actual	Base Level	Trigger Level Imports: Change From Base Level	Base Level	Trigger Level Imports: Change From Base Level	Base Level	Trigger Level Imports: Change From Base Level	Base Level	Trigger Level Imports: Change From Base Level
Beef Cow Numbers[a]	Millions	39.3	38.1	0	37.6	-.1	46.3	-.2	47.1	-.1
Ratio Steer-Heifer Slaughter	Ratio	.882	.900	0	.893	-.003	.789	.007	.843	.006
Farm Production[b]										
Fed Beef	Bil. lbs.	18.0	17.2	0	16.4	0	19.9	2.0	21.3	-.1
Non-Fed Beef	Bil. lbs.	4.4	4.0	0	3.4	.1	5.8	0	7.2	0
Pork	Bil. lbs.	19.4	20.0	0	21.5	0	23.5	.1	22.8	.1
Broilers	Bil. lbs.	12.1	12.4	0	12.6	0	13.4	0	13.9	0
Farm Prices (1967 Dollars)										
Fed Beef	$/cwt.	22.2	28.7	-.5	36.3	-.4	27.1	0	28.3	-.4
Non-Fed Beef	$/cwt.	14.0	23.3	-.3	25.6	-.2	22.5	0	26.1	-.3
Pork	$/cwt.	19.2	24.9	-.1	23.7	-0	30.2	0	36.3	-.2
Broilers	$/cwt.	9.2	13.1	-.1	14.8	-.2	18.2	-.1	22.8	-.2
U.S. Beef Imports	Bil. lbs.	1.566[c]	1.453	.145	1.580	.153	1,578	.151	1,922	.172
U.S. Net Exports Feedgrains	Mil. m. tns.	56.9	60.3	0	63.5	.1	81.7	.1	97.9	.1

[a] 1983 is an actual level.

[b] Farm production and beef imports are in carcass weight except pork, which is in live weight.

[c] This is the actual level of the adjusted base quota. Actual imports of beef in 1982 were 1,939 million pounds.

Appendix Table A3 (continued)

Implications of the Assumption of Adjusted Base Level of U.S. Beef Imports vs. the Trigger Level[a] of U.S. Beef Imports

Response Variables	Units	1982 Actual	1983 Base Level	1983 Trigger Level Imports: Change From Base Level	1984 Base Level	1984 Trigger Level Imports: Change From Base Level	Average 1985-91 Base Level	Average 1985-91 Trigger Level Imports: Change From Base Level	1991 Base Level	1991 Trigger Level Imports: Change From Base Level
Retail Prices (1976 Dollars)										
Table Beef	¢/lb.	83.9	94.5	-.9	112.1	-1.1	94.5	0	94.5	-.8
Hamburger Beef	¢/lb.	51.9	68.0	-.6	76.7	-.8	77.3	-.1	83.7	-.6
Pork	¢/lb.	60.7	71.1	-.1	71.9	-.2	85.8	-.2	99.7	-.4
Broilers	$/lb.	24.8	31.6	-.2	34.0	-.3	37.9	-.1	43.8	-.3
Consumption Per Person[b]										
Table Beef	Lbs.	51.9	49.4	0	46.4	.1	47.6	.2	52.9	.4
Hamburger Beef	Lbs.	25.4	22.3	.4	20.7	.5	34.2	-.2	36.0	0
Pork	Lbs.	58.4	54.2	0	57.8	0	57.5	.8	57.4	.2
Broilers	Lbs.	49.7	49.7	0	50.2	0	51.2	.1	51.6	0

[a] The trigger level is 110 percent of the adjusted base quota on beef imports.

[b] Retail weights.

APPENDIX B

SELECTED MSUAM SUBROUTINES

Appendix B

Selected MSUAM Subroutines

```
      SUBROUTINE BEEF(J,ITR)
      COMMON NY, NZ, NYMAX, NZMAX, NCMAX, NYRMAX, CRIT, IYRBAS, IYR1,
     1       IYRFIN, INPAR(13), COMPON(20), EXOGY(250), DEFINY(250),
     2       NFY(250),NLY(250),NFZ(250), NLZ(250), NAMY(250), NAMZ(250),
     3       EY(250),PREVY(250),YY(250),Y(250,40),ACTY(250,40),Z(250,40)
      INTEGER COMPON, DEFINY, EXOGY
      COMMON/ALIVIN/BFCOWTL,DCOWTL,DHEIFTL,SOWFSLL,SOWFFLL
      COMMON /DUMMY/ DV6368,DV67,DV680N,DV690N,DV71,DV710N,DV72,
     1               DV720N,DV73,DV74,D75,DV77,DV79,DV790N,DV7981,
     2               DV80,DV800N,DV81,DV810N,DV82,DV820N,DV830N,MDV71,
     3               MDV72,MDV73,MDV74,DV850N,DV870N,DV890N,DV910N,
     4               DV930N,DV950N,DV970N,DV990N,DV83
      COMMON /TIMES/ TIME, TSQR, LOGT
      REAL LOGT
C ::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
C
C **********************************************************************
C * THIS SUBROUTINE PROVIDES DOMESTIC (U.S.) RETAIL MEAT DEMAND        *
C * RELATIONSHIPS AND THE NECESSARY LINKAGE/TRANSMISSION EQUATIONS     *
C * WITH LIVESTOCK DEMAND AND PRODUCTION RELATIONSHIPS IN "XMODL".     *
C *                                                                    *
C **********************************************************************



C    ^^^^^^^^^^^^^^^^^^^^^^^^^
C    FED BEEF DEMAND COMPONENT
C    ^^^^^^^^^^^^^^^^^^^^^^^^^

C EQUATION YY(201) IS RATIO OF FED STEER & HEIFER SLAUGHTER TO TOTAL
C STEER & HEIFER SLAUGHTER : THIS TRANSMISSION EQUATION PROVIDES LINK
C WITH DOMESTIC CONSUMPTION OF FED & NON-FED BEEF.

      IF(TIME .GE. 83 .AND. YY(201) .GE. .97)  YY(201)= .97

      IF(EXOGY(201) .EQ. 0)

C    RSLFSHSH  CONSTANT   CORN PRICE   FEEDER CALF PRICE   RATIO LAGGED
     &YY(201)=.27575-.112584*Y(73,J-1)-.00425*Z(31,J-1)+1.002*Y(201,J-1)

C ::::::ADD FACTOR::::::
     &+EY(201)
     &-.051*DV83

C IDENTITY YY(202) IS DOMESTIC CONSUMPTION OF FED BEEF,RETAIL,PER HEAD.
C FACTOR .74 IS FOR CONVERSION OF CARCASS TO RETAIL WEIGHTS.

      IF(EXOGY(202) .EQ. 0)

C    DCFBFRC    FBEFQT  RSLFSHSH        POPC
     &YY(202)=((Y(7,J)*Y(201,J))*.74)/Z(201,J)

C IDENTITY YY(203) IS DOM. CONS. OF NON-FED BEEF,RETAIL,PER HEAD.
C FACTOR .72 IS FOR CONVERSION OF CARCASS TO RETAIL WEIGHTS.

      IF(EXOGY(203) .EQ. 0)

C    DCNFBFRC     NFBIMT NFBFQT FBEFQT  RSLFSHSH              POPC
     &YY(203)=((Y(83,J)+Y(9,J)+(Y(7,J)*(1-Y(201,J))))*.72)/Z(201,J)

C IDENTITY YY(204) IS DOM. CONS. OF PORK,RETAIL,PER HEAD.
C FACTOR .70 IS FOR CONVERSION OF LIVE TO CARCASS WEIGHTS.
C FACTOR .90 IS FOR CONVERSION CARCASS TO RETAIL WEIGHTS.
```

```
      IF(EXOGY(204) .EQ. 0)
C       DCPKRC    PORKQT              POPC
     &YY(204)=(Y(6,J)*.70*.90)/Z(201,J)

C  IDENTITY YY(205) IS DOM. CONS. OF BROILERS,RETAIL,PER HEAD.
C  FACTOR .93 IS FOR CONVERSION OF CARCASS TO RETAIL WEIGHTS.

      IF(EXOGY(205) .EQ. 0)

C       DCBRC     CHIKQT        POPC
     &YY(205)=(Y(11,J)*.93)/Z(201,J)

C  IDENTITY Z(203,J) IS DOM.CONS. OF OTHER RED MEAT,RETAIL,PER HEAD.
C  DCORMRC=DCVLRC+DCLMRC+DCPKRC ,WHERE DCVLRC IS DOM.CONS VEAL,RETAIL,
C  PER HEAD SET CONSTANT AT 477.74 MILL. LBS.(AV.1973-1982),AND WHERE
C  DCLMRC IS DOM.CONS LAMB,RETAIL,PER HEAD SET CONSTANT AT 366.89 MILL.
C  LBS. (AV. 1973-1982). 844.63 IS THEIR AV.


C       DCORMRC                         DCPKRC
      Z(203,J)=844.63/Z(201,J)+Y(204,J)

C  IDENTITY Z(204,J) IS DOM.CONS.POULTRY MEAT,RETAIL,PER HEAD.
C  DOM.CONS.TURKEY,RETAIL,PER HEAD:DCTKC=(.95*TURKQT)/POPC
C  DOM.CONS.OTHER CHICKEN,RETAIL,PER HEAD IS SET CONSTANT AT 685.7 MILL
C  LBS. (AV. 1973-1982).

C       DCPMC     DCBRC      DCOCHC                DCTKC
      Z(204,J)=Y(205,J)+685.7/Z(201,J)+(.95*Y(10,J))/Z(201,J)

C.......................................................................
C  BASE MODEL EQUATION --TABLE BEEF

*      IF(EXOGY(206) .EQ. 0)

*     &YY(206)=136.577-1.36217*Y(202,J)-1.71667*Y(203,J)-.29505*Z(203,J)
*     &         -1.48682*Z(204,J)+.055673*Z(202,J)
C.......................................................................
C  EQUATION YY(206) IS RETAIL FED BEEF PRICE ,REAL.
C  LEGENDRE POLYNOMIALS:PT1FB=PT1*DCFBFRC=Z(206,J)*YY(202);
C                       PT2FB=PT2*DCFBFRC=Z(207,J)*YY(202);
C                       PT1DICR=PT1*DICR=Z(206,J)*Z(202,J).

C     >>>>>>>> TEST ON LEGENDRE POLYNOMIAL>>>>>>>
C      IF(TIME .GE. 83)  Z(206,J)=.875
C      IF(TIME .GE. 83)  Z(207,J)=.265625
C     >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>

**     IF(TIME .EQ. 83) YY(202)=48.41
**     IF(TIME .EQ. 84) YY(202)=45.47
**     IF(TIME .EQ. 85) YY(202)=41.94
**     IF(TIME .EQ. 86) YY(202)=40.77
**     IF(TIME .EQ. 87) YY(202)=41.45

*      ADJFB=0
*      IF(TIME .GE. 83) ADJFB=(TIME-82)*.0209728

      IF(EXOGY(206) .EQ. 0)
```

```
C     RPBFR  CONSTANT          DCFBFRC           DCNFBFRC          DCORMRC
     &YY(206)=248.211-2.24523*Y(202,J)-1.99025*Y(203,J)-.196445
C                           DCPMC              DICR                  PT1FB
     &     *Z(203,J)-2.09728*Z(204,J)+.0327113*Z(202,J)+1.28044
C                                   PT2FB
     &         *(Z(206,J)*Y(202,J))-.751415*(Z(207,J)*Y(202,J))

C ************* ADD FACTOR TO DOWNWARD ADJUST RPBFR  ******************
     &          -10.7*DV83 + EY(206)


C PERCENTAGE CHANGE IN FARM PRICE OF FED-BEEF (FBEFPT).
      CHGFBPT=((Y(77,J)-Y(77,J-1))/Y(77,J))*100

C EQUATION YY(207) IS MARKETING MARGIN FED BEEF, REAL.

      IF(EXOGY(207) .EQ. 0)

C     MMBFR   CONSTANT          FBEFPT                          MMBFR LAGGED
     &YY(207)=-.76678+.387886*Y(77,J)-.107338*CHGFBPT+.51698*Y(207,J-1)
C                     DCFBFR(AGGREGATE)
     &+.0006426*(Y(202,J)*Z(201,J))

C NFVBFR=RPBFR-MMBFR , THEREFORE NFVBFR=Y(206,J)-Y(207,J).

C EQUATION YY(208) IS BY-PRODUCT VALUE FED BEEF(CHOICE BEEF),REAL.
C THESE BY-PRODUCT VALUES ARE ALSO USED FOR NON-FED BEEF.

      IF(EXOGY(208) .EQ. 0)

C     BPVBFR   CONSTANT          RPBFR           RPBFR LAGGED
     &YY(208)=-4.93105+.197844*Y(206,J)-.0798649*Y(206,J-1)
C                       CPI
     &          +.464575*Z(6,J)

C IDENTITY YY(77) IS FARM PRICE OF FED BEEF.
C FACTOR 2.42 IS FOR CONVERSION OF RETAIL WEIGHT EQUIVALENTS TO FARM
C PRODUCT WEIGHT (SEE LPS-1982).

      IF(EXOGY(77) .EQ. 0)

C     FBEFPT     NFVBFR      BPVBFR
     &YY(77)=(Y(206,J)-Y(207,J)+Y(208,J))/2.42


C     ^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^
C     NON-FED BEEF DEMAND COMPONENT
C     ^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^

C.....................................................................
C BASE EQUATION -- HAMBURGER BEEF

*     IF(EXOGY(209) .EQ. 0)

*     &YY(209)=103.89-1.01231*Y(202,J)-1.74968*Y(203,J)-.30159*Z(203,J)
*    &         -1.16762*Y(205,J)+.0400658*Z(202,J)
C.....................................................................

C EQUATION YY(209) IS RETAIL NON-FED (HAMBURGER) PRICE,REAL.
C LEGENDRE POLYNOMIALS:PT1NFB=PT1*DCNFBFRC=Z(206,J)*YY(203);
C                      PT1DICR = PT1*DICR=Z(206,J)*Z(202,J);
```

```
**      IF(TIME .EQ. 83)  YY(203)=21.85
**      IF(TIME .EQ. 84)  YY(203)=20.29
**      IF(TIME .EQ. 85)  YY(203)=22.93
**      IF(TIME .EQ. 86)  YY(203)=27.05
**      IF(TIME .EQ. 87)  YY(203)=32.14

*       ADJHB=0
*       IF(TIME .GE. 83)  ADJHB=(TIME-82)*.0101688

      IF(EXOGY(209)  .EQ. 0)

C     RPHMBR  CONSTANT         DCFBFRC         DCNFBFRC        DCORMRC
     &YY(209)=84.8024-1.32579*Y(202,J)-1.81235*Y(203,J)-.059379
C                              DCBRC            DICR             PTINFB
     &     *Z(203,J)-1.01688*Y(205,J)+.0460527*Z(202,J)+.618289
C                                              PTIDICR
     &     *(Z(206,J)*Y(203,J))-.0073819*(Z(206,J)*Z(202,J)) + EY(209)

C  PERCENTAGE CHANGE IN BEEF COW PRICE.
      CHGBCP=((Y(78,J)-Y(78,J-1))/Y(78,J))*100

C  EQUATION YY(210)  IS MARKETING MARGIN NON-FED BEEF,REAL.

      IF(EXOGY(210)  .EQ. 0)

C      MMHMBR  CONSTANT        BFCOWP                          MARGIN LAGGED
     &YY(210)=-7.40812+.902218*Y(78,J)-.174959*CHGBCP+.592968*Y(210,J-1)


C  NFVHMBR=RPHMBR-MMHMBR, THEREFORE, NFVHMBR=Y(209,J)-Y(210,J).

C  IDENTITY YY(78)  IS FARM PRICE OF NON-FED BEEF(COMMERCIAL COWS-OMAHA)
C  FACTOR 2.4 IS FOR CONVERSION OF RETAIL WEIGHT EQUIVALENTS TO FARM
C  PRODUCT WEIGHT  (SEE LPS-1982)
C  THE SAME BY-PRODUCT VALUES FOR FED BEEF ARE USED FOR NON-FED BEEF.

      IF(EXOGY(78)  .EQ. 0)

C      BFCOWP        NFVHMBR        BPVBFR
     &YY(78)=(Y(209,J)-Y(210,J)+Y(208,J))/2.4


C     ^^^^^^^^^^^^^^^^^^^^^
C     PORK DEMAND COMPONENT
C     ^^^^^^^^^^^^^^^^^^^^^

C  EQUATION YY(211)  IS RETAIL PORK PRICE,REAL.

**      IF(TIME .EQ. 83)  YY(204)=53.12
**      IF(TIME .EQ. 84)  YY(204)=56.74
**      IF(TIME .EQ. 85)  YY(204)=59.19
**      IF(TIME .EQ. 86)  YY(204)=55.84
**      IF(TIME .EQ. 87)  YY(204)=58.90

      ADJPK=0
      IF(TIME .GE. 83)  ADJPK=(TIME-82)*.000405687

      IF(EXOGY(211)  .EQ. 0)

C       RPPKR   CONSTANT        DCFBFRC         DCNFBFRC        DCPKRC
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```
     &YY(211)=92.0591-.333509*Y(202,J)-.350867*Y(203,J)-1.04475
C                     DCBRC                 DICR
     &         *Y(204,J)-1.52061*Y(205,J)+(.0405687-ADJPK)*Z(202,J)

C  PERCENTAGE CHANGE IN FARM PORK PRICE.
      CHGPKP=((Y(76,J)-Y(76,J-1))/Y(76,J))*100

C  EQUATION YY(212) IS MARKETING MARGIN PORK,REAL.

      IF(EXOGY(212) .EQ. 0)

C       MMPKR  CONSTANT        PORKPT                         MMPKR LAGGED
     &YY(212)=10.7757+.501111*Y(76,J)-.09423*CHGPKP+.135758*Y(212,J-1)
C                       DCPKR(AGGREGATE)
     &+.00044585*(Y(204,J)*Z(201,J))

C  NFVPKR=RPPKR-MMPKR, THEREFORE, NFVPKR=Y(211,J)-Y(212,J).

C  BY-PRODUCT VALUE PORK,REAL.

      IF(EXOGY(213) .EQ. 0)

C       BPVPKR  CONSTANT          RPPKR          RPPKR LAGGED          CPI
     &YY(213)=.200317+.078822*Y(211,J)-.0242294*Y(211,J-1)-.51654*Z(6,J)

C  IDENTITY YY(76) IS FARM PRICE PORK,REAL.
C  FACTOR 1.73 IS FOR CONVERSION OF RETAIL WEIGHT EQUIVALENTS TO FARM
C  PRODUCT WEIGHT (SEE LPS-1982).

      IF(EXOGY(76) .EQ. 0)

C       PORKPT      NFVPKR      BPVPKR
     &YY(76)=(Y(211,J)-Y(212,J)+Y(213,J))/1.73


C     ^^^^^^^^^^^^^^^^^^^^^^^^
C     BROILER DEMAND COMPONENT
C     ^^^^^^^^^^^^^^^^^^^^^^^^
C......................................................................
C  BASE EQUATION -- BROILER

*       IF(TIME .GE. 64) DVCONST=1

*       IF(EXOGY(214) .EQ. 0)

*     &YY(214)=89.5305-.381576*Y(202,J)-.42859*Y(203,J)-.216839*Y(204,J)
*     &          -2.41336*Y(205,J)+.0240165*Z(202,J)-26.2127*DVCONST
*     &          +.958143*DVCONST*Y(205,J)

C......................................................................
C  EQUATION YY(214) IS RETAIL BROILER PRICE,REAL.
C  LEGENDRE POLYNOMIALS:PT1BR=PT1*DCBRC =Z(206,J)*YY(205);
C                       PT1DICR=PT1*DICR=Z(206,J)*Z(202,J).

**      ADJ=0

**      IF(TIME .EQ. 83) ADJ=.63
**      IF(TIME .EQ. 84) ADJ=.68
**      IF(TIME .EQ. 85) ADJ=.71
**      IF(TIME .EQ. 86) ADJ=.74
**      IF(TIME .EQ. 87) ADJ=.73
```

```
*       ADJ=0
*       IF(TIME .GE. 83) ADJ=(TIME-82)*.01391736

      IF(EXOGY(214) .EQ. 0)

C        RPBRR  CONSTANT          DCFBFRC          DCNFRFRC          DCPKRC
     &YY(214)=65.2321-.381513*Y(202,J)-.401215*Y(203,J)-.201923
C                          DCBRC              DICR                   PT1BR
     & *Y(204,J)-2.08474*Y(205,J)+.0301588*Z(202,J)+.693*(Z(206,J)
C                                              PT1DICR
     &          *Y(205,J))-.0079447*(Z(206,J)*Z(202,J)) + EY(214)

C  PERCENTAGE CHANGE IN FARM BROILER PRICE.
      CHNGBRP=((Y(80,J)-Y(80,J-1))/Y(80,J))*100

C  EQUATION YY(215) IS MARKETING MARGIN BROILERS,REAL.

      IF(EXOGY(216) .EQ. 0)

C        MMBRR  CONSTANT          CHIKPT                            MMBRR LAGGED
     &YY(215)=9.30512+.151686*Y(80,J)+.06899*CHNGBRP+.63596*Y(215,J-1)
C                         DCBRR(AGGREGATE)
     &-.0004135*(Y(205,J)*Z(201,J))

C  FVBRR=RPBRR-MMBRR.
C  NOTE:FVBRR=CHIKPT=FARM PRICE BROILERS.

C  IDENTITY YY(80) IS FARM PRICE BROILERS,REAL.

      IF(EXOGY(80) .EQ. 0)

C        CHIKPT  RPBRR   MMBRR
     &YY(80)=Y(214,J)-Y(215,J)


      RETURN
      END
```

```
      SUBROUTINE CPIFOOD(J)
      COMMON NY, NZ, NYMAX, NZMAX, NCMAX, NYRMAX, CRIT, IYRBAS, IYR1,
     1       IYRFIN, INPAR(13), COMPON(20), EXOGY(250), DEFINY(250),
     2       NFY(250),NLY(250),NFZ(250), NLZ(250), NAMY(250), NAMZ(250),
     3       EY(250),PREVY(250),YY(250),Y(250,40),ACTY(250,40),Z(250,40)
      INTEGER COMPON, DEFINY, EXOGY
C  BEEF
C  FARM VALUE:
      FVBF=-2.442+2.208*Y(77,J)*Z(6,J)
C  MARKET SPREAD:
      MSBF=-10.350+41.8*Z(6,J)
C  PORK
C  FARM VALUE
      FVPK=7.238+1.465*Y(76,J)*Z(6,J)
C  MARKET SPREAD:
      MSPK=-9.195+39.3*Z(6,J)
C  BROILERS
C  FARM VALUE:
      FVBR=-.573+1.447*Y(80,J)*Z(6,J)
C  MARKET SPREAD:
      MSBR=8.182+11.066*Z(6,J)
C  EGGS
C  FARM VALUE.
      FVEG=-.496+1.003*Y(82,J)*Z(6,J)
C  MARKET SPREAD:
      MSEG=12.674+8.261*Z(6,J)
C  TURKEYS
C  FARM VALUE:
      FVTK=3.368+1.130*Y(81,J)*Z(6,J)
C  MARKET SPREAD:
      MSTK=12.584+10.197*Z(6,J)
C  DAIRY PRODUCTS
C  FARM VALUE:
      FVMBDP=5.525+11.606*Y(79,J)*Z(6,J)
C  MARKET SPREAD:
      MSMBDP=18.448+54.467*Z(6,J)
C  CEREAL & BAKERY PRODUCTS
C  FARM VALUE:
      FVMBCP=4.696+9.225*Y(75,J)*Z(6,J)
C  MARKET SPREAD:
      MSMBCP=-10.615+108.771*Z(6,J)
C  FATS & OILS
C  FARM SPREAD:
      FVMBFO=1.736+.590*Y(72,J)*Z(6,J)
C  MARKET SPREAD:
      MSMBFO=.957+18.231*Z(6,J)
C  RETAIL PRICE VALUES OF EACH PRODUCT
      RPBF=FVBF+MSBF
      RPPK=FVPK+MSPK
      RPBR=FVBR+MSBR
      RPEG=FVEG+MSEG
      RPTK=FVTK+MSTK
      RPMBDP=FVMBDP+MSMBDP
      RPMBCP=FVMBCP+MSMBCP
      RPMBFO=FVMBFO+MSMBFO
      VRBF=RPBF*0.8595
      VRPK=RPPK*0.6070
      VRRM=VRBF+VRPK
      VRBR=RPBR*0.4065
      VRTK=RPTK*0.0910
      VRPM=VRBR+VRTK
      RVMBEG=-1.488+.4683*RPEG
      RVEST=VRRM+VRPM+RVMBEG+RPMBDP+RPMBCP+RPMBFO
      RVSTIDX=RVEST/433.71
      Z(77,J)=-.02662+1.01612*RVSTIDX
      RETURN
      END
```

APPENDIX C

LISTING OF DATA USED IN RETAIL DEMAND ESTIMATIONS

Appendix C

Listing of Data Used in Retail Demand Estimations

	CPI	POPC	DICR	AGE5TO24	AGE25TO64	RPBF
1950	.721000	150.800	1900.18	30.8300	50.2500	76.4000
1951	.778000	151.600	1916.15	30.5300	50.0200	89.4000
1952	.795000	153.300	1942.78	30.8800	49.7500	87.8000
1953	.801000	156.600	2010.58	31.0600	49.4300	70.0000
1954	.805000	159.700	1999.87	31.1300	49.0400	69.4000
1955	.802000	163.000	2103.64	31.4200	48.6300	68.4000
1956	.814000	166.100	2166.33	31.6900	48.2100	67.0000
1957	.843000	169.100	2164.83	32.0200	47.7000	71.6000
1958	.866000	172.200	2139.14	32.4500	47.1400	82.1000
1959	.873000	175.300	2211.23	32.9300	46.5900	84.0000
1960	.887000	178.100	2228.15	33.3800	46.1300	82.1000
1961	.896000	181.100	2254.02	33.9000	45.6200	80.3000
1962	.906000	183.700	2324.02	34.4900	45.1700	83.7000
1963	.917000	186.500	2373.28	35.0600	44.8000	80.4000
1964	.929000	189.100	2507.98	35.5900	44.4500	78.4000
1965	.945000	191.600	2627.71	36.1300	44.1700	82.0000
1966	.972000	193.400	2732.61	36.6600	44.0200	84.4000
1967	1.00000	195.300	2805.48	37.0800	43.9800	84.6000
1968	1.04200	197.100	2889.39	37.3000	44.1300	88.7000
1969	1.09800	199.100	2922.68	37.5600	44.1600	98.6000
1970	1.16300	201.900	2961.07	37.7000	44.1200	101.700
1971	1.21300	204.900	3024.62	37.7700	44.0800	108.100
1972	1.25300	207.500	3116.65	37.3500	44.4900	118.700
1973	1.33100	209.600	3278.02	37.0700	44.8200	142.100
1974	1.47700	211.600	3194.36	36.8200	45.1600	146.300
1975	1.61200	213.800	3180.28	36.6000	45.4200	154.800
1976	1.70500	215.900	3244.58	36.3600	45.8000	148.200
1977	1.81500	218.100	3313.20	35.9000	46.1800	148.400
1978	1.95400	220.500	3395.42	35.3400	46.5800	181.900
1979	2.17400	223.000	3386.39	34.7000	47.0000	226.300
1980	2.46800	225.600	3271.84	34.0600	47.4200	237.600
1981	2.72400	227.700	3271.40	33.3600	47.8500	238.700
1982	2.89100	229.800	3270.10	32.6600	48.2700	242.500
	1	2	3	4	5	6

	RPHMB	RPPK	RPBR	DCBFR	DCFBFR	DCNFBFR
1950	56.6000	53.7000	57.0000	7555.08	3153.30	4401.78
1951	66.4000	57.7000	59.7000	6715.88	3313.76	3402.12
1952	63.3000	56.1000	60.0000	7556.49	3639.00	3917.49
1953	45.0000	60.0000	58.4000	9599.58	4160.97	5438.61
1954	40.6000	63.3000	52.5000	10045.1	3779.39	6265.74
1955	39.5000	53.5000	54.3000	10432.0	4069.18	6362.82
1956	38.5000	51.3000	47.3000	10995.8	4301.11	6694.71
1957	42.0000	59.3000	46.0000	11008.4	4275.18	6733.23
1958	52.9000	63.7000	45.3000	10607.5	4522.87	6084.65
1959	54.9000	56.2000	41.1000	10851.1	5514.46	5336.61
1960	52.4000	55.8000	41.6000	11451.8	5801.12	5650.71
1961	51.2000	58.3000	37.3000	11916.4	6286.38	5630.00
1962	52.1000	58.7000	39.4000	12160.9	6488.49	5672.45
1963	51.3000	55.9000	38.6000	13036.4	7267.00	5769.35
1964	49.5000	55.4000	37.8000	13974.5	7879.61	6094.88
1965	50.8000	65.2000	39.0000	14101.8	7913.62	6188.14
1966	54.2000	73.4000	41.2000	14911.1	8763.79	6147.35
1967	54.6000	66.6000	38.1000	15389.6	9523.36	5866.28
1968	56.1000	66.8000	39.8000	16004.5	10281.3	5723.19
1969	62.4000	73.6000	42.1000	16326.2	10904.7	5421.54
1970	66.2000	77.4000	40.6000	16963.6	11677.7	5285.91
1971	68.1000	59.8000	41.0000	17084.6	11796.0	5288.54
1972	74.4000	82.7000	41.4000	17728.8	12720.1	5008.75
1973	95.7000	109.200	59.6000	16881.2	12125.0	4756.21
1974	97.2000	107.800	56.0000	18113.0	11296.4	6816.57
1975	87.8000	134.600	63.2000	18790.9	9422.06	9368.83
1976	87.6000	134.000	60.7000	20372.3	11468.8	8903.49
1977	85.4000	125.400	60.1000	20012.9	11730.9	8281.99
1978	111.000	143.600	66.5000	19236.4	12654.1	6582.32
1979	155.000	144.100	67.7000	17405.2	11981.2	5423.93
1980	158.000	139.400	71.9000	17258.4	11365.0	5893.44
1981	155.000	152.400	73.7000	17578.4	11346.9	6231.54
1982	149.900	175.400	71.6000	17758.9	11926.3	5832.62
	1	2	3	4	5	6

	DCVLR	DCLMR	DCPKR	DCBRR	DCDCHR	DCTKR
1950	1100.84	542.880	9711.52	1301.00	1796.00	612.000
1951	909.600	454.800	10126.9	1572.00	1702.00	671.000
1952	1015.74	569.430	10372.9	1794.00	1590.00	714.000
1953	1346.76	657.720	9255.06	1917.00	1507.00	741.000
1954	1437.30	654.770	8911.26	2177.00	1452.00	842.000
1955	1369.20	668.300	10089.7	2246.00	1210.00	818.000
1956	1395.24	664.400	10348.0	2868.00	1171.00	860.000
1957	1302.07	625.670	9571.06	3222.00	1074.00	990.000
1958	998.760	637.140	9643.20	3765.00	1062.00	1015.00
1959	858.970	753.790	10991.3	3980.00	1058.00	1092.00
1960	926.120	765.830	10739.4	4164.00	782.000	1099.00
1961	851.170	814.950	9380.98	4699.00	722.000	1335.00
1962	845.020	845.020	10856.7	4738.00	743.000	1283.00
1963	764.650	820.600	11395.2	5058.00	681.000	1266.00
1964	813.130	699.670	11535.1	5236.00	663.000	1384.00
1965	823.880	632.280	10480.5	5669.00	716.000	1424.00
1966	734.920	696.240	10521.0	6186.00	691.000	1504.00
1967	624.960	683.550	11678.9	6321.00	792.000	1668.00
1968	591.300	650.430	12101.9	6457.00	776.000	1557.00
1969	537.570	597.300	12085.4	6930.00	711.000	1643.00
1970	484.560	585.510	12580.4	7433.00	728.000	1613.00
1971	450.780	573.720	14000.8	7483.00	770.000	1707.00
1972	373.500	601.750	13043.5	7920.00	747.000	1846.00
1973	314.400	503.040	12016.4	7790.00	686.000	1775.00
1974	402.040	423.200	13055.7	7868.00	749.000	1860.00
1975	748.300	384.840	10818.3	7853.00	719.000	1812.00
1976	712.470	388.620	11593.8	8610.00	616.000	1962.00
1977	697.920	348.960	12170.0	8958.00	669.000	1980.00
1978	441.000	330.750	12326.0	9693.00	641.000	2019.00
1979	356.800	289.900	14227.4	10598.0	650.000	2204.00
1980	360.960	338.400	15408.5	10606.0	689.000	2370.00
1981	364.320	321.057	14793.7	11063.0	707.000	2450.00
1982	379.170	340.104	13415.7	11430.0	731.000	2484.00
	1	2	3	4	5	6

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