

TEXTILE MILL FIBER CONSUMPTION IN THE UNITED STATES:
AN ECONOMETRIC ANALYSIS

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CHAPTER I

INTRODUCTORY REMARKS

1.1. The Scope of the Analysis

The major task of this study is to specify and estimate derived demand functions for the purpose of describing and predicting the volume of textile fiber which is put into process at the textile mills. This analysis is supplemented by an empirical description of the cycles in the rate of growth of textile fiber usage and an examination of the nature of the alleged "textile cycle." Using the powerful tools of regression analysis and spectral analysis of time series, both parts of the analysis extend well beyond previous examinations of fiber usage and its cyclical components. The study itself, while specific in its focus, is also applicable to the investigation of demand behavior in other areas.

Our primary objective is to isolate the relative importance of the major factors which determine the volume of the different fibers used to produce cloth. In the industry literature, the volume of fiber used in production is referred to as "mill consumption," and we retain this terminology. We specify and estimate fiber consumption functions which emphasize dynamic considerations such as habitual behavior, consumer's expectations, and producer's and purchaser's stocks. This emphasis on dynamic elements stems largely from the lack of success of traditional static models of fiber consumption and from the relative (although still limited) success of Houthakker and Taylor in their monograph on annual United States consumption expenditures¹.

¹ H. S. Houthakker and Lester D. Taylor, Consumer Demand in the United States, 1929-1970, Analysis and Projections (Harvard University Press, Cambridge, Massachusetts, 1966).

The regression analysis covers the period 1920-1966 and investigates annual movements in mill fiber consumption. The major fiber categories considered are cotton, wool, and man-made fibers; subdivisions of the wool and man-made fiber groups are studied separately. Previous analyses of the demand for textile fiber have served as useful pilot studies for this inquiry². These studies are deficient in that they primarily employ only static models and deal only with cotton and wool usage; the prominence of the different types of man-made fiber is the most significant recent development in fiber consumption.

We continue the econometric investigation into the nature of textile fiber consumption by studying the cyclical patterns of the consumption series. The purpose here is to characterize the nature of the alleged, two-to-three year "textile cycle." While much attention has been given to the textile cycle, a great deal of confusion still surrounds its nature. We will examine empirically the various claims that have been made about the cycle with respect to its length, its regularity, its independence from movements in the general economy, its changes since the Second World War, its ubiquity throughout the industry, and its amplitude relative to similar movements in other industries. Since such questions about

² See William H. Witherell, "Dynamics of the International Wool Market: An Econometric Analysis," Research Memorandum No. 91, Econometric Research Program, Princeton, New Jersey, September, 1967; James R. Donald, Frank Lowenstein, and Martin S. Simon, "The Demand for Textile Fibers in the United States," Technical Bulletin No. 1301, United States Department of Agriculture, Economic Research Service, Washington, D. C., November, 1963; C. E. Ferguson and Metoděj Polasek, "The Elasticity of Import Demand for Raw Apparel Wool in the United States," Econometrica, Vol. 30, No. 4, October, 1962, pp. 670-699; and International Research Program on Prospective Trends in Consumption of Textile Fibers, Part IV (Secretariat of the International Cotton Advisory Committee, Washington, D. C., March, 1962.)

fiber consumption behavior cannot be answered with regression tools, we turn to spectral analysis of the time series. By supplementing the regression analysis with spectral analysis we are able to provide additional insights into the quantitative nature of fiber consumption.

While the study offers little innovation in the methodology of econometrics, it does illustrate how several techniques may be used to supplement each other. Least squares regression analysis is the basic econometric tool. It is supplemented by covariance analysis to determine the stability of the parameters estimated in the regression equations and by spectral analysis to examine the cyclical tendencies in the data. The three tools permit a concise overview of the major factors seemingly responsible for fiber consumption.

1.2. The Organization of the Study

Chapter 2 describes both the major fiber categories and the products produced from textile fibers and outlines the manufacturing process involved. Chapter 3 concentrates on the specification of a dynamic model to explain fiber consumption. The variables in the analysis and the data are discussed in Chapter 4. The results of the estimation and prediction are presented in Chapter 5. Chapter 6 summarizes and compares the regression results and discusses the overall success of the dynamic models. The hypotheses characterizing the "textile cycle" are presented and tested in Chapter 7. Concluding remarks and suggestions for future research follow in Chapter 8.

CHAPTER 2

INSTITUTIONAL SETTING

2.1. Introduction

To define the more technical terms used and to provide an overview of the setting of the analysis, some institutional background is necessary. We begin in Section 2.2 by describing the major fiber categories. Here we list the major types of fiber, historical movements in their relative importance, and important characteristics of their supply. Section 2.3 discusses the relative importance of the major end uses of products manufactured from the fiber. Finally, Section 2.4 outlines the series of operations involved in the transformation of fiber into finished consumer goods.

2.2. The Major Fiber Categories

The major fiber classifications include three categories of natural fibers and two of man-made fibers. The three natural fiber categories are cotton, wool, and "other fibers," including silk, flax, sisal, hemp, and jute. Cotton is classified according to length and grade. The bulk of the cotton produced is between 7/8 and 1 1/8 inches long and is referred to as medium staple. Grades account for differences in color, texture, and the presence of impurities, and these are fairly homogeneous for cotton of a particular length. For wool there are two major grades of fiber: carpet and apparel wool. Carpet wools, which comprise approximately twenty percent of total annual world production, are generally coarse and often discolored and are obtained from unimproved breeds of sheep. They are used mainly as fill or in floor covering. Apparel wool is finer and more uniform in quality and is suitable for apparel and blankets. The "other natural fibers," while less well known, are not insignificant. In 1963 they accounted for almost twenty-two percent of total fiber consumption, with the

poundage of jute, sisal, and hemp almost three times as great as that of wool^{1,2}.

The two man-made fiber categories are the rayon-acetate and the synthetic fibers. The primary distinction between these two groups is the two different chemical processes used in their manufacture. Rayon-acetate (cellulosic or regenerative) fibers are manufactured from materials which naturally contain long polymer fiber-like chains, but in a form not readily transferable into individual fiber strands. The production process isolates these strands. The synthetic (non-cellulosic) fibers are not regenerated from existing polymers, but rather they are built up from individual molecules which couple under certain conditions. The three major groups of these synthetic fibers are the nylons, the polyesters, and the acrylics, although fibers synthesized from rubber, glass, and metal are often included in the classification.

Both cellulosic and synthetic man-made fibers are produced in continuous strands called filaments. These strands may be spun directly into filament yarn at the fiber plant. Alternatively, the strands may be cut into short slivers resembling natural fiber, called staple, or gathered together and loosely woven in a rope-like manner, called tow. Both staple and tow require spinning at the textile mill, while the filament yarn does not³.

¹ Textile Economic Bureau, Inc., Textile Organon, Stanley B. Hunt, ed., New York, Monthly, January, 1967.

² In the subsequent discussion, fiber percentages are based on consumption totals excluding these "other fibers," since we do not examine the consumption behavior of these other fibers.

³ For a discussion of the various man-made fibers, both filament yarn and staple, see Commonwealth Economic Committee, Industrial Fibers, London, Annually, various issues.

The first man-made fiber to be produced commercially was rayon filament yarn in 1910⁴. Thirty years later, in 1939, the first synthetic man-made fiber, nylon, was produced. Rayon did not compete on a large scale until 1926 when, with the introduction of dull luster, viscose yarn, it began to replace silk as a major fiber. Rayon staple was not marketed until the early thirties and then only in small volume. Nylon was not marketed on a large scale before the Second World War, although it was successful before the War in women's hosiery. In the early fifties, two additional synthetic fiber groups were introduced, the polyesters (Dacron) and the acrylics (Acrilan and Orlon). The consumption of the synthetic fibers grew rapidly, with their products competing in most phases of textile output.

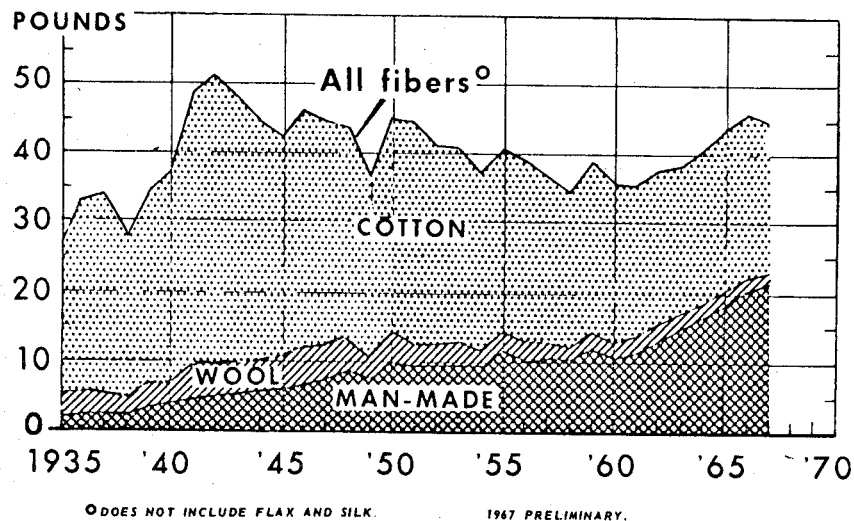
Figure 2.1 describes the relative importance of the major fiber groups since 1935. On the vertical axis the pounds of fiber put into process at the textile mill (referred to as mill consumption) are measured. Before World War II cotton and wool dominated domestic consumption, with wool commanding only a peripheral share of the market. By 1940 the cellulosic fibers, rayon and acetate, had increased their market share to only 10%, while cotton commanded over 80%. Since the War the importance of the fiber groups has altered significantly, for the man-made fibers have experienced tremendous growth. By 1965 the combined synthetic and rayon-acetate fibers accounted for 54% of the total major fibers used at domestic mills. Synthetics alone increased their share of the total market to almost 30%. Both cotton and wool declined in importance, and wool declined more rapidly.

Table 2.1 also shows the relative usage of the individual fibers since the Second World War, distinguishing between five different categories of man-made fiber. The percentages in the

⁴ Jesse W. Markham, Competition in the Rayon Industry (Harvard University Press, Cambridge, Massachusetts, 1952), p. 14.

Figure 2.1. Mill Consumption of Fibers, Per Capita.

MILL CONSUMPTION OF FIBERS, PER CAPITA



Source: United States Department of Agriculture, Cotton Situation, Economic Research Service, Washington, D.C., bimonthly, March, 1968.

Table 2.1. Percentage of Total Mill Consumption of Different Fibers.

	Cotton	Wool	Rayon and Acetate		Non-Cellulosic		Textile Glass
			filament yarn	staple	filament yarn	staple	
1950	65.5 (68.8)	4.9 (9.3)	20.2 (14.5)	6.1 (5.8)	2.4 (1.5)	0.4 (.3)	0.5 (.3)
1958	59.0 (65.5)	2.8 (5.6)	16.0 (10.9)	8.1 (8.2)	8.1 (5.3)	3.3 (2.7)	2.7 (1.8)
1965	44.2 (53.5)	2.1 (4.6)	12.3 (9.3)	8.3 (9.2)	18.3 (11.0)	10.3 (9.1)	4.5 (3.2)

Source: Compiled from Textile Economics Bureau, Inc., Textile Organon, January, 1967, p. 18.

table underscore the growth of man-made fibers noted above and indicate the pattern of growth within the man-made fiber category. The percentages represent the proportion of total fiber consumption commanded by the major fiber categories, calculated in terms of efficiency pounds⁵. The figures in parentheses, calculated in terms of physical pounds, are provided for comparison.

Since 1950 cotton consumption has lost approximately one third of its previous share, and wool, approximately three fifths. Rayon and acetate experienced a rapid growth immediately following the War but have since declined slightly with the tremendous surge of synthetic filament and staple. In 1958 the rayon-acetate fibers were still the dominant man-made fibers and cotton was very strong, but since then the non-cellulosic synthetics have shown remarkable growth. Unless percentages are reported in efficiency pounds, the ascendancy of man-made fibers is not given its proper weight.

We present certain characteristics of the supply of the different fibers, emphasizing the role of institutional factors in the determination of fiber prices. Since 1933 the United States Government has undertaken a massive loan program to provide a support level for the prices paid to farmers for upland cotton (99% of total domestic production). At the beginning of each annual season, cash

⁵ Textile fiber consumption is reported in physical pounds. However, a pound of each of the fibers will not produce the same quantity of end products. This difference is due largely to the variation in the weight per square yard of the different fibers for the same end use and to the waste incurred in processing the different fibers. In the comparison of the relative importance of the various fibers, it is desirable to take these "quality" differences into account. The Department of Agriculture has provided a list of factors to convert physical pounds into equivalent pounds (see J. R. Donald, F. Lowenstein, and M. S. Simon, "The Demand for Textile Fibers in the United States," Technical Bulletin No. 1301, United States Department of Agriculture, Economic Research Service, Washington, D. C., November, 1963, pp. 126-135). The percentages above and in the following table are computed in terms of equivalent poundage. In the table, the percentages in terms of physical pounds are included in parentheses; they overstate the relative importance of wool and understate that of man-made fiber.

is lent to the farmers to be repaid either in the form of money (if the subsequent crop is marketed) or in the form of the nonmarketed cotton itself⁶. The loan policy allows the farmer to seek a more advantageous price than the support level. The domestic price for cotton, however, is typically very close to the annual support price⁷. Thus the price for cotton received by farmers is practically fixed by the Government. Between April, 1964 and June, 1967, one further institutional arrangement influenced the price paid by the textile mills for cotton. Before April, 1964, foreign mills were able to purchase United States cotton at a lower price than that offered to domestic mills because of export subsidies. In April, 1964, the United States Government began to make equalization payments to the domestic mills. In June, 1967 the payments were discontinued, but the support level was also lowered to keep the price paid by the mill at approximately the same level as that under the equalization scheme.

Wool is one of the few international commodities which is not subject to international control agreements. Wool is traded at open auction in the major producing countries (Australia, New Zealand, and South Africa) and in the United Kingdom. Buyers from all over the world compete in these markets⁸. Wool is traded in subsidiary markets in some minor producing and consuming countries, but the prices in these markets adhere very closely to the prices determined

⁶ The loan policy tends to spread cotton marketings over the season, reducing the seasonal variation in cotton price.

⁷ Kurt H. Schaffir, "Operations Research in the Textile Industry," Publications in Operations Research (John Wiley and Sons, Inc., 1969, No. 9, Chapter 14), p. 353.

⁸ For a discussion of the wool auction markets, see William H. Witherell, "Dynamics of the International Wool Markets: An Econometric Analysis," Research Memorandum No. 91, Econometric Research Program, Princeton, New Jersey, September, 1967, and S. P. Burley, "Fluctuations in the Australian Economy: Viewed by Frequency Techniques," Research Memorandum No. 94, Econometric Research Program, Princeton, New Jersey, March, 1968.

in the major markets. In the United States there are a small number of trading centers, of which Boston is the most important⁹, and the prices determined in the Boston market reportedly adhere closely to the wool price determined in the larger auctions¹⁰.

Man-made fiber production is centered in a few large chemical companies which have either developed their own fibers or which are paying royalties to produce those developed by others. In the developmental stages, access to the fiber is generally restricted to only a few participants. Once the fiber reaches the stage of mass production, prices are administered by the chemical companies and are subject to infrequent change. The pricing policy of the oligopolistic firms has been to keep the list prices very stable. An illustration of the infrequency with which synthetic fiber list prices change is provided in Figure 2.2¹¹.

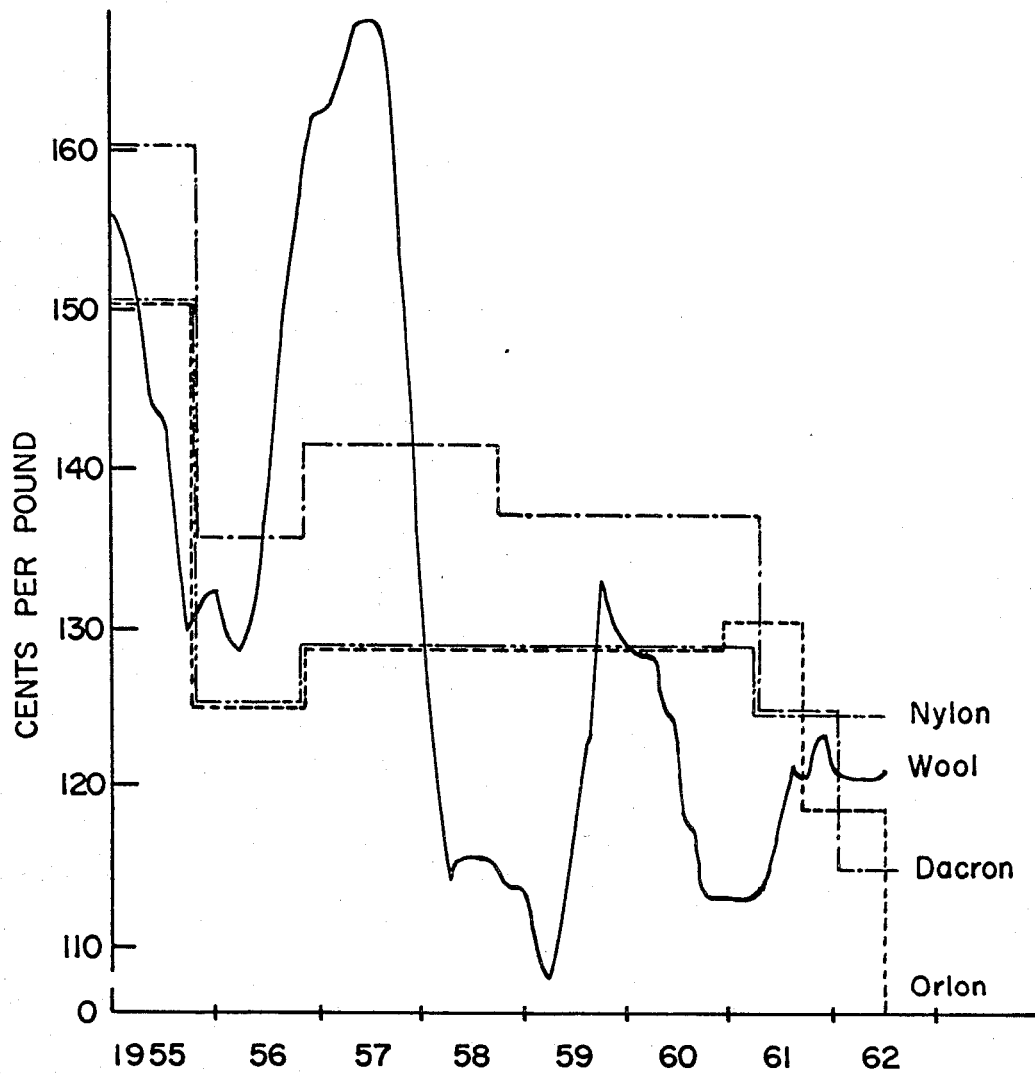
The actual cost of obtaining fiber may include other considerations besides the list or market price; thus the list price may not accurately reflect the effective price. First, there is the possibility of off-list selling in which case the money price and the list price are not the same. Second, there are other potential service arrangements, ranging from shipping terms to technical assistance and greater promotional effort, which affect the ease or difficulty of acquiring the fiber and then selling the fabric. Generally, the effective price of the fiber is a vector of

⁹ About 70 percent of the domestic and imported wools are traded here, and in 1962, about 40 percent of the apparel wool traded here was imported; for a discussion of the Boston market, see C. E. Ferguson and Metodey Polasek, "The Elasticity of Import Demand for Raw Apparel Wool in the United States," Econometrica, Vol. 30, No. 4, October, 1962, pp. 671-673.

¹⁰ See Ferguson and Polasek, op. cit., p. 672; A. M. Hermie, "Prices of Apparel Wool," Technical Bulletin No. 1041, United States Department of Agriculture, Washington, D. C., 1951, pp. 8-10; and Witherell, op. cit., pp. 234-244.

¹¹ Prices of the cellulosic fibers, rayon and acetate, exhibit similar stability. For a discussion of cellulosic prices and the representativeness of the list price, see Markham, op. cit., pp. 68-98.

Figure 2.2. Wool and Representative Non-Cellulosic Fiber Prices.



Wool - fine graded territory, scoured basis at Boston,
Nylon - 3 and 6 denier, staple,
Orlon - 3 denier, staple,
Dacron - 3 denier, staple.

Compiled from graphs constructed by The Wool Bureau, Inc., New York. Man-made fiber data originally provided by the Rayon Publishing Corporation, Modern Textile Magazine, New York.

considerations of which the list price is just one element. Other considerations appear to be much more important for the man-made fibers than for the natural fibers; we pay particular attention to the man-made fibers below.

To the extent that off-list selling occurs, the list price does not accurately reflect the effective price of the fiber. While off-list selling is uncommon in natural fiber transactions, it has occurred in man-made fiber transactions. Markham notes a wide divergence between list and money prices during the depression years, 1930-1932, in a period of excessive inventory accumulation. Markham reports, "Rayon company officials characterize the two years between June, 1930, and June, 1932, as a period of distress selling, chiseling, and off-list selling."¹² For example, the president of the Tubize Company admitted that "his company sold under list price during 1931 and 1932 and that, in spite of his admiration and affection for his competitors, he believed that they did also."¹³ Summarizing activity over the entire prewar and early postwar period, Markham concludes that "generally, list price less the usual freight allowances reflects fairly accurately the net realized price on rayon yarn except for periods characterized by a severe and protracted slump in rayon sales."¹⁴ He continues that to the extent there did exist off-list selling in market slumps since 1932, "they seem to have been both sporadic and short-lived."^{15,16} Pricing practices are not so well documented for the postwar period.

¹² Markham, op.cit., p. 76.

¹³ Ibid., p. 73.

¹⁴ Ibid., p. 73.

¹⁵ Ibid., p. 78.

¹⁶ Markham notes the possibility of the reverse phenomenon of small price premiums being charged in extremely tight yarn markets but continues, "Generally, this practice seems to have been limited to a few producers and to very short intervals." See Markham, op.cit., p. 79.

There are indications that during the latter half of the 1950's, when cellulosic fiber experienced diminished sales volume, there was an occasional tendency to sell many types of rayon yarn below list¹⁷. We lack information about the incidence of off-list selling in synthetic fibers. The fibers have experienced continual growth which, if Markham's prewar observations can be extrapolated, would reduce the tendency for off-list selling.

The effective price of the fiber is determined by many other factors besides the list or market price. The first of these is service arrangements such as shipping and handling and special technical assistance¹⁸. The latter was especially important in the early stages of man-made fiber development; the fiber producers and the

¹⁷ Rayon Publishing Corporation, "New Trends in Rayon," Modern Textile Magazine, New York, September, 1956, p. 40 and "New Trends in Rayon," Modern Textile Magazine, New York, September, 1957, p. 52.

¹⁸ An example of some of the contingent service arrangements for rayon yarn transactions is printed by the Textile Economics Bureau, Inc., Textile Organon, op.cit., January, 1962:

The largest rayon producer's quoted prices are based on "seller to select and to pay transportation charges of common and contract carriers except when shipment moves west of the Mississippi River, in which event only the actual cost of transportation to the Mississippi River crossing, based on the lowest published freight rate, shall be allowed. Title to pass when merchandise is delivered to consignee." Other producers prepay or allow transportation to any point within the continental United States, except Alaska.

SELLING TERMS. The usual selling terms have been net 30 days since 1941.

BOOKING PERIOD. From September 1939 to date, the advance booking period has been 60 days, e.g. as of March 1st, the producer accepts orders through the following May.

Markham has noted that in the prewar such items as term discounts, shipping terms, booking periods, and price guarantees were followed uniformly over the industry; see Markham, op.cit., pp. 78-79.

mills worked closely together in improving the fiber for large scale use¹⁹. Second, promotional campaigns and quality improvement affect the effective price of the fiber by making its products more readily marketable. Such improvements reduce the effective cost of the fiber to the mills because products made from these fibers can be more easily marketed. Both promotional success and quality improvement appear to have been important elements in determining the competitive position of man-made fiber, especially synthetic fiber²⁰. However, the natural fibers, wool and cotton, have also been heavily promoted.

2.3. The Major Uses of Textile Fiber Products

The Textile Economics Bureau has classified final textile products into the following five major end use categories:

1. Men's and boy's apparel
2. Women's, misses' and children's apparel
3. Home furnishings
4. Other consumer-type products
5. Industrial uses

The first two are apparel items. The third category is home furnishings, which includes a variety of goods from bedspreads and sheets to carpets and upholstery. These goods are primarily semi-durables and may be subject to stylistic obsolescence. "Other

¹⁹ See Schaffir, op.cit., pp. 354-355.

²⁰ The trade literature contains many references to the importance of these items. See especially Robert C. Shook, "The Future of Tire Cord: Rayon or Nylon," in Modern Textile Magazine, op.cit., July, 1956, pp. 32-33 and 65-66; Lowel P. Wicker, "Record Carpet Sales Expected," in Modern Textile Magazine, op.cit., January, 1964, pp. 21-22; Jordan P. Yale, "The Strategy of Nylon's Growth: Create New Markets," in Modern Textile Magazine, January, 1964, pp. 32-33; Peter W. Sherwood, "The Outlook for the New Man-Made Fibers," in Modern Textile Magazine, op.cit., June, 1965, pp. 50-51; Jordan P. Yale, "Innovation: Its Impact on Man-made Fibers," in Modern Textile Magazine, op.cit., September, 1966, pp. 50-52.

consumer-type products" range from apparel and luggage lining to doll clothing and artificial hair pieces. The remaining category, industrial items, represents textile products which are used as intermediate goods in other industries. Tire cord yarn is a large component. Other products in the category include industrial belting, sewing thread, electrical applications, tents, paper and plastic reinforcing, and ropes and bags.

The Textile Economics Bureau has recorded the pounds of each fiber used in the various end use categories. These data measure the volume of particular fibers (in fabrics) used in the production of the numerous items in each group. We subsequently refer to these figures as end use consumption, to be differentiated from mill consumption which measures the volume of fiber put into process at the textile mill.

Table 2.2 summarizes how each of the fiber categories, cotton, wool, and man-made fibers, have been divided between the different end uses. Percentages are included for both 1960 and 1965²¹. Column 1 indicates that cotton is used primarily in apparel items, although household items account for a little over one third and industrial items, for almost 15% of the total. This pattern has remained unchanged over the five year period. Between 60% and 70% of all wool is used in apparel products, and its industrial usage is negligible. The remainder is used in household products such as blanketing and carpeting. In 1960 the man-made fibers were divided evenly over the three end uses. By 1965, however, household uses had risen sharply relative to industrial uses, while apparel uses had remained the same. The table also summarizes the allocation of total textile fiber consumption among the end uses. Column 4 indicates that apparel products are the major outlet for fibers, with household items a close second, and industrial uses third. Over the five year period, household items rose relative to apparel and almost overtook apparel as the major outlet.

²¹

The percentages do not illustrate that fiber consumption in all of the categories has increased.

Table 2.2. The Allocation of Individual Fibers Over End Uses:
In Percentage of Total End Use Consumption of Each
Fiber.^a

		<u>Cotton</u>	<u>Wool</u>	<u>Man-Made Fibers</u>	<u>Total End Use Consumption</u>
Apparel ^b	1960	44.6	62.2	31.9	42.3
	1965	44.9	68.2	32.5	41.0
Household ^b	1960	35.5	35.5	33.3	34.8
	1965	38.0	29.5	41.5	39.0
Industrial	1960	14.6	1.8	30.3	18.2
	1965	13.6	1.7	23.2	17.0
Tire Cord	1960	.005	-	18.10	5.7
	1965	.003	-	12.35	5.4

a. Percentages will not add to 100% because of the neglected end use consumption category of exports of semifinished goods such as grey or finished cloth.

b. The apparel classifications are combined and "other consumer-type products" is included in household items. Tire cord is listed separately.

Source: Compiled from Textile Economics Bureau, Inc.,
Textile Organon, January, 1967, p. 4.

Table 2.3. The Percentage Share of Each Fiber in the Specified End Use.^{a,b}

		<u>Cotton</u>	<u>Wool</u>	<u>Man-Made Fibers</u>
Apparel	1960	66.6	11.0	22.4
	1965	56.7	10.8	32.5
Household	1960	63.4	8.4	28.2
	1965	50.0	4.6	45.4
Industrial	1960	50.0	0.8	49.2
	1965	41.1	0.6	58.3

- a. Percentages are in terms of physical pounds.
- b. Tire Cord is almost exclusively supplied from man-made fibers and so is not included - see Table 2.2.

Source: Compiled from Textile Economics Bureau, Inc., Textile Organon, January, 1967, p. 4.

In Table 2.3, we focus upon the end uses rather than the fibers to see how each end use has been supplied by the various fibers. Row 1 indicates that the apparel industry is supplied primarily by cotton, with man-made fibers second, and wool third. Even though the large majority of wool is used for apparel, the actual volume is a small percentage of total apparel production. Household items are also primarily cotton products with man-made fibers again second. In 1960 industrial items were evenly supplied by cotton and man-made fibers, but by 1965 man-made fibers had risen relative to cotton to become the primary source. The rise in the importance of man-made fibers was just as dramatic in the apparel and household items, but it was not sufficient to overcome cotton's lead.

2.4. The Production-Marketing Sequence Between the Mill and the Retailer

The fabrication of raw fiber into finished goods involves the following sequence of operations. The initial step is the cleaning and the preparation of the raw fiber for spinning. Then the fiber is spun into yarn and knit or woven into cloth. The next step, referred to as finishing, is to dye, bleach, print, or otherwise process the cloth so that it will be more serviceable. The cloth is then cut into useful end products and distributed through wholesalers or retailers to consumer outlets. These successive steps are referred to here as the production-marketing sequence.

The preparation, spinning, and weaving functions are typically combined under the same management and are handled by large, automated mills, the major industrial establishments along the sequence. The majority of the cloth produced by these mills is a nearly homogeneous, unfinished, grey fabric²². These mills attempt to smooth their production as much as possible, backlogging orders for cloth in periods of high demand and producing for stock in the absence of new or unfilled orders²³.

Before the grey cloth is cut into end use products, it is bleached, dyed, or printed, and in some cases treated with chemical additives to improve its quality. These are known as the finishing operations. Those responsible for these operations are called converters; they purchase grey cloth and then determine the specifications to which the cloth is to be finished. Elements of style are first introduced in the office of the converters. Success in

²²It is interesting that the immense variety of products on retailer's shelves are produced from a few weight classes of grey cloth.

²³Schaffir has noted that the costs of altering the production level include the potential loss of skilled labor once the level is reduced and the fact that Southern mills have used the argument of steady employment to confront demands for unionization. There are also economies of continuous production resulting from the reduction of the expensive changeover and setup costs; see Schaffir, op.cit., pp. 347-363, and especially pp. 360-363.

converting depends upon the ability both to introduce styles which will be bought by the cutters and to provide lower cost imitations.

Historically the converters have speculated in grey cloth. In fact, speculative buying has been prevalent. For example, Zarnowitz has observed that "the demand for cotton fabric is abundant with short but sharp speculative ordering movements reflecting chiefly the changing price anticipations of converters."²⁴ There is no futures market for grey cloth. The speculation is by overcommitment when prices are expected to rise and by restraint when price declines appear imminent. The existence of forward trading in the grey cloth market does permit the converters to purchase goods for future delivery in addition to currently available spot merchandise, allowing speculative buying in greater volume²⁵.

²⁴Victor Zarnowitz, "Unfilled Orders, Price Changes, and Business Fluctuations," Review of Economics and Statistics, Volume XLIV, Number 4, November, 1962, p. 372.

²⁵ Observers have claimed that, because there is no organized futures market for staple cotton cloth, speculation is one-sided, allowing only optimistic expectations to be expressed in the market. (See T. J. Stanback, Jr., "The Textile Cycle: Characteristics and Contributing Factors," The Southern Economic Journal, Vol. 25, No. 2, October, 1958.) However, while speculation may be one-sided, it is not because of the lack of a futures market, for the existence of forward ordering theoretically provides an opportunity to express any opinion about the future course of the market so that neither optimistic nor pessimistic anticipations may dominate the market. Speculation is at times one-sided because spot merchandise may not always be available (and the situation probably would not alter if there were a futures market). Pessimistic speculators can theoretically wait to pick up goods in the spot markets in the future; however, because spot merchandise is not always readily available, taking a short position may be a risky procedure if the converter actually needs the cloth to meet his commitments. Under such conditions there is an inherent bias in the market against the converter who wishes to express his expectation that prices will fall. Thus there may be a greater tendency for optimistic anticipation to be expressed. Moreover, if there were a futures market the situation would not be significantly altered, for it would be subject to the same shortcoming as is the system of forward ordering. The option to sell for future delivery in the face of expected price declines requires that the speculator be assured of a source of spot supply. Even if the futures market did exist, it would be just as difficult for the converter to express his pessimism.

The finished cloth is then shipped to the cutters where it is manufactured into apparel, household, and industrial items. The cutters produce both to order and in anticipation of demand, depending upon how quickly the style of their products might become outdated. The finished items are distributed to the consumers through wholesale and retail outlets or to industrial purchasers either directly or through wholesalers. It is a simplification to characterize the production-marketing sequence as a series of independent industries each of which performs only one function. Vertical integration along the sequence has resulted in an overlap of functions by some establishments. Thus in any one of the individual industries there are both manufacturers who perform only one function and those who perform other functions as well. Some mills have established their own converting departments and produce finished cloth (approximately 13% of primary textile mills' output is finished cloth); large garment houses may buy grey cloth directly from the mill and provide the finishing; and some retail outlets assume the wholesale function. A few large chain stores even produce their own apparel, starting from the raw fiber.

The actual number of steps in the sequence between the purchase of fiber and the manufacturing of end use products varies with the type of fiber. The above description of the sequence is based upon the operations performed in the production of cotton products. It also closely resembles the man-made fiber production-marketing sequence, except that filament yarn is ready for weaving and, with both filament yarn and staple, the preliminary fiber processing required is minimal. The woolen sequence is different, for there are no independent converters and no grey cloth market. The converting function is performed exclusively by the mills, which deal directly with the cutters and produce primarily to their specifications.

CHAPTER 3

ECONOMIC SETTING: SPECIFICATION OF FIBER CONSUMPTION MODELS

3.1. Introduction

In this chapter we outline alternative static and dynamic specifications of the consumption function and discuss their relative merits. In Section 3.2, the traditional static fiber consumption function is examined. Section 3.3 introduces two dynamic models which are developed further and transformed into a form suitable for estimation in Section 3.4. The interdependence of mill consumption and price is discussed in Section 3.5. The chapter is followed by two appendices. The first is an extension of the theoretical framework of the dynamic models presented in Section 3.3. The second presents a more disaggregated version of the dynamic models.

3.2. Traditional Empirical Consumption Analysis

A standard approach in empirical fiber demand analysis is to estimate with single equation techniques a static function of the form

$$(3.1) \quad MC_t = f_1 \{ P_{1t}, P_{2t}, Y_t, Z_t, u_t \}, \text{ where } MC_t \text{ is the}$$

per capita volume of fiber put into process at the textile mill and is termed mill consumption. Per capita mill consumption is a function of the current (or immediately past) values of the following variables: the price of the fiber, P_{1t} , the price of competing fiber, P_{2t} , per capita disposable income, Y_t , and other pertinent factors, Z_t . A disturbance term, u_t , is included to account for additional variables which have not been specified, inherent randomness, and errors in the measurement of fiber consumption. Several observations can be made about this general approach:

(1) A major and often emphasized shortcoming of empirical demand studies is their neglect of possible interdependence between the dependent and independent variables. It is often the case that the price of the product is not truly exogenous but is an equilibrium quantity determined jointly with the level of consumption. Such joint dependence requires that the consumption function be studied within its simultaneous equation context¹. Even if the exact form of the other relationships in the model cannot be specified, there are estimating techniques which will correct for the effects of simultaneity on the parameter estimates (although commonly used techniques introduce a bias of their own).

(2) It is tempting in such analysis to add explanatory variables to increase the coefficient of determination. A theoretical limit to the inclusion of independent variables is the number

¹ For example, consider the market model:

$$(3.2a) \quad MC_t = f_1 \{P_{1t}, P_{2t}, Y_t, Z_t, u_{1t}\},$$

$$(3.2b) \quad Q_t = f_2 \{P_{1t}, X_t, u_{2t}\},$$

$$(3.2c) \quad H_t = f_3 \{H_{t-1}, P_{1t}, S_t, u_{3t}\},$$

$$(3.2d) \quad MC_t = Q_t - H_t + H_{t-1},$$

where Q_t and H_t represent the production and mill stock of raw fiber. Consumption is equated to the supply of fiber (by equation (3.2d)) which results from production and inventory decisions. The final values of fiber price, production, and stock result from the interaction of demanders and suppliers and equilibrate at levels agreeable to both. Witherell uses a similar model to describe the world wool market (see William H. Witherell, "Dynamics of the International Wool Market: An Econometric Analysis," Research Memorandum No. 91, Econometric Research Program, Princeton, New Jersey, September, 1967, pp. 167-209).

of independent observations in the data, which determines the available degrees of freedom; practical "rules of thumb" limit the explanatory variables to approximately one third of the total number of observations. In the use of time series data, however, multicollinearity problems are often introduced before this latter limit is reached. Thus, in the use of time series data, it is advisable to assess the degree of independent variability in the explanatory variable space to obtain an indication of when multicollinearity will become a severe problem. Of course, the individual variables must still be selected carefully.

(3) Economic theory provides little insight into the a priori mathematical form of the consumption function. It is customary to specify and estimate alternative mathematical formulations.

(4) A glaring difficulty with most empirical demand functions of the above static form is the occurrence of autocorrelation in the residuals. This destroys the efficiency of the usual estimation procedures and the accuracy of common statistical tests. Serial correlation is very prevalent in economic time series analysis². The use of time series, then, can often lead to serious difficulty in the interpretation of the regression results and in prediction unless such serial correlation is taken into account or corrected.

(5) The above specification of the static model is suspect, for it implicitly assumes that current consumption is a function of

2

An indication of the serial correlation evident in economic time series is found in the work of Granger (See C.W.J. Granger, "The Spectral Shape of an Economic Variable," *Econometrica*, Vol. 34, No. 1, January, 1966, pp. 150-161). He finds that many economic data have very high power concentrated in the low frequency (long period) bands of their spectral density functions and labels it the "typical spectral shape." (See Appendix A to Chapter 7 for further discussion of this spectral property.) Fiber consumption data themselves do have the typical shape. Even though it has been shown that low-order autoregressive schemes can generate a typical spectral shape, one must be careful not to turn immediately to a low-order autoregressive model, for high-order schemes can also generate the typical spectral shape.

the current, or immediately lagged, values of economic variables thought to be responsible for consumption activity. It neglects the possibility that current consumption is also affected by a succession of past occurrences, including such dynamic elements as anticipations and consumer stocks and habits. Alternative consumption functions have been devised to account for the impact of past occurrences upon present consumption, recognizing that the effect of a particular factor may be extended over time. These dynamic formulations have become prevalent in empirical time series demand studies. We will see that the dynamic formulation provides an economic rationale as to why consumption should experience smooth adjustment to changes in price and income and thus, in part, why we might expect to find evidence of first-order serial correlation in consumption time series. In fact, the possibility that static models are incorrectly specified because of the omission of dynamic considerations provides one explanation of the serial correlation observed in the static models^{3,4}.

(6) The above formulation involves a high degree of aggregation. It recognizes that the volume of fiber processed at the mill is ultimately derived from the desires of consumers of the final goods, as represented by the level of personal disposable income. But the model does not recognize that the production and merchandising activity of the intermediary fabricators between the mill and the consumer may affect the volume of fiber consumed. For example, consider a case where per capita disposable income and the raw fiber prices remain constant, but the price of cotton finished cloth or of final cotton products changes relative to the price of man-made fiber products. There may be substitution between the cotton

³ The dynamic formulation typically includes the lagged dependent variable as an explanatory variable. If the lagged dependent variable should be included in the equation but is not, then it is implicitly accounted for by the error term. If the dependent variable is subject to an autoregressive scheme, then so is the residual.

⁴ We find later that dynamic models may account for such autocorrelation in yet another (but hardly convincing) manner.

and man-made fiber products which would eventually affect their relative consumption. Model (3.1) would not explain such a change, for it only accounts for fiber substitution through changes in the fiber prices. Also, consider the case where the intermediate producers along the production-marketing sequence revise their inventory objectives. The resultant stock movements may also affect the volume of fiber consumption without a change in per capita disposable income or the raw fiber prices. Furthermore, if per capita disposable income were to change, its effects upon fiber consumption would vary according to the inventory decisions along the sequence. Thus the above specification smooths over the mills and the intermediaries along the sequence, combining them and the final consumers into a single unit. However, for a given set of raw fiber prices and per capita disposable income, there may be several levels of total mill consumption of a particular fiber, depending upon the time path of the levels of prices, stocks, and production levels along the sequence.

Model (3.1) aggregates over the production-marketing sequence. The empirical question arises whether the specification allows reasonable prediction and reliable inferences or whether it is necessary to incorporate some of the characteristics of mill and intermediary production behavior. Pilot studies, as well as the results below, indicate that to explain the movement of the aggregates it is not necessary to uncover all the minute and complex interdependencies and feedbacks between the mills, the intermediaries, and the final consumers⁵. Nevertheless, there may be

⁵ See, for example, James R. Donald, Frank Lowenstein, and Martin S. Simon, "The Demand for Textile Fibers in the United States," Technical Bulletin No. 1301, United States Department of Agriculture, Economic Research Service, Washington, D.C., November, 1963. They expand the static formulation to specify mill stock movements by including an adjusted stock-to-unfilled-orders ratio. Theoretically, however, the variable should replace disposable income. Also, see C. E. Ferguson and Metodey Polasek, "The Elasticity of Import Demand for Raw Apparel Wool in the United States," Econometrica, Vol. 30, No. 4, October, 1962, pp. 670-699.

alternative consumption levels consistent with a given set of fiber prices and disposable income⁶.

3.3. A Dynamic Model of Consumption Behavior

Alfred Marshall distinguishes between the short-run and the long-run response of quantity supplied to a change in one of its determinants⁷. He notes that because certain factors of production can be altered only gradually over time, the "normal" or long-run desired level of supply can be reached only after a sufficient period of time had been allowed for adjustment. Nerlove and Bergstrom have included these elements in a dynamic model of consumption behavior⁸. They recognize the existence of certain temporary constraints or costs which deter consumers from immediately altering their consumption to the level they would eventually desire if a sufficient period were allowed for adjustment.

The model consists of two relationships. The first defines the normal consumption level:

$$(3.3) \quad MC_t^n = f(P_{1t}, P_{2t}, Y_t, Z_t, u_{1t}).$$

This function summarizes the aggregate quantity that would eventually be desired by consumers if the determining factors were to remain constant in the future. The second equation of the model recognizes that this normal, long-run desired level of consumption need not be

⁶ In Appendix B, we extend the model to specify explicitly the behavior of the intermediaries along the production-marketing sequence.

⁷ Alfred Marshall, Principles of Economics (Macmillan and Co., Ltd., 8th ed., London, 1936) pp. 378-379.

⁸ Marc Nerlove, "Distributed Lags and Demand Analysis for Agricultural and Other Commodities," Agricultural Handbook No. 141, United States Department of Agriculture, Agricultural Marketing Service, Washington, D.C., June, 1958; and H. S. Houthakker and Lester D. Taylor, Consumer Demand in the United States, 1929-1970, Analysis and Projections (Harvard University Press, Cambridge, Mass., 1966) pp. 27-29.

realized immediately:

$$(3.4) \quad \frac{dMC_t}{dt} = \delta(t) \times (MC_t^n - MC_t),^9$$
 where the mathematical form

of $\delta(t)$ will determine the path of the dynamic adjustment. The model recognizes a timeless and stable relationship between consumption and the factors affecting purchasing. It further recognizes that this relationship is not always observed in the data because of the complicating factors operating in the short run¹⁰. An interesting feature of the model is that it not only allows for differences between the "short-run" and the "long-run" marginal propensities to consume but also accounts for them¹¹.

There are several motives for such partial adjustment. Consumers may not expect the current values of the explanatory variables to remain unchanged, so that they may exhibit caution in

⁹ The reaction equation in its continuous time formulation is due to Bergstrom; Nerlove has presented a difference equation analogue.

¹⁰ Nerlove argues that the normal demand is the only quantity uniquely determined by prices and income, so that unless the distinction between normal consumption and possible "shorter-run" movements is made, there is no sense in estimating an equation which specifies consumption as a function of these variables; see Nerlove, op.cit. p. 15.

¹¹ For a discussion of short- and long-run marginal propensities to consume reported in empirical consumption analysis, see Gardner Ackley, Macroeconomic Theory (The Macmillan Co., New York, 1961) pp. 209-252.

adjusting to the normal level¹². Even in a world of certainty, there are institutional, psychological, and technological factors which prevent immediate change. A major psychological factor is the force of habit. Habitual behavior can be a powerful deterrent to both the rapid increase and decrease of consumption, as shown by Houthakker and Taylor¹³. Habitual response is manifest in the actions of both the producers who use raw fiber and the purchasers of textile products. Mill management changes production levels slowly, smoothing production to avoid costs of altering production, and consumers of textile products require time to become identified with relatively new products or to inform themselves about the price movements of goods competing with those in their current market baskets. Institutional considerations also restrict consumption adjustments, since the existence of stocks of both

¹² By including the current values of price, income, etc., in the normal demand function and then asserting that consumers base their behavior upon this normal level, we have implicitly assumed that consumers have static expectations. Nonstatic expectations can be introduced explicitly by expressing the normal demand function in terms of the expected "permanent" levels of the explanatory variables. The function will then summarize the quantity that would eventually be consumed given that the anticipated value of the variables were realized and remained constant over time. There exist several expectational schemes which can be used to represent nonstatic anticipations. However, the introduction of such formulations in empirical analysis has not been particularly successful. (See, for example, Michael Lovell, "Determinants of Inventory Investment," in Models of Income Determination, Studies in Income and Wealth, Vol. XXVIII, Conference on Research in Income and Wealth, National Bureau of Economic Research, Princeton University Press, Princeton, New Jersey, 1964, pp. 177-224.) A common fault of the various formulations is that they represent expectations as single valued (these expectational schemes generally involve a weighted sum of preceding observations); generally this is not the case. A second and related difficulty is that expectations involve more than a particular lagged weighting scheme; they are affected by many qualitative factors involving outside occurrences. Nevertheless, the possibility of introducing nonstatic expectations explicitly does exist.

¹³ Houthakker and Taylor, op.cit., p. 153.

producers and final consumers provide possible deterrents to immediate adjustment. Producers can meet current requests for consumer items from their stocks of intermediate and finished goods, so that these current requests need not have an immediate impact upon mill consumption. Incidentally, the model does account implicitly for some activity along the production-marketing sequence. The existence of stocks in the hands of the final consumers also may restrict immediate adjustment, for if services are still provided by previously purchased goods, consumers may not respond so quickly as they would if they did not possess these stocks¹⁴. Technological factors can also be responsible for partial adjustment. Additional desired fiber usage may be restricted by the lack of the necessary plant, equipment, and skill required to process a particular fiber¹⁵.

These factors are responsible for the lagged adjustment of consumption to its normal level. The actual time path of the adjustment is described by the solution to equation (3.4). Equation (3.4) is a first-order, nonhomogeneous differential equation with a variable coefficient, $\delta(t)$. The function form of $\delta(t)$ will describe the manner in which consumers adjust toward their normal level. To avoid immense complication, we assume that $\delta(t)$ is a positive constant and label it the "coefficient of adjustment." When $\delta(t)$ is a constant, the solution to (3.4) is

$$(3.5) \quad MC_t = (MC_0 - MC^n)e^{-\delta t} + MC^n,$$

where MC^n is the normal level and MC_0 is the initial level¹⁶.

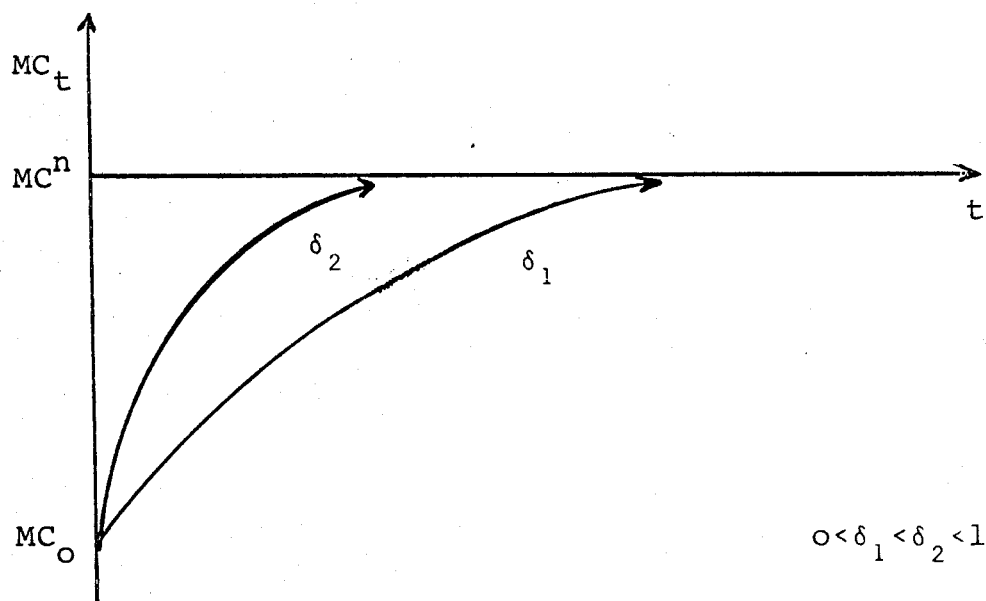
¹⁴ Ibid.; they have not found consumer stocks to be so influential as the force of habit.

¹⁵ For a more complete list of deterrents to instantaneous adjustment, see Nerlove, op.cit., pp. 5-7, 14-18 and 20-25; Ackley, op.cit., pp. 268-309; and Michael Lovell, "Manufacturers' Inventories, Sales Expectations, and the Acceleration Principle," Econometrica, Vol. 29, No. 3, July, 1961, pp. 293-314.

¹⁶ We have assumed here that there are no further changes in the explanatory variables of (3.3).

The adjustment path implied by (3.5) is presented graphically in Figure 3.1.

Figure 3.1. The Implied Adjustment Path of the Reaction Equation.



As indicated in Figure 3.1, the adjustment is proportional to the discrepancy between actual consumption and the long-run, normal level, so the actual level approaches the normal level asymptotically. Also, if the coefficient of adjustment is larger (i.e. δ_2 as opposed to δ_1), the adjustment path bends in more toward the origin, implying that the normal level is approached more quickly.

According to the adjustment path specified above, consumer inertia becomes stronger as the equilibrium normal consumption level is approached. Consumers will be slower to react when the discrepancy between actual and normal is small, but as the gap widens, they will be less hesitant to alter their past behavioral patterns. It is as if there were a "reaction threshold" surrounding the normal consumption level, outside of which the restrictions

of the force of habit, the costs of adjustment, and the existence of stocks are no longer operative. A priori, the adjustment process is not an unreasonable approximation of consumer behavior. Also, it can be shown that the specified adjustment path closely approximates that which consumers would follow in order to minimize the cost incurred over time by being out of equilibrium¹⁷.

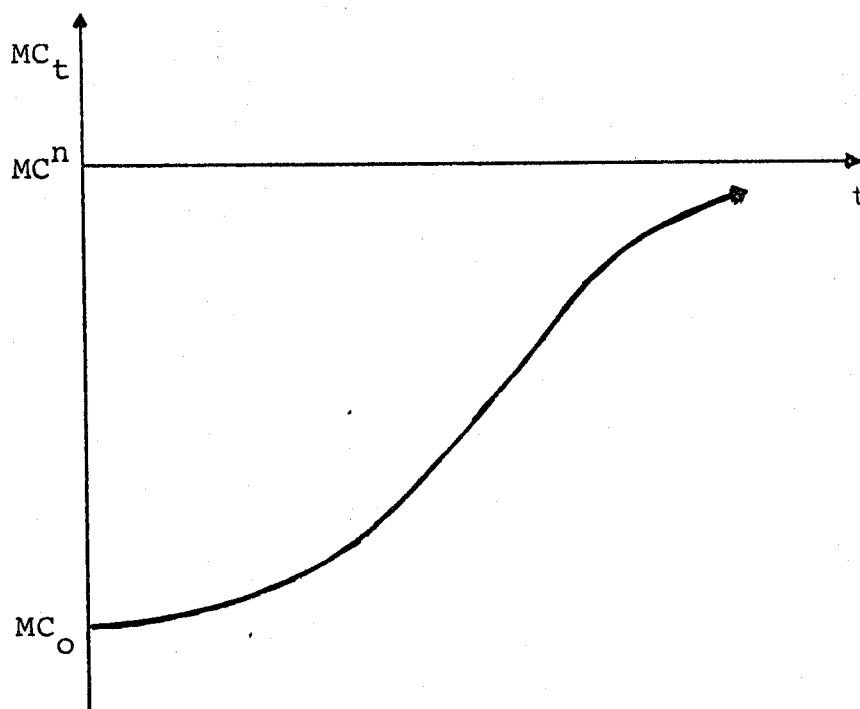
The assumption that the coefficient of adjustment is an unspecified constant — that the reaction path is a smooth, monotonically increasing (or decreasing) function, as in Figure 3.1 — is a simplification. First, it ignores the possibility that consumers may not expand and contract their consumption at the same rate. Different factors generally affect the resistance to an increase and to a decrease in consumption. For example, the forces that are influential in restricting expanded consumption are the existence of pipeline and consumer stocks, the need for complementary consumption items, and the force of habit. The main deterrents to an immediate reduction are the force of habit and the desire to maintain previous production levels.

Second, the assumed reaction path does neglect other reasonable forms of adjustment. For example, the above path does not allow consumers to react slowly at first and then gradually gain momentum. Technological and strong habitual factors could induce such an initial delay. A reaction path which describes this alternative behavior is graphed in Figure 3.2. Such curves have been used to describe the rise over time in the production of new products which are included gradually in the consumer's market basket¹⁸. The actual choice of a path should be based upon the

¹⁷ See Appendix 3.A for further discussion.

¹⁸ See, for example, Zvi Griliches, "Hybrid Corn: An Exploration in the Economics of Technological Change," Econometrica, Vol. 25, No. 4, October, 1957, pp. 501-522; Metoděj Polasek and Alan Powell, "Wool Versus Synthetics: An International Review of Innovation in the Fiber Market," Australian Economic Papers, Vol. III, June-December, 1964, pp. 49-64; or Nerlove, op.cit., pp. 17-20.

Figure 3.2. An Alternative Adjustment Path.



types of rigidities involved; however, the number of rigidities is very large, and it is very difficult to determine their relative strengths. We choose the original reaction path because it is easier to implement statistically and because it is founded in the theory of cost minimization over time, as indicated in Appendix A.

A third simplification of (3.5) is that the implied path is smooth (although it can be modified to allow for stochastic disturbances) and does not allow for possible seasonal or subcyclical patterns of purchasing behavior¹⁹. The actual adjustment path may wander about the smooth path so that the latter may be only an approximation²⁰.

¹⁹ Production smoothing policies may dampen such movements. Evidence of production smoothing behavior by textile mills is presented by Kurt H. Schaffir, "Operations Research in the Textile Industry," in Publications in Operations Research, Number 9, Chapter 14 (John Wiley and Sons, Inc., New York, 1964) pp. 357-360.

²⁰ This point is expanded at the end of section 3.4.

3.4. Two Alternative Forms of the Dynamic Model

Now that the essential features of the model have been outlined, we examine more closely its economic and statistical properties. The level of normal fiber consumption, represented in (3.3), cannot be observed; thus the equation cannot be estimated. However, (3.3) can be substituted into (3.4) to avoid the necessity of observing the normal level. Using a linear approximation to (3.3), the substitution produces

$$(3.6) \quad \frac{dMC_t}{dt} = \delta (\alpha + \beta_1 Y_t + \beta_2 P_{1t} + \beta_3 P_{2t} + \beta_4 Z_t - MC_t + u_{1t}),$$

where δ is the coefficient of adjustment. The dependent variable in (3.6), the first derivative of mill consumption with respect to time, is also not observable, so that the model must be further transformed. We consider two alternative transformations, distinguishing between the difference equation analogue of Nerlove and a finite approximation to Bergstrom's continuous model.

3.4.1. Difference Equation Analogue of the Model: The Nerlove Model

The model may be expressed in the form of a difference equation. For purposes of illustration we consider the linear approximation of the normal demand curve and restrict the number of independent variables^{21,22}. The derivative term in (3.4) is

²¹ The addition of explanatory variables is completely straightforward and does not introduce the "over identification" problem common to alternative dynamic models.

²² Below, we include a constant term in the normal demand equation. This specification involves the conceptual difficulty that if the normal demand equation is projected backward, it may specify a long-run consumption level in excess of income. This problem bothered earlier investigators of long-run consumption functions; in fact, the attempt to explain observed nonproportionality was a central element in the studies of Smithies which have pioneered current dynamic consumption theory. (See Ackley, op.cit., pp. 236-246.)

replaced by a first difference term, so that the model has the following form:

$$(3.7) \quad MC_t^n = \alpha + \beta_1 Y_t + \beta_2 P_t + u_{1t}, \text{ and}$$

$$(3.8) \quad MC_t - MC_{t-1} = \delta (MC_t^n - MC_{t-1}) + u_{2t}, \text{ where } 0 < \delta \leq 1.$$

We carefully specify the disturbance terms in the model. The residual term in the normal demand function allows for unspecified determinants of normal, long-run consumption and for the inherent randomness that would occur even if a long-run equilibrium were reached. The residual in (3.8) permits possible random deviation in consumer adjustment from the smooth, exponential path. These disturbances may be due to misspecification, inherent randomness, or measurement error in consumption data. We assume that the two disturbance terms are normally distributed and are mutually and serially independent, each with zero mean and constant variance, $\sigma_{u_1}^2$ and $\sigma_{u_2}^2$, respectively. Finally, the limits upon the coefficient of adjustment are determined by the underlying theory of the model, which postulates partial adjustment; the limits assure stability.

Equation (3.8) can be solved for MC_t in terms of MC_t^n :

$$(3.9) \quad MC_t = \sum_{\tau=0}^t \delta(1-\delta)^{t-\tau} MC_{\tau}^n + \sum_{\tau=0}^t (1-\delta)^{t-\tau} u_{2\tau}.$$

Consumption is represented as a Koyck distributed lag of the normal consumption levels²³. By substituting (3.7) and its successively lagged formulations into this distributed lag function, mill consumption can also be represented as a Koyck distributed lag of prices, of income, of the residuals, etc:

²³ See Nerlove, op.cit., pp. 18-20.

$$(3.10) \quad MC_t = \alpha + \beta_1 \sum_{\tau=0}^t \delta(1-\delta)^{t-\tau} Y_{\tau} + \beta_2 \sum_{\tau=0}^t \delta(1-\delta)^{t-\tau} P_{\tau} \\ + \sum_{\tau=0}^t \delta(1-\delta)^{t-\tau} u_{1\tau} + \sum_{\tau=0}^t (1-\delta)^{t-\tau} u_{2\tau}.$$

These forms of the model incorporate a history of past occurrences in the explanation of current consumption behavior. Also, mill consumption in period t is a function not only of the disturbance terms in period t but also of those in previous periods. Thus the effects of a random disturbance are felt over many periods, but with diminishing intensity. This property of the model introduces a small sample bias into the parameter estimates. We emphasize that consumption is not initially specified as a Koyck distributed lag of normal consumption levels. The lag scheme has followed incidentally from the representation of consumer behavior by (3.7) and (3.8).

It is not possible to estimate the model in its above form. However, when equation (3.7) is substituted into equation (3.8), the resultant equation contains only observable quantities and prices, and it is possible to derive the parameter estimates of the two original equations from this reduced relationship. Substitution produces

$$(3.11) \quad MC_t - MC_{t-1} = -\delta MC_{t-1} + \delta\alpha + \delta\beta_1 Y_t + \delta\beta_2 P_{1t} + \delta u_{1t} + u_{2t}.$$

Rearranging terms,

$$(3.12) \quad MC_t = (1-\delta)MC_{t-1} + \delta\alpha + \delta\beta_1 Y_t + \delta\beta_2 P_{1t} + w_t,$$

where $w_t = \delta u_{1t} + u_{2t}$.²⁴

²⁴Lovell notes that since the magnitude of the residual is unaffected, it is immaterial which of these two equations is fitted by least squares; the regression coefficients and their estimated standard errors will be identical. The coefficient of determination, however, is typically larger for (3.12). (See Lovell, *op.cit.*, p. 298.)

The properties of the residual can be deduced from the properties of the original disturbances; w_t is normally distributed and serially independent, with zero mean and variance $\sigma^2\sigma_{u_1}^2 + \sigma_{u_2}^2$:

$$(3.13a) \quad E(w_t) = \delta E(u_{1t}) + E(u_{2t}) = 0.0,$$

$$(3.13b) \quad E(w_t w_t) = E(\delta^2 u_{1t}^2 + 2\delta u_{1t} u_{2t} + u_{2t}^2) = \delta^2 \sigma_{u_1}^2 + \sigma_{u_2}^2.$$

$$(3.13c) \quad E(w_t w_{t-1}) = E(\delta^2 u_{1t} u_{1t-1} + \delta u_{1t-1} u_{2t} + \delta u_{1t} u_{2t-1} + \delta^2 u_{2t} u_{2t-1}) = 0.0.$$

Equation (3.12) is not a demand function but merely a relationship between observable quantities which provides a scheme to estimate the parameters of the original model. The estimating equation is similar to the static formulation above except for the inclusion of the lagged value of consumption, which may reduce the autocorrelation evident in estimated static functions. The coefficients in (3.12), $\delta\beta_1$, $\delta\beta_2$, etc., indicate the amount by which consumption will respond during the period to a change in one of the independent variables. We call $\delta\beta_1$, $\delta\beta_2$, etc., the "short-run" coefficients, since they describe the instantaneous response of consumption. The coefficients, β_1 , β_2 , etc., (not multiplied by the coefficient of adjustment) are the parameters of (3.7), which describes the normal consumption level. These parameters indicate how the normal level will respond to a change in one of the independent variables and thus how actual consumption will respond in the long run after sufficient time is allowed for full adjustment. The coefficients, β_1 , β_2 , etc., are referred to as the long-run coefficients. Since δ is a positive fraction, $\delta\beta_1$, for example, will be less than β_1 , so that the short-run response of consumption, $\delta\beta_1$, will be less than the long-run response. This is a direct result of the assumption of only gradual adjustment of consumption toward its normal level.

3.4.2. Finite Approximation Formulation of the Model:
The Bergstrom Model

The dynamic model in its continuous form is

$$(3.7) \quad MC_t^n = \alpha + \beta_1 Y_t + \beta_2 P_{1t} + u_{1t},^{25} \text{ and}$$

$$(3.14) \quad \frac{dMC_t}{dt} = \delta(MC_t^n - MC_t) + u_{2t}, \text{ where}$$

$$0 < \delta.^{26}$$

Substitution produces

$$(3.15) \quad \frac{dMC_t}{dt} = -\delta MC_t + \delta\alpha + \delta\beta_1 Y_t + \delta\beta_2 P_{1t} + W_t, \text{ where}$$

$$W_t = \delta u_{1t} + u_{2t}.$$

Since consumption is observed only at discrete time intervals, it is necessary to use a finite approximation of (3.15) to estimate the parameters²⁷.

Four observations precede the approximation procedure. The total consumption during the period τ is defined as

$$(3.16) \quad \overline{MC}_{t_0} \equiv \int_{t_0}^{t_0 + \tau} MC_t dt.$$

²⁵ Again, the addition of explanatory variables introduces no conceptual problems.

²⁶ The assumed limits of the reaction coefficient are based upon underlying theory and assure stability.

²⁷ The approximation procedure parallels that used by Houthakker and Taylor, op.cit., pp. 8-16. We work through the approximation in order to follow the behavior of the residual terms.

This notation is used to represent the definite integral of the other variables as well. Second,

$$(3.17) \quad \overline{MC}_{t_0} \approx \frac{\tau}{2} \{MC_{t_0 + \tau} - MC_{t_0}\}.$$

This approximation assumes that MC_t is a linear function between t_0 and $t_0 + \tau$. The change in consumption within each period is defined as

$$(3.18) \quad \Delta^*MC_{t_0} \equiv MC_{t_0 + \tau} - MC_{t_0};$$

it follows that

$$(3.19) \quad \Delta^*MC_{t_0 + \tau} \equiv MC_{t_0 + 2\tau} - MC_{t_0 + \tau}.$$

Finally,

$$(3.20) \quad \Delta^*MC_{t_0} \equiv MC_{t_0 + \tau} - MC_{t_0} = \alpha\delta\tau + \delta\beta_1\bar{Y}_{t_0} + \delta\beta_2\bar{P}_{t_0} - \delta\overline{MC}_{t_0} + \delta\bar{u}_{1t} + \bar{u}_{2t},$$

taking the definite integral of equation (3.15) over the range, t_0 through $t_0 + \tau$.

A corollary of the fact that economic data are observed only at discrete time intervals is that the disturbances are also "observed" only at discrete intervals. For the purposes of statistical estimation we are interested in the stochastic properties of these "observed" disturbances. Thus we do not assign properties to the residuals u_{1t} and u_{2t} , but rather to

$$\bar{u}_{1t_0} \equiv \int_{t_0}^{t_0 + \tau} u_{1t} dt \quad \text{and} \quad \bar{u}_{2t_0} \equiv \int_{t_0}^{t_0 + \tau} u_{2t} dt,$$

where τ represents the length of the period of observation. Again, it is assumed that \bar{u}_{1t_0} and \bar{u}_{2t_0} are normally distributed and mutually and serially independent, each with zero mean and constant variance.

We can now describe the approximation procedure. From (3.17),

$$(3.21) \quad \overline{MC}_{t_0 + \tau} - \overline{MC}_{t_0} = \frac{\tau}{2} \{ MC_{t_0 + 2\tau} - MC_{t_0 + \tau} + MC_{t_0 + \tau} - MC_{t_0} \} = R.$$

$$(3.22) \quad R = \frac{\tau}{2} \{ \Delta^* MC_{t_0 + \tau} + \Delta^* MC_{t_0} \},$$

based on (3.18) and (3.19). Therefore,

$$(3.23) \quad MC_{t_0 + \tau} - MC_{t_0} = \frac{\tau}{2} \{ \Delta^* MC_{t_0 + \tau} + \Delta^* MC_{t_0} \},$$

from (3.21) and (3.22). But from (3.20),

$$(3.24) \quad \begin{aligned} \Delta^* MC_{t_0 + \tau} + \Delta^* MC_{t_0} &= \alpha \delta \tau + \delta \beta_1 \bar{Y}_{t_0 + \tau} + \delta \beta_2 \bar{P}_{t_0 + \tau} - \delta \overline{MC}_{t_0 + \tau} \\ &\quad + \delta \bar{u}_{1t_0 + \tau} + \bar{u}_{2t_0 + \tau} + \alpha \delta \tau + \delta \beta_1 \bar{Y}_{t_0} + \delta \beta_2 \bar{P}_{t_0} \\ &\quad - \delta \overline{MC}_{t_0} + \delta \bar{u}_{1t_0} + \bar{u}_{2t_0}. \end{aligned}$$

Therefore,

$$(3.25) \quad \begin{aligned} \overline{MC}_{t_0 + \tau} - \overline{MC}_{t_0} &= \alpha \delta \tau^2 + \frac{\tau}{2} \delta \beta_1 (\bar{Y}_{t_0 + \tau} + \bar{Y}_{t_0}) + \frac{\tau}{2} \delta \beta_2 (\bar{P}_{t_0 + \tau} + \bar{P}_{t_0}) \\ &\quad - \frac{\tau}{2} \delta (\overline{MC}_{t_0 + \tau} + \overline{MC}_{t_0}) + \frac{\tau}{2} \{ \delta (\bar{u}_{1t_0 + \tau} + \bar{u}_{1t_0}) \\ &\quad + (\bar{u}_{2t_0 + \tau} + \bar{u}_{2t_0}) \}. \end{aligned}$$

We remove the bars for notational ease and collect terms:

$$(3.26) \quad MC_{t_0 + \tau} = \frac{\alpha \delta \tau^2}{1 + \frac{\tau}{2} \delta} + \frac{(1 - \frac{\tau}{2} \delta)}{(1 + \frac{\tau}{2} \delta)} MC_{t_0} + \frac{\frac{\tau}{2} \delta \beta_1}{1 + \frac{\tau}{2} \delta} \{Y_{t_0 + \tau} + Y_{t_0}\} \\ + \frac{\frac{\tau}{2} \delta \beta_2}{1 + \frac{\tau}{2} \delta} \{\bar{P}_{t_0 + \tau} + \bar{P}_{t_0}\} + v_{2t_0 + \tau},$$

where $v_{2t_0 + \tau} = \frac{\frac{\tau}{2}}{1 + \frac{\tau}{2} \delta} \{ \delta(u_{1t_0 + \tau} + u_{1t_0}) + (u_{2t_0 + \tau} + u_{2t_0}) \}$.²⁸

²⁸ Equation (3.26) may also be expressed in first difference form. From (3.25),

$$MC_{t_0 + \tau} + \frac{\tau}{2} \delta MC_{t_0 + \tau} - MC_{t_0} + \frac{\tau}{2} \delta MC_{t_0} - \frac{\tau}{2} \delta MC_{t_0} + \frac{\tau}{2} MC_{t_0} = \\ \alpha \delta \tau^2 + \frac{\tau}{2} \delta \beta_1 (Y_{t_0 + \tau} + Y_{t_0}) + \frac{\tau}{2} v_{1t_0 + \tau} + \frac{\tau}{2} \delta \beta_2 (P_{t_0 + \tau} + P_{t_0}),$$

where $v_{1t_0 + \tau} = \delta(u_{1t_0 + \tau} + u_{1t_0}) + (u_{2t_0 + \tau} + u_{2t_0})$.

It follows that

$$(3.27) \quad MC_{t_0 + \tau} - MC_{t_0} = \frac{\tau \delta}{(1 + \frac{\tau}{2} \delta)} MC_{t_0} + \frac{\alpha \delta \tau^2}{1 + \frac{\tau}{2} \delta} + \frac{\frac{\tau}{2} \delta \beta_1}{1 + \frac{\tau}{2} \delta} (Y_{t_0 + \tau} + Y_{t_0}) \\ + \frac{\frac{\tau}{2} \delta \beta_2}{1 + \frac{\tau}{2} \delta} (P_{t_0 + \tau} + P_{t_0}) + \frac{\frac{\tau}{2}}{1 + \frac{\tau}{2} \delta} v_{1t_0 + \tau}.$$

The lagged value of consumption appears on the right hand side, and the magnitude of the residual is the same as in equation (3.26). We are free to estimate either form.

In more simple notation, equation (3.26) becomes

$$(3.28) \quad MC_t = B_0 + B_1 MC_{t-\tau} + B_2 \{Y_t + Y_{t-\tau}\} + B_3 \{P_t + P_{t-\tau}\} + v_{2t},$$

where

$$B_0 = \frac{\alpha \delta \tau^2}{1 + \frac{\tau}{2} \delta},$$

$$B_1 = \frac{1 - \frac{\tau}{2} \delta}{1 + \frac{\tau}{2} \delta},$$

$$B_2 = \frac{\frac{\tau}{2} \delta \beta_1}{1 + \frac{\tau}{2} \delta},$$

$$B_3 = \frac{\frac{\tau}{2} \delta \beta_2}{1 + \frac{\tau}{2} \delta},$$

and

$$\tau \delta = \frac{2(1-B_1)}{1+B_1},$$

$$\tau \alpha = \frac{B_0}{1-B_1},$$

$$\beta_1 = \frac{2B_2}{1-B_1},$$

$$\beta_2 = \frac{2B_3}{1-B_1}.$$

v_{2t} is normally distributed with zero mean:

$$(3.29a) \quad E\{v_{2t}\} = E\{\delta K v_{1t} + \delta K u_{1t-\tau} + K v_{2t} + K u_{2t-\tau}\} = 0, \text{ where}$$

$$K = \frac{\frac{\tau}{2}}{1 + \frac{\tau}{2} \delta}.$$

The variance of v_{2t} is

$$(3.29b) \quad \{E v_{2t} v_{2t}\} = 2 \left[\frac{\tau}{2} \right]^2 \{ \delta^2 \sigma_{u_1}^2 + \sigma_{u_2}^2 \}.$$

However, v_{2t} is not serially independent:

$$E\{v_{2t} v_{2t-\tau}\} = E \{ \text{sixteen terms; all but two} = 0 \text{ taking expected values} \} =$$

$$\delta^2 K^2 \sigma_{u_1}^2 + K^2 \sigma_{u_2}^2 = \frac{\frac{\tau^2}{4}}{(1 + \frac{\tau}{2}\delta)^2} \{ \delta^2 \sigma_{u_1}^2 + \sigma_{u_2}^2 \} \neq 0. \quad 29$$

²⁹

Serial correlation has been introduced where there was none before. Under special assumptions about the autoregressive structure of the residuals in the model, it is possible to produce a reduced equation, like (3.26), whose residuals are not autocorrelated: if

$$\bar{u}_{1t} = \rho_1 \bar{u}_{1t-\tau} + \bar{\xi}_{1t}, \text{ and}$$

$$\bar{u}_{2t} = \rho_2 \bar{u}_{2t-\tau} + \bar{\xi}_{2t},$$

where $\rho_1 = \rho_2 = -1$, and $\bar{\xi}_{1t}, \bar{\xi}_{2t}$ are normally and independently distributed with the usual properties, then

$$\bar{v}_{2t} = \frac{\frac{\tau}{2}}{1 + \frac{\tau}{2}\delta} \{ \delta \bar{\xi}_{1t} + \bar{\xi}_{2t} \},$$

and \bar{v}_{2t} is normally distributed and serially independent. To assume that the residuals of the underlying equations follow this latter form so that the \bar{v}_{2t} are independently distributed is indeed a strong assumption.^{2t}

We are free to adopt an arbitrary time scale and choose $\tau = 1.0$ for annual observations, .25 for quarterly observations, etc. Again equation (3.28) is not a demand equation but merely a relationship between observable variables.

In the continuous formulation of the model the period of observation may vary without altering the basic nature or validity of the model. Thus the dynamic adjustment process is not specified in terms of a specific period of observation. The estimated value of several of the parameters will depend upon the period of observation. These parameters include the coefficient of adjustment, autonomous consumption, and the variance-covariance elements of the residual. It is reasonable that the coefficient of adjustment be proportional to the period allowed for adjustment. Likewise, the level of autonomous consumption should depend on the length of time over which it accumulates. It is also intuitively reasonable that the variance and covariances of the disturbance in mill consumption are a function of τ , for just as the coefficient of adjustment should decrease as less time is allowed for adjustment, the observed variability in consumption should diminish as less time is provided for that variability. The coefficients of income and price in the normal demand equation, β_1 and β_2 , are independent of the period of observation. This illustrates that the model specifies a stable relationship over time between consumption and income, price, etc. Furthermore, comparison of the coefficients of Y_t , for example, in (3.7) and (3.28), illustrates that while this stable relationship does underlie consumption behavior, it may not be observed in the short run.

If the model correctly specifies consumption behavior, the value of the coefficient of adjustment and the size of autonomous consumption will be proportional to the period of observation, while the coefficients of income and price in the normal demand equation will remain unchanged. An interesting experiment and useful test of the continuous form of the model is to estimate its parameters with both annual and quarterly data to see if this relationship holds. We must be very careful, however, in

interpreting the results of such a test, because the coefficient of adjustment may depend upon the period of observation in yet another manner. If the actual adjustment path is not smooth (as is approximated), then quarterly observations may produce a different average path than annual observations. Thus the difference between the estimated reaction coefficients for an annual and a quarterly model may be more complicated than the proportionality between the two periods of estimation. Houthakker and Taylor's dynamic model does not perform well for both annual and quarterly aggregate consumption data, and this source of misspecification may be a major factor³⁰.

3.5. The Interdependence Between Fiber Mill Consumption and Price

The model specifies that mill consumption is a function of the price of the fiber. It makes no allowance that the fiber price may in turn be a function of mill consumption. The degree of interdependence between economic variables can depend upon the elapsed period between observations. Even a recursive system will appear simultaneous if the period of observation is so long that one cannot distinguish the reaction period upon which the recursive model is specified. As an example, if the yearly support level for cotton were based partly upon the size of past stock surpluses, simultaneity would be more of a problem in a consumption function with a ten year period than in one with an annual period. We are interested in the interdependence between fiber consumption and price that will be effective within a period of one year.

A review of the institutional characteristics of fiber price determination illustrates that fiber prices are practically exogenous. It further indicates that in those cases where current mill consumption may affect price, the specification of the

³⁰ Houthakker and Taylor, op.cit., p. 125.

interdependence is either nearly impossible or requires an extensive world model. We consider the major fiber categories in turn.

The market price of cotton is supported by the United States Government and is typically very close to the support level³¹. The market price occasionally rises slightly above the support level, but these increases are short-lived and do not raise the annual average price significantly over the support level. Thus the market price appears to be a function of the factors which determine the support level. While the current level of mill consumption may be such a factor, its impact involves a long delay since the support level is usually fixed for a long period of time, and its effect is certainly irregular and difficult to specify³². Thus we assume that the current price of cotton is determined independently from current mill consumption.

The annual average domestic price of apparel and carpet wool follows closely the price determined in the large, international auctions. Indications are that the international price of apparel wool is determined largely independently of United States mill consumption, for the domestic mill consumption is only ten percent of the world total. Any effects of domestic mill consumption on the international price appear to be slight and irregular, so we assume that the apparel wool price is exogenous³³. However, the influence that the domestic consumption of carpet wool has upon the world price appears to be much greater, since United States consumption represents a large share of the world total. The current domestic consumption of carpet wool may affect the world

³¹ See Schaffir, op.cit., p. 353.

³² The fact that the price paid by the mills differed from the market price by the amount of an equalization rebate from April, 1963, to June, 1967, does not alter the results, for the rebate was not adjusted according to current conditions.

³³ See Ferguson and Polasek, "The Elasticity of Import Demand for Raw Apparel Wool in the United States," Econometrica, Vol. 30, No. 4, October, 1962, pp. 671-673.

price, and a bias may be introduced into single equation consumption estimates. For this reason we separate carpet wool from apparel wool. Carpet wool either can be handled separately or, if bias is felt to be excessive, can be left to be analyzed within its market context.

Man-made fiber list prices are much more stable over time than those of cotton or wool. The administered prices typically remain constant for long periods of time, with occasional short-run changes which last for only a few months. The list price, however, is not the only aspect of the man-made fiber price, and the other aspects may be more sensitive to change in the short run. To the extent that these other elements are rebates and service arrangements, the effective price may be more sensitive to current consumption than the list price. To the extent that they are promotion expenses and quality improvement, the effective price is likely less sensitive. While man-made fiber prices may be somewhat dependent upon mill consumption, it is most difficult to account explicitly for possible simultaneity, since specification of the dependence requires an investigation of the strategies of oligopolistic pricing. Nevertheless, the effect of consumption upon price is most likely neither regular nor direct, for fiber manufacturers have traditionally altered service arrangements only under unusual circumstances, and quality improvement is largely technological³⁴.

This review of the influence of mill consumption upon the price of textile fibers indicates that to a large extent fiber prices are exogenously determined, mitigating the potential seriousness of single equation bias. It is further recognized that to the extent fiber prices are a function of current mill consumption, the effect is irregular, indirect, and not easily quantifiable.

³⁴ See Markham, *op.cit.*, pp. 73-78, and Alan Powell and Metodey Polasek, "Wool Versus Synthetics: An International Review of Innovation in the Fiber Market," Australian Economic Papers, Vol. III, June-December, 1964, pp. 49-64.

Appendix 3.A. The Reaction Path Revisited

The path which consumers follow in adjusting to the long-run normal is arbitrarily specified. There are certain costs to the consumers as a whole associated with being out of equilibrium, and we inquire about the pattern of consumption which would result if consumers as a group behaved so as to minimize these costs over time. Under reasonable assumptions about the aggregative cost function it can be shown that in the neighborhood of equilibrium, the implied adjustment path of such cost minimization is the same as that specified in the model above³⁵. This is further indication of the reasonableness of the reaction process assumed in the dynamic model.

The cost incurred when current consumption is not equal to the long-run normal level involves two components. Because consumers are assumed to reach the normal level eventually, there must be certain extra costs or disutility incurred in consuming at a level out of equilibrium. Second, because consumers do not adjust to the normal level immediately, there must be additional costs or disutility of adjusting too quickly³⁶. It is reasonable to specify that the total cost or disutility is a function of both the difference between the normal and actual consumption, $y(t)$, and the rate

³⁵

The development below stems from the work of Paul A. Samuelson, "A Catenary Turnpike Theorem Involving Consumption and the Golden Rule," American Economic Review, Vol. 15, No. 3, June, 1965, pp. 486-495. Howrey pointed out the applicability of this work and deserves much of the credit for the following derivation. The problem with which Samuelson deals parallels our problem except that while he maximizes a strictly concave function, we minimize an (assumed) strictly convex function. Samuelson's observation that the Euler equation is sufficient as well as necessary for a maximum holds by analogy for our case.

³⁶

For example, if consumers are receiving services from their current stocks, there is a disutility (or opportunity cost) associated with discarding them prematurely.

with which this difference is reduced (in absolute value):

$$(3.30) \quad CS_t = f \left(y(t), \frac{dy(t)}{dt} \right),$$

where $y(t) = MC^n - MC_t$ ³⁷; CS_t is assumed to be strictly convex with respect to its arguments, and

$$\frac{\partial f}{\partial y} > 0.0, \quad \frac{\partial^2 f}{\partial y^2} < 0.0, \quad \frac{\partial f}{\partial \dot{y}} > 0.0, \quad \text{and} \quad \frac{\partial^2 f}{\partial \dot{y}^2} < 0.0.$$

As the disequilibrium level or the rate of change of the level increases, so does the cost, but with diminishing severity. Note that CS_t is not an explicit function of time.

We are interested in determining the form of $y(t)$ which will

$$\text{Min.} \quad \int_0^T f(y, \dot{y}) dt,$$

$$\text{s.t.} \quad \lim_{t \rightarrow \infty} y(t) = 0.,$$

$$\text{and } y(t) = y^0 \text{ at } t = 0.; \quad y^0 = MC^n - MC(0.).$$

The first constraint demands that the function $y(t)$ possess the property that equilibrium can be approached in the limit.

This problem reduces to finding the solution, $y(t)$, to the Euler equation:

$$(3.31) \quad \frac{d}{dt} \frac{\partial f}{\partial \dot{y}} - \frac{\partial f}{\partial y} = 0.$$

³⁷ We assume the normal level, MC^n , to be given a priori, as in (3.5).

Expanding (3.31), the Euler equation can be rewritten as

$$(3.32) \quad \frac{\partial^2 f}{\partial y \partial \dot{y}} \dot{y} + \frac{\partial^2 f}{\partial \dot{y}^2} \ddot{y} - \frac{\partial f}{\partial y} \equiv H(y, \dot{y}, \ddot{y}) = 0.$$

We cannot solve directly for $y(t)$. However, we can consider the linear approximation of the Euler equation in the neighborhood of equilibrium ($y_e = 0 = \dot{y}_e = \ddot{y}_e$) and derive the form of $y(t)$ which solves the equation. We expand the function $H(y, \dot{y}, \ddot{y})$ at y_e and consider only the linear terms:

$$(3.33) \quad H(y, \dot{y}, \ddot{y}) = H(y_e, \dot{y}_e, \ddot{y}_e) + \left(\frac{\partial H}{\partial y}\right)_{y_e} y + \left(\frac{\partial H}{\partial \dot{y}}\right)_{\dot{y}_e} \dot{y} \\ + \left(\frac{\partial H}{\partial \ddot{y}}\right)_{\ddot{y}_e} \ddot{y} + \dots$$

$$H(y_e, \dot{y}_e, \ddot{y}_e) = H(0., 0., 0.) = 0.^{38}$$

Differentiating (3.32) and substituting in (3.33),

$$(3.35) \quad - \left(\frac{\partial^2 f}{\partial y^2}\right)_{y_e} y + \left(\frac{\partial^2 f}{\partial \dot{y}^2}\right)_{\dot{y}_e} \ddot{y} = 0.$$

³⁸ Since f is not an explicit function of t , the Euler equation may be written

$$(3.34) \quad f - \dot{y} \frac{\partial f}{\partial \dot{y}} = H(y, \dot{y}, \ddot{y}).$$

Since $f(0, 0) = 0$, $H = 0$ when the Euler equation is evaluated at $y(t) = 0$, $\dot{y}(t) = 0$.

Or, simplifying notation, $-\bar{\alpha}y(t) + \bar{\beta}\ddot{y}(t) = 0$, where $\bar{\alpha}, \bar{\beta} < 0$.

Therefore

$$(3.36) \quad \ddot{y}(t) = \frac{\bar{\alpha}}{\bar{\beta}} y(t).$$

Samuelson observes that the solution to (3.36) is the catenary

$$(3.37) \quad y(t) = A_1 e^{\lambda t} + A_2 e^{-\lambda t},$$

where $\lambda = + \left(\frac{\bar{\alpha}}{\bar{\beta}}\right)^{1/2}$ is a real number,

greater than zero³⁹. This is the path of consumption over time which the consumers will follow if they jointly minimize their costs or disutility both of being out of equilibrium and of adjusting their consumption. The values of A_1 and A_2 follow from the boundary conditions: when $t=0$, $A_1 + A_2 = y(0) = y^0$, the initial disequilibrium. Because $y(t)$ must eventually approach zero, $A_1 = 0$; then $A_2 = y^0$.

Thus

$$(3.38) \quad y(t) = y^0 e^{-\lambda t},$$

where $\lambda = + \left(\frac{\bar{\alpha}}{\bar{\beta}}\right)^{1/2}$ is a positive constant. In the text, the

solution to the reaction equation of the dynamic consumption model (3.4) is

$$(3.5) \quad MC_t = (MC_0 - MC^n) e^{-\delta t} + MC^n,$$

or

$$(3.5a) \quad MC^n - MC_t = (MC^n - MC_0) e^{-\delta t}.$$

³⁹ See Samuelson, op.cit., p. 492.

Both equations (3.38) and (3.5a) specify identical reaction paths (provided $\lambda = \delta$), so the reaction path assumed in the text is the same as that implied by the cost minimization procedure described here.

Appendix 3.B. A More Disaggregated Version of the Fiber Consumption Model

The demand for textile fiber at the mill is derived from the behavior of the end product consumers. We recognize this by including personal disposable income as a shift variable in the mill consumption function. In this appendix we specify more thoroughly the demand facing the textile mill.

The textile mill produces cloth which is then shipped to the cutting industry to be manufactured into finished apparel, household, and industrial items. The strength of the demand facing the textile mills can be measured directly by the total poundage of fabrics used in the production of these final items, i.e., by the volume of end use consumption. If the poundage of end use consumption is represented by X_t , the model of Section 3.3 becomes

$$(3.39) \quad MC_t^{j,n} = \alpha + \beta_1 X_t + \beta_2 P_{1t} + \beta_3 P_{2t} + \epsilon_{1t}^j$$

$$(3.40) \quad \frac{dMC_t^j}{dt} = \delta_1^j (MC_t^{j,n} - MC_t^j) + \epsilon_{2t}^j \quad .40$$

We allow for the partial adjustment of mill consumption to end use consumption due to psychological, institutional, and technological constraints on the behavior of the mills and the converters.

⁴⁰ We have added the superscript j to mill consumption to indicate explicitly that we are dealing with a specific fiber j . MC_t^j , then, refers to the mill consumption of fiber j during period t .

Equation (3.39) asserts that the levels of total end use consumption and fiber prices determine the level of mill consumption. The prices of the individual fibers may affect the total volume of end use consumption; possible dependence between these explanatory variables may introduce multicollinearity problems and complicate the interpretation of their coefficient estimates. However, the effect that a change in a particular fiber price has upon total end use consumption is probably very small, since the fiber price is typically only a small component of the price of the product produced by the cutter⁴¹. Changes in the price of a particular fiber are not likely to affect greatly the price of the finished cloth derived from the fiber and thus the poundage of the fiber consumed in the production of end use items. Second, even if the price of a particular fiber exerts a significant influence upon the end use consumption of that fiber, its effect upon total end use consumption would be much less because of the limited contribution of any one fiber to the total. Thus the potential distortion in the parameter estimates of the above model because of such possible interdependence is probably very slight⁴².

We may extend the model by expressing end use consumption as a function of the determinants of final consumer behavior:

$$(3.41) \quad X_t^n = a + b_1 Y_t + b_2 Z_t + \varepsilon_{3t},$$

$$(3.42) \quad \frac{dX_t}{dt} = \delta_2 (X_t^n - X_t) + \varepsilon_{4t}.$$

⁴¹ The following argument parallels that of Ferguson and Polasek, op.cit., p. 679.

⁴² A possible further extension of the model is to specify the mill consumption of a particular fiber as a function of the end use consumption of that particular fiber. End use consumption could then be specified as a function of per capita disposable income and the alternative fabric prices. Such an explanation of mill consumption explicitly allows for the effect of substitution among fabrics of various fibers. But this formulation enhances the possibility of the problem above, and fabric substitution is probably not a very significant force in the determination of fiber consumption.

Again the specification provides for certain dynamic aspects of the behavior of the cutters, wholesalers, retailers, and final consumers⁴³.

The above expressions for end use consumption do not mention explicitly the price of the finished fabrics used in the cutting process or the price of the resulting end products, although either could be easily included in Z_t . Movements in the general level of

⁴³

The demand for end use fiber can be recast in a slightly different form. We assume that consumers desire services from textile products in relation to their income position. These services may be rendered either by existing consumer stocks or by additional acquisitions. It is further assumed that the services rendered from past expenditure depreciate over time. The depreciation rate over time is assumed to be constant; temporal changes in product quality have probably reduced the rate of depreciation, while the increasing incidence of style obsolescence has tended to increase the rate. If S_t^* represents the desired services to be rendered and S_t , the actual services, the model in its difference equation analogue form is

$$(3.43a) \quad S_t^* = a_1 + a_2 Y_t;$$

$$(3.43b) \quad S_t^* = S_t$$

implies that consumers are able to fulfill their desires;

$$(3.43c) \quad S_t = X_t + (1-d) S_{t-1}.$$

The estimating equation has the form

$$(3.43d) \quad X_t = a_1 d + a_2 (Y_t - Y_{t-1}) + a_2 d Y_{t-1}.$$

This formulation is very similar to that of Houthakker and Taylor, op.cit., pp. 8-21 and cannot be distinguished from it statistically. The formulation is originally due to Nerlove, op.cit., pp. 88-92.

cloth prices or of finished product prices may affect the volume of cloth consumed by the cutter. Since neither finished fabric nor final products are a homogeneous item, indices to represent their general price movements could be used. With respect to fabric price, these prices often stay within narrow ranges while the weight of the cloth will vary to compensate for fluctuating costs. The introduction of the price of finished cloth may also present an estimation problem by introducing single equation bias, for the price of finished fabric may be sensitive to the level of end use consumption⁴⁴.

With respect to finished product price, Houthakker and Taylor's results indicate little relationship between the consumption and the deflated prices of men's and women's apparel and household goods⁴⁵. Nevertheless, we can introduce these prices into the consumption function.

It is also possible to distinguish between the various end use categories. Data exist which describe the division of fiber between these categories. Let

x_t^i = total cutter end use consumption of all fibers consumed in end use i ; remember that

X_t = total cutter consumption of all fibers consumed in all end uses.

Then (3.44) $X_t = \sum_{i=1}^5 x_t^i$. We may repeat the equation set (3.41-3.42)

⁴⁴ It is possible to introduce a supply function to specify such feedback and to allow both end use consumption and fabric price to be determined simultaneously; such a supply-demand specification involves immense simplification because of the heterogeneity of the finished cloth.

⁴⁵ Houthakker and Taylor, op.cit., pp. 68-69, 73, 84-85.

for each end use:

$$(3.45) \quad x_t^{i^n} = r_0^i + r_1^i Y_t + r_2^i Z_t + \varepsilon_3^i,$$

$$(3.46) \quad \frac{dx_t^i}{dt} = \delta_2^i (x_t^{i^n} - x_t^i) + \varepsilon_4^i$$

for all i end uses, where, repeating,

$$(3.44) \quad X_t = \sum_{i=1}^5 x_t^i.$$

When we add (3.39) and (3.40), we have the extended form of the model.

The reduced level of aggregation here provides a more precise specification of how such variables as personal disposable income affect fiber consumption. Two refinements have been made. First we have dropped the implicit assumption that the relative size of the end use categories must remain stable if their levels are governed by different marginal propensities to consume. We now account explicitly for such distribution effects. Second, by distinguishing between end use categories, it is possible to introduce additional variables which may better represent the strength of demand for items in a particular end use category; for example, even though industrial items are eventually consumed by the public, an index of industrial production is perhaps a better indicator of such activity.

The model still retains a high degree of aggregation and presents a simplified view of fiber consumption. Final consumer activity is instrumental in influencing the level of total end use consumption (of all fibers). This level is used to indicate the strength of the demand for all fibers, which in turn affects the various fibers according to relative fiber prices and other factors. It is possible that for a given level of per capita disposable income, various end use consumption levels may result, due to the interaction of units along the sequence. Likewise, various levels

of mill consumption may be consistent with a given level of end use consumption and a set of fiber prices. Thus again we have abstracted somewhat from the underlying network of interdependencies.

In the following chapter, imports and exports are introduced as an additional source and outlet of textile products. We indicate here how imports and exports are incorporated into the extended form of the model. In the following discussion, familiarity with the material in Chapter 4 is assumed.

In the extended form of the model, the distinction between imports and exports of intermediate and finished goods can now be utilized. First, the domestic consumption of goods to be processed by the domestic cutting industry is

$$(3.47) \quad D_t^j = MC_t^j - e_t^{j^s} + m_t^{j^s}.$$

The portion of the model dealing with the behavior of the mills and the converters is then recast in terms of D_t^j , i.e. D_t^j becomes a function of the total fiber processed by the United States cutting industry. Second, to include the effect of exports and imports of finished goods, we form the variable

$$(3.48) \quad R_t = \sum_j e_t^{j^f} - m_t^{j^f},$$

which is the net surplus of end use fiber goods exported. This represents an additional demand (or source of supply if negative) for end use fiber consumed at domestic mills. The data preclude the further classification of R_t into the five end use categories. Rather than form expressions for the domestic consumption of cut items in the different end use categories we include R_t as a variable in the normal demand equations for each of the end use classifications.

CHAPTER 4

DATA AND VARIABLES

4.1. Introduction

We have outlined two dynamic models of consumption behavior. To complete the specification, we examine the quality of the mill consumption and fiber price data and discuss further the determinants of consumption behavior. The remainder of the chapter is divided into two sections. The first, Section 4.2, introduces common sources of observation error in economic time series and examines closely the mill consumption and the fiber price data. We stress the importance of careful examination of the data in econometric analysis. In Section 4.3, we discuss some of the factors which affect fiber consumption. The factors include the imports and exports of textile fiber products, population changes, aggregate consumption expenditure, and interfiber competition. The section concludes with a discussion of the possible effects of excluding relevant factors.

4.2. Data and Observation Error

4.2.1. Errors of Observation: Introduction

The data are the sine qua non of empirical investigation, and the estimates can only be as accurate as the basic data. We have devoted much effort to securing a reasonable description of consumers' aggregate behavior, but, as Morgenstern has warned, the model may be satisfactory and still not yield useful results if there are excessive inaccuracies in the data¹. Observation error is a fundamental characteristic of economic data; the true values of economic magnitudes are rarely, if ever, recorded. Error may enter the recording process at many points and in many different

¹ Oskar Morgenstern, *On the Accuracy of Economic Observations* (Princeton University Press, Princeton, New Jersey, 2nd edition, 1963).

forms; sources of error range from deceitful reporting and inefficient collection to obsolete and unclear classifications^{2,3}.

The undesirable effect of observation error is best illustrated by examining its influence upon least square parameter estimates. The stock-adjustment, dynamic model of consumption behavior reduces to a first-order difference equation in consumption. Like the traditional, single equation, multiple regression model, observation error in the independent variable produces biased and inconsistent estimates^{4,5}. But unlike the traditional model, the autoregressive model will possess serially correlated residuals if

² For an exhaustive survey of potential data inaccuracy, see Ibid., Chapter 2 and 3.

³ Other factors besides observation error may jeopardize numerical evaluation. Morgenstern mentions two primary additional sources of error, viz., the errors of approximation and those of rounding. (Ibid., pp. 104-107.) It is very possible that we may encounter errors of approximation. Both the difference equation analogue and the approximation to the continuous form of the model are approximations. Other sources of approximation error, as the use of per capita data and the treatment of synthetic fiber prices, are discussed later. With respect to rounding error, we comment that the computations in the analysis are not excessively complicated.

⁴ Observation error is considered as an error term with a specified distribution which is added to the true value.

⁵ See Jack Johnston, Econometric Methods (McGraw-Hill Book Company, Inc., New York, 1963) p. 148, for a summarization of the consequences of observation error.

there is observation error in the dependent variable⁶. Thus, even

⁶ Suppose

$$C_t = c_t + u_t \quad \text{and} \quad Y_t = y_t + v_t,$$

where u_t and v_t are independently distributed under the usual assumptions and c_t and y_t are the true values of the observed C_t and Y_t . In terms of the true values, the autoregressive model is

$$c_t = \delta c_{t-1} + \beta_1 y_t + w_t.$$

But in terms of the observed variables,

$$C_t - u_t = \delta C_{t-1} - \delta u_{t-1} + \beta_1 Y_t - \beta_1 v_t + w_t, \quad \text{or}$$

$$C_t = \delta C_{t-1} + \beta_1 Y_t + [u_t - \delta u_{t-1} - \beta_1 v_t + w_t].$$

Let $z_t = [u_t - \delta u_{t-1} - \beta_1 v_t + w_t]$, where $E[z_t] = 0$.

We can illustrate that z_t and z_{t-1} are autocorrelated. This follows from the fact that u_t enters the current and future disturbance.

$$E[z_t z_{t-1}] = E[-\delta u_{t-1}^2] = -\delta \sigma_u^2.$$

Thus C_{t-1} is no longer predetermined, since u_{t-1} implies C_{t-1} and since u_{t-1} is a component of z_t . Next, we investigate the dependence between each of the independent variables, Y_t and C_{t-1} , and the error term, z_t .

$$E[(z_t)(Y_t - E(Y_t))] = E[z_t(Y_t - y_t)], \quad \text{since } E(Y_t) =$$

$$E(y_t + v_t) = y_t, \quad \text{and}$$

$$E[z_t v_t] = E[(u_t - \delta u_{t-1} - \beta_1 v_t + w_t)(v_t)] = E[-\beta_1 v_t^2] = -\beta_1 \sigma_v^2.$$

Furthermore,

$$E[z_t(C_{t-1} - E(C_{t-1}))] = E[z_t(C_{t-1} - c_{t-1})] = E[z_t u_t],$$

$$\text{since } E(C_{t-1}) = E(c_{t-1} + u_{t-1}) = E(c_{t-1}) = c_{t-1} \quad \text{and}$$

$$[C_{t-1} - c_{t-1}] = u_{t-1}.$$

$$E[z_t u_t] = E[(u_t - \delta u_{t-1} - \beta_1 v_t + w_t) u_t] = E[u_t^2] = \sigma_u^2.$$

Thus, we can expect biased and inconsistent estimates.

if observation error is present only in the dependent variable, the coefficient estimates will be biased and inconsistent.

There is a maximum likelihood estimation scheme to derive consistent estimates under a regime of observation error in the independent variables⁷. The usefulness of this method is restricted by the requirements of its application and, in the case of the autoregressive model, by the possibility of observation error in the dependent variable. In the latter case, use of the scheme is precluded by the presence of induced serial correlation in the residuals. Even if this difficulty could be avoided, the method still has demanding assumptions, requiring a priori knowledge of the variances of the individual estimating errors and of the covariance between each of these errors and also requiring that the errors have well behaved distributions. However, it is difficult to state even the order of magnitude of observation error, especially when the errors have been compounded in indices or through aggregation⁸. Second, not only the magnitude, but also the stability of the error is difficult to measure, especially over a long period of time⁹. Finally, it is highly probable that the errors of observation will not be serially independent¹⁰.

We are aware of the likely presence of observation error and of the adverse effect it has upon the precision of the estimates, but we do not have an accurate measure of the magnitude of the error or of its effect. We can, however, select the data (and, in some cases, the ambition of the analysis or the length of the period of observation) to minimize the possibility of observation error. This is the strategy which we adopt, being

⁷ Johnston, op.cit., pp. 168-170.

⁸ Morgenstern, op.cit., p. 51.

⁹ Ibid., p. 53, for a discussion of the time independence of the above variance-covariance matrix.

¹⁰ Ibid., pp. 55-57.

especially sensitive to sources of observation error in the dependent variable, mill or domestic consumption¹¹. Instances where we try to minimize the presence of observation error include the following: a foreign trade balance index for man-made staple and filament yarn is rejected even though additional explanatory power is sacrificed; end use consumption is not used as an independent variable in the dynamic consumption model; and we exclude certain observations from the period of estimation to eliminate suspicious data.

4.2.2. Textile Fiber Consumption

Mill consumption is defined slightly differently for the natural than for the man-made fibers. Cotton and wool mill consumption are measured as the fiber is put into process at the mills. For cotton, it is as the bale is opened at the spinning mill. Wool mill consumption is measured when the scoured (clean) apparel and carpet wool are first used in the woolen or worsted spinning process. Poundages of reprocessed and reused wool are not included in consumption data. The consumption of man-made fiber, on the other hand, is not measured as the fiber is fed into production, but rather as the fiber reaches the mill; that is, imports of raw fiber and shipments from the fiber producers are combined to represent fiber consumption. Mill consumption data are

¹¹

Such a scheme may seem contradictory to the observation that it is most difficult to achieve an idea of even the order of magnitude of the error. We hope, however, to achieve an idea of the relative accuracy of different sets of data by reviewing the collection procedure, the sample size, the collecting institution, the simplicity of the definitions of categories, etc. We hope to make general recommendations.

published by the Department of Commerce and the Textile Economics Bureau^{12, 13}.

Neither the Department of Commerce nor the Textile Economics Bureau provides detailed descriptions of the collection procedure, the representativeness of the sample size, or indications of possible quality changes in the data. Although it is most difficult to formulate precisely an estimate of the observation error or a clear indication of the main sources of the error, several weaknesses of the data can be illustrated. The major problems are misrepresentation of the data, possible error introduced by the aggregation over different quality fibers, and an occasional desire of mill management to report falsely. The consumption data for man-made fiber may misrepresent mill consumption, since they record the receipt of the fiber at the mill rather than usage. Movements in the mill's fiber stock will result in a difference between the volume consumed and shipped. The lag between the delivery and the processing is short and less important than that for the natural fibers¹⁴. Also, the inventory movement is less subject to speculation because of the stability of man-made fiber prices over the short run. Nevertheless, inventory movements do occur and are occasionally sizable. Second, the consumption data may be

¹² The mill consumption of cotton, silk, cellulosic staple, cellulosic filament, synthetic staple, and synthetic filament is recorded by the Textile Economics Bureau, Inc., Textile Organon, Stanley B. Hunt, ed., New York, Monthly, March, 1961, pp. 40-41 and various later issues. The mill consumption of apparel wool and of carpet wool is recorded by the United States Department of Agriculture, "Wool Statistics and Related Data, 1920-1964," Statistical Bulletin 363, Economic Research Service, Washington, D.C., July, 1964, Table 80, and in various statistical supplements.

¹³ Man-made fiber shipments and imports are further classified according to waste and non-waste. Waste represents only a minor portion of total consumption.

¹⁴ Commonwealth Economic Committee, Industrial Fibers, London, England, Annual, 1964, p. 93.

misrepresentative because they do not distinguish between the different qualities of fibers. For example, since inferior grades of cotton lead to more spindle breakage and waste, increased cotton usage may only reflect the use of lower grades of fiber and not a fundamental increase in consumption. However, the use of a quality index may introduce more inaccuracies than its exclusion would avoid.

The third deficiency concerns the accuracy of the reporting sources. Mill management may occasionally falsify the actual volume consumed of a particular fiber. This possibility is suggested by past behavior where the stated ratio of fibers in blended fabrics differed from the actual ratio. During the early years of nylon scarcity, labels reportedly were worded to imply a greater nylon content. Also, secret activity surrounded the blending of rayon and cotton during the mid-fifties. Rayon was very inexpensive relative to cotton, so that it was beneficial for the mills to include as much rayon in cotton blends as they could. Market analysts reported, "Many cotton mills are blending rayon with cotton without announcing this fact;" a mill president admitted, "We are all sneaking it in."¹⁵ It is not difficult to imagine that under such circumstances mills may have incorrectly recorded their fiber usage, so the possibility of deceitful reporting should not be eliminated.

The end use consumption data represent the amount of fiber used in the production of the final goods. They are measured at the cutting level, the point nearest the final consumer at which the end use can be identified. The data are presented in pounds by the Textile Economics Bureau¹⁶. Observation error appears to

¹⁵ Rayon Publishing Corporation, "New Trends in Rayon", in Modern Textile Magazine, New York, Monthly, September, 1956, p. 40.

¹⁶ The end use data are compiled and recorded by the Textile Economics Bureau, Inc. in various monthly issues of the Textile Organon. See especially November, 1961, pp. 174-190; January, 1966, pp. 4-21; and January, 1967, pp. 4-16.

be more prevalent in these data than in the mill consumption data¹⁷. There is first the difficulty of collecting reliable data at the fabricating level where there are a large number of manufacturers and diverse product lines. Second, there are indications of careless reporting; the Bureau indicates that differences between cellulosic and non-cellulosic and between yarn and staple are not always noted by the reporting firms. The cutters are not totally at fault because of the frequent absence of well defined categories to be reported. In woven and knit blends, the component fibers need not be reported in their actual proportions. Instead, wide categories are offered, so that a 60%-40% blend may be included in a 50%-50% and over category¹⁸. Well defined, clear classifications are also absent in the treatment of the consumption of reprocessed and waste fiber; the same fiber may be listed in two different end use items¹⁹. A third weakness of the collection procedure is the partial coverage in collecting the fiber consumption figures in some man-made end use categories. In summary, the collection procedure suffers from a lack of precise and easily measurable

17

The following criticisms have been compiled from references that the Textile Economics Bureau has made to its own data. The Bureau deserves much credit for being interested in and discussing intelligently the deficiencies of its series.

18

The Bureau claims that this deficiency in the collection procedure has probably overstated the poundage of cotton in blends.

19

Not all of the original unbaled fiber is immediately consumed in end uses; some of it becomes waste. This waste fiber, however, may eventually find its way into some end use item. It is the practice of the Bureau to exclude from consideration the end uses which consume this waste but to account for the waste by adding its estimated value to the non-waste fiber consumed. If the reprocessed waste is reported in its end use, the same fiber will have been reported twice. Because reprocessed waste is a significant portion of blanket, carpet, drapery, and upholstery, the Bureau has chosen to report this portion of the waste fiber. The double counting involved is particularly noticeable in the end use consumption of wool, where spinning wastes are especially high and carpeting provides a large outlet.

definitions. We consider the end use data as more approximate than the mill consumption data.

Later, we define domestic consumption, which differs from mill consumption by the explicit introduction of international movements of the fiber. The available data recording the exports and imports of textile products are divided into two categories: intermediate goods, including yarn and cloth, and finished goods, including cut items²⁰. These data are presented by the Bureau of Census in units of yards or square yards, and the Department of Agriculture has computed indices to convert the yardage data into equivalent pounds of raw fiber and probable associated waste. The conversion factors are somewhat arbitrary due to the uncertainties involved in the conversion process.

4.2.3. Units of Consumption Data

Mill consumption, imports, exports, and cutter consumption are reported in physical pounds of fiber. Because of differences in the amount of spinning waste and in the yardage typically produced from a pound of fiber, physical pounds are not an accurate measure of the potential usefulness of a pound of a given fiber. The Department of Agriculture has compiled ratios to convert the actual pounds of a particular fiber into the pounds of cotton that would be needed to provide the same coverage²¹. All fibers can be reduced to the common denominator of cotton equivalent pounds. The Department of Agriculture's ratios should change over time as significant quality refinements increase the utility of certain fibers. Such change is allowed for only in the case of high

²⁰

The exports and imports are divided among the major fiber classifications, but the finished good imports and exports are not classified according to their end use category.

²¹

For a discussion of the conversion procedure, see James R. Donald, Frank Lowenstein, and Martin S. Simon, "The Demand for Textile Fibers in the United States," Technical Bulletin No. 1301, United States Department of Agriculture, Economics Research Service, Washington, D.C., November, 1963, pp. 31-36 and 126-135.

tenacity cellulosic (rayon) filaments. These ratios then seem to provide only a rough indication of the relative covering ability of the different fibers. Because of the arbitrariness of such data, we do not convert all poundages into their cotton equivalency. But we do use these ratios as rough guides in the interpretation of some of the regression results.

4.2.4. Textile Fiber Prices

In choosing a price series, we can use either the price of a representative grade of fiber or an index derived from averaging over the prices of several grades. The raw price data for a particular grade are subject to the most common sources of observation error²². Indices may compound the inaccuracies in the raw data and increase the difficulty of quantifying the measurement error²³. Perhaps the most alarming inaccuracy of price statistics is their frequent failure to measure the phenomenon which they propose to measure. List prices can be misrepresentative because of the possible occurrence of off-list selling and because of the potential failure of the list price to reflect accurately other service arrangements which simultaneously affect the cost of acquiring the fiber.

The list or market price is only a proxy for the effective price. To the extent that other aspects of fiber transactions are important and variable and move irrespective of the list price, the money price loses some of its force as a proxy. This is more of a problem for man-made fibers than for natural fibers. Man-made fiber list prices, however, appear to be an adequate surrogate for these other factors. The prices have declined secularly, as quality improvement and promotion has increased, and the price decreases were more sharp in the early periods when technological improvements were most effective.

²²

See Morgenstern, op.cit., pp. 181-182 and the remainder of Chapter X.

²³

See Morgenstern, op.cit., p. 189, footnote #10.

4.2.5. Fiber Price Data

All fiber prices are deflated by the Wholesale Price Index of the Bureau of Labor Statistics²⁴. The Wholesale Price Index rather than the Consumer Price Index is used; since fibers are intermediate products, the Wholesale Price Index may better represent the average trends in fiber prices.

Several indices are available for measuring the price of cotton. The Department of Agriculture has an index which is weighted over several grades of cotton²⁵. As an index, it is subject to a possible compounding of observation error and the possibility that movements in the index may be partially a function of the weighting scheme. The Textile Economics Bureau publishes the price of a given grade of cotton (in index form); this measure is subject to the difficulty that different grades may exhibit divergent price behavior^{26, 27}. The price of apparel wool is also

²⁴ The Wholesale Price Index is constructed by the United States Dept. of Commerce, Bureau of Labor Statistics, and is reported in U.S. Department of Commerce, op.cit., in various issues.

²⁵ The series is listed as the "Seasonal Average Price Received by Farmers on American Upland Cotton, all grades," and is reported in United States Department of Agriculture, "Statistics on Cotton and Related Data, 1925-1962," Statistical Bulletin 329, Economic Research Service, Washington, D.C., April, 1963, Table 46, and in various statistical supplements.

²⁶ See the Textile Economics Bureau, Inc., Textile Organon, op.cit., various monthly issues. The series is based upon the annual average price of a particular grade in several markets (see Table 4.1).

Table 4.1. Cotton Prices in Textile Economics Bureau Index

<u>period</u>	<u>grade</u>	<u>number of markets included in ave.</u>
1920-53	15/16"	10
1954	1"	10*
1955-1964	1"	14
1965-66	1"	15

*The price difference between the two grades was .003.

Source: Textile Economics Bureau, Inc., op.cit.

²⁷ Both series have been corrected to account for the equalization payments during 1964-1966 so that the series reflect the price paid by the mills for cotton.

represented both by a Department of Agriculture index²⁸ and by the price of a particular grade^{29,30}. Representative fiber prices are chosen for both carpet wool³¹ and silk³².

In the case of man-made fibers, we are hesitant to use the price of a particular fiber to represent the money price of all the fibers within a category. Unlike the natural fibers, the man-made fibers have widely diverse quality and attributes. Second, the components of the major fiber classifications have altered considerably over time. Where possible, we construct a price index

²⁸ The series is listed as the "Annual Average Price Received by Farmers for Shorn Wool" and is reported in United States Department of Agriculture, "Wool Statistics and Related Data, 1920-1964," op.cit., July, 1965, Table 164, and in various statistical supplements.

²⁹ Australian (apparel) wool, 64's, 70's warp and half warp, clean basis (American yield), Boston (duty paid), is reported in United States Department of Agriculture, "Wool Statistics and Related Data, 1920-1964," op.cit., Table 198, and in various statistical supplements. The series is originally compiled from the Commonwealth Marketing Service, Weekly Review of the Boston Wool Market. The importance of Australian apparel wool prompted this series.

³⁰ Interesting work regarding the representativeness of a particular wool price has been done with spectral analysis. Witherell has found that the movement of alternative wool prices is highly coherent over frequency bands corresponding to periods greater than one year. See William H. Witherell, "Dynamics of the International Wool Market: An Econometric Analysis," Research Memorandum No. 91, Econometric Research Program, Princeton University, Princeton, New Jersey, September, 1967, pp. 234-244.

³¹ The carpet wool series used is the Buenos Aires wool, 5's (40's), clean basis (American yield), Boston (in bond), annual average, 1937-1966 and is reported in United States Department of Agriculture, "Wool Statistics and Related Data, 1920-1964," op.cit., Table 221, and in various statistical supplements. The original source is the Commonwealth Marketing Service, The Weekly Review of the Boston Wool Market.

³² The silk series represents AA-AAA grade, Japanese, 20-22 denier, white, at New York, as reported by the Textile Economics Bureau, Inc., Textile Organon, op.cit., in various monthly issues.

over all fibers in a category. The index weights the prices of these individual fibers by a measure of their current importance (in terms of production or shipment). Indices are constructed to represent the money price for the cellulosic staple, cellulosic filament yarn, and synthetic staple categories. Sufficient data do not exist to construct an adequate index of the synthetic filament yarn price, so we use the price of a particular grade of nylon yarn. The cellulosic staple index includes the annual average list price of a representative rayon staple fiber and that of an acetate staple fiber³³. The expression for the index of cellulosic staple price, $I_{\text{cell.stp.}_t}$, is

$$I_{\text{cell.stp.}_t} = P_{\text{ray.stp.}_t} * W_{r_t} + P_{\text{act.stp.}_t} * W_{a_t},$$

$$\text{subject to } W_{r_t} + W_{a_t} = 1.$$

The weights, W_{r_t} and W_{a_t} , are the percentages of total cellulosic staple production accounted for by rayon staple and acetate staple, respectively³⁴. The remaining variables in the index are the price

³³ The cellulosic staple series are rayon staple, first quality, standard type, 1.5 denier, 1 1/2", bright luster, viscose process staple, and acetate staple, first quality, standard type, 5 denier, any length, bright luster. Both series are reported by the Textile Economics Bureau, Inc., Textile Organon, op.cit., various monthly issues, and in United States Department of Agriculture, "Wool Statistics and Related Data, 1920-1964," op.cit., Table 361 and 362. These series were originally collected by the Bureau of Labor Statistics through 1951 and the Textile Economics Bureau thereafter.

³⁴ For example, $W_{r_t} = \frac{\text{production of rayon staple}}{\text{total production of cellulosic staple}}$.

The production data are recorded in millions of pounds by the Textile Economics Bureau, Inc., Textile Organon, op.cit., various issues.

of rayon staple ($P_{\text{ray. stp. } t}$) and the price of acetate staple,

($P_{\text{act. stp. } t}$), at time t . The index for cellulosic filament yarn

differentiates between regular tenacity and high tenacity rayon yarn and includes representative prices for rayon regular tenacity, for acetate regular tenacity, and for rayon high tenacity yarn (tire cord yarn)³⁵. Weights for the three individual prices are computed from filament production data³⁶. For the synthetic staple price index, we choose a representative price from each of the three major staple categories: polyamides, polyesters, and acrylics.

³⁵ The actual grades of cellulosic filament used are

- i) rayon viscose, 150 denier, 40 filament, regular tenacity, first quality, standard twist, bright luster on cones,
- ii) acetate filament, 150 denier, 40 filament, first quality, intermediate twist, bright and dull luster,
- iii) rayon tire yarn on beams, 1100 denier from 1936-1946 and 1650 denier from 1946-1967. (Since the War, the 1650 denier price is a better indication of the expenditure for tire yarn. In 1946, the price difference was negligible.)

The first two series are reported by the Textile Economics Bureau, Inc., Textile Organon, op.cit., in various issues. The third series is collected by the Rayon Publishing Corporation, Modern Textile Magazine, op.cit., in various issues.

³⁶ The production data are reported by the Textile Economics Bureau, Inc., Textile Organon, op.cit., various monthly issues.

These prices are then weighted by the percentage contribution of each category to total synthetic staple shipments³⁷.

Data are not available to construct a similar index for synthetic filament yarn. The alternative is to use the price of a representative fiber in the category. The major portion of filament yarn produced in the United States is nylon, although both acrylic and polyester yarns have attained small market shares. Nylon yarn is subdivided into regular tenacity and high tenacity (tire cord) yarn. The Bureau of Labor Statistics publishes price indices for several different, individual grades of nylon fiber. The production (or shipment) data are not even available to weight these different types of nylon, so one of these indices is chosen³⁸.

³⁷

- i) The polyamide price used is the annual average of 3 and 6 denier nylon, staple and tow, bright and semi-dull, normal tenacity, not crimpset.
- ii) Dacron staple and tow, 3 denier, type 54, 1¼" - 4½", is the representative polyester price.
- iii) Two acrylics are considered:
 - a) Orlon acrylic staple, 3 denier, semi-dull and bright, and
 - b) Acrilan staple fiber, 3 and 5 denier, bright and semi-dull. Their price movements are very similar and only those of Orlon are included.

These price series are reported by United States Department of Agriculture, "Wool Statistics and Related Data, 1920-1964," op.cit., Table 363, 366, 367, and 370, and in various statistical supplements. The original source of these prices is the Rayon Publishing Corporation, Modern Textile Magazine, op.cit.

³⁸

We choose from the Bureau of Labor Statistics indices for 15, 70, and 840 denier filament yarn; see United States Department of Labor, Wholesale Prices and Price Indexes, Bureau of Labor Statistics, Washington, D.C., Monthly, various issues.

4.3. Additional Variables Employed in the Consumption Analysis

4.3.1. Imports and Exports of Textile Products

The exports and imports of intermediate and finished textile products will affect the volume of fiber put into process in United States mills. As more of these products are imported, there is less need for domestic mill products; on the other hand, exports represent an additional outlet and increased activity. To account for such influences we treat these flows as exogenous and net them out from mill consumption. What is left is a new variable which represents the volume of fiber consumed in products used in the United States. This new variable, labeled "domestic consumption," may replace mill consumption as the dependent variable in our model.

Domestic consumption is calculated by subtracting the export flow and adding the import flow to mill consumption. We introduce

$e_t^{j^s}$ = poundage equivalent of exports of intermediate goods fabricated from fiber j during period t ,

$e_t^{j^f}$ = poundage equivalent of exports of finished goods fabricated from fiber j during period t ,

$m_t^{j^s}$ = poundage equivalent of imports of intermediate goods fabricated from fiber j during period t ,

$m_t^{j^f}$ = poundage equivalent of imports of finished goods fabricated from fiber j during period t .

The level of disaggregation results from the format in which the data are presented. Then

$E_t^j = e_t^{j^s} + e_t^{j^f}$ is the total exports of intermediate and manufactured items derived from fiber j . $M_t^j = m_t^{j^s} + m_t^{j^f}$ is the total imports of such goods derived from fiber j . We then form the new variable

$$DC_t^j = MC_t^j - E_t^j + M_t^j,$$

where DC_t^j is the domestic consumption of fiber j during period t .

We can compute the trade balance, $M_t - E_t$, directly for cotton, carpet wool, and apparel wool. The man-made fiber data, however, are not disaggregated to distinguish between synthetic and cellulosic fiber (or between staple and filament yarn)³⁹. A scheme was considered to disaggregate the total man-made fiber trade balance into each of the four major man-made fiber categories, but because of the large possibility of observation error, it was not employed⁴⁰. Omission was especially compelling since early experiments indicated that the absence of such foreign trade effects resulted in only a minor decrease in the explanation of consumption of the four man-made fiber classifications.

4.3.2. Population Changes

We allow for changes in population by expressing the fiber consumption and the aggregate income variables in per capita terms⁴¹.

³⁹

The import and export data are presented by United States Department of Agriculture, "Statistics on Cotton and Related Data, 1925-1962," op.cit., April, 1963, Tables 15, 16, 17, 18, 19, 20, and in various supplemental statistical bulletins. The data have been converted into pounds of equivalent raw fiber.

⁴⁰

The scheme divides the aggregate man-made fiber trade balance into the four categories: synthetic staple, synthetic filament, cellulosic staple, and cellulosic filament. The weighting scheme assumes that the share of the trade balance applicable to each category is related directly to its share of domestic production (since waste is listed only by the cellulosic and non-cellulosic categories, we have divided it similarly between the staple and filament subdivisions). Since the foreign producers of the rayon and acetate fibers have long been established and the foreign production of synthetic fiber has lagged behind that of the United States, the approximated trade surpluses may be biased toward synthetic fiber.

⁴¹

We use the population of the continental United States as of July 1, including Armed Forces overseas, collected by the Bureau of Census and reported in U.S. Department of Commerce, Survey of Current Business, Office of Business Economics, Washington, D.C., various issues, and U.S. Department of Agriculture, "Statistics on Cotton and Related Data, 1925-1962," op.cit., Table 13.

This procedure ignores possible changes in the population composition that also may affect fiber consumption. Different age groups typically purchase different types of goods and if the distribution of these age groups within the population is changing, then a per capita weighting scheme will not provide an accurate indication of the number of effective consumers of a particular product.

In the construction of a population deflation index for a particular classification of goods, it is appropriate to account for individual consumption differences by giving greater weight to those units which have a larger marginal propensity to consume the product in question. For example, in deflating the end use and mill consumption data it is appropriate to recognize that the age-group from fifteen through sixty has a greater tendency to purchase textile products than the age-groups in both tails⁴². It is also appropriate to differentiate between sex in providing a population deflator for men's and for women's apparel⁴³.

Several population indices which take age differences into account have been devised for clothing expenditures⁴⁴. Available data to calculate such weighting schemes are sparse, and arbitrary extrapolations have to be made. Because of the uncertainty

⁴² See Textile Economics Bureau, Inc., Textile Organon, op.cit., January, 1962, p. 26.

⁴³ Such a deflator is devised by Donald, Lowenstein, and Simon, op.cit., pp. 92-94.

⁴⁴ Ibid., pp. 92-94 and 135-142. This index is based upon a 1941 survey conducted by Faith M. Williams and Alice C. Hanson, "Money Disbursements of Wage Earners and Clerical Workers, 1934-1936," Bulletin 638, U.S. Bureau of Labor Statistics, Washington, D.C., 1941, and supplemented by the 1940 Census. This index gives primary weight to women and men between 15 and 40. Children under 15 are given more weight in the index than people over 60. Also, see Textile Economics Bureau, Inc., Textile Organon, op.cit., January, 1962, p. 62; this index simply gives double weight to consumers between the age of 15 and 60 and even weight in the tails.

surrounding the construction of such indices, it is questionable whether they provide a more accurate description of population changes than a per capita scale. We assume that the distortion produced by an equiweight per capita scale is not large.

There are alternative functional forms which a population variable may assume. Rather than use per capita data, we may enter the level of population as an additional explanatory variable. Each specification implies a different hypothesis about the constancy of the dispersion of the residual term; thus the choice may be based partially upon the behavior of the estimated residuals⁴⁵. There is no a priori assurance that if one model has heteroskedastic residuals, the other will not. In fact, both models may be heteroskedastic or homoskedastic. Heteroskedasticity has not been a problem with the per capita model.

4.3.3. Personal Disposable Income and Personal Consumption Expenditure

The demand for textile fiber at the mill is derived from the behavior of the end product purchasers; therefore, an indicator of the purchasing power of such consumers is included in the model. The per capita level of both personal disposable income and of personal consumption expenditures is considered⁴⁶. Both variables

⁴⁵ See Stephen M. Goldfeld and Richard E. Quandt, "Tests to Discriminate Between Linear and Ratio Models," Research Memorandum No. 65, Econometric Research Program, Princeton University, Princeton, New Jersey, May, 1964.

⁴⁶ The disposable personal income data and the personal consumption expenditure data are reported in U. S. Department of Commerce, op.cit., in various issues. Also, see U. S. Department of Agriculture, "Wool Statistics and Related Data, 1920-1964," op.cit., July, 1964, Table 316.

are deflated by the Consumer Price Index of the Bureau of Labor Statistics⁴⁷. The annual level of disposable income may be deficient because it does not represent such factors as the current standard of living or expected permanent income. The level of personal consumption expenditures may be a better indicator of the resources effectively available to consumers and of consumers' feelings about the permanency of their income⁴⁸. In the consumption functions, both the levels and the first differences of the variables are entered.

4.3.4. Interfiber Competition: Substitutability and Complementarity

We test whether the various fibers are substitutes or complements by including the money price of the alternative fiber in the consumption function⁴⁹. Some problems arise when the man-made fiber prices are included in the consumption functions of the natural fibers.

⁴⁷ The Consumer Price Index is constructed by the Bureau of Labor Statistics and is reported in the U. S. Department of Commerce, op.cit., in various issues.

⁴⁸ See M. Hamburg, "Demand for Clothing," in Consumption and Savings, Friend and Jones, eds., University of Pennsylvania, 1960; and H. S. Houthakker and Lester D. Taylor, Consumer Demand in the United States, 1929-1970, Analysis and Projections (Harvard University Press, Cambridge, Mass., 1966) p. 33.

⁴⁹ Utility maximizing consumers are assumed to be sensitive to price changes between fibers and to adjust their consumption patterns by substituting fibers or by altering their purchasing of a particular blend of fibers. The inclusion of the volume consumed rather than the price, which is discussed below, does not have such a precise theoretical justification. Finally, in the text, the terms substitutability and complementarity are not used in the Hicksian-Slutsky sense, but rather refer to the sign of the partial derivative of the quantity of one good with respect to the price of the other and so include the income effect as well as the "cross" substitution effect.

One problem is the possibility that the money price of man-made fibers may not reflect the effective fiber price, i.e., the actual cost of obtaining the fiber. In the case of carpet wool, the misrepresentation of the synthetic price is so acute that it is necessary to devise an alternative scheme to quantify the relationship between the wool and synthetic fibers. Here the volume of the synthetic fiber consumed rather than the synthetic price is included, since it is a better proxy of the overall effect of man-made fibers. However, this procedure does introduce difficulties of its own. First, it imposes an additional constraint upon the specification, asserting proportionality between the consumption of the two fibers. Second, the procedure may introduce simultaneity bias and inconsistent estimates, unless synthetic mill consumption is considered as exogenous. There is some evidence that synthetic consumption is exogenous. Previous studies of the growth of synthetic fibers have stressed technological developments as the primary determinant of synthetic consumption behavior. Yale concentrates upon technological change and promotional impetus rather than economic interaction to describe the consumption of synthetic fiber in its initial stage of development⁵⁰. Polasek and Powell cite technological, rather than economic, factors in synthetic's demise of wool, finding little evidence for the hypothesis that relative prices played any role in the rise of synthetic consumption⁵¹. However, our results indicate that economic determinants do affect synthetic fiber consumption and that the volume has not increased irrespective of the consumption

⁵⁰ Jordan P. Yale, "Innovation: The Controlling Factor in the Life Cycle of the Synthetic Fiber Industry," in Modern Textile Magazine, Rayon Publishing Corporation, New York, September, 1966, pp. 50-52.

⁵¹ Metodey Polasek and Alan Powell, "Wool Versus Synthetics: An International Review of Innovation in the Fibre Market," Australian Economic Papers, Vol. III, June-December, 1964, pp. 49-64.

level of the natural fibers, so we do not dismiss the possibility of bias so easily⁵².

There is a second major difficulty with including the man-made fiber price in the consumption function of the natural fibers, and this problem is not solved by replacing the price by the volume of synthetic fiber consumed. The difficulty arises because during part of the period of observation for the natural fibers, the man-made fibers did not exist. For example, we investigate cotton consumption from 1920-1966 and include as an explanatory variable an index of synthetic staple price. However, synthetic staple was not marketed on a large scale until the early fifties, so it is necessary to represent the price before the product was introduced. There are two alternative courses to follow. First, we may divide the period of observation into two periods and include the synthetic price in only the later period, or we may approximate the synthetic price in the former period and estimate the function over the entire period⁵³. If the approximation is reasonable, the second procedure permits more efficient use of the data because we can then test the advisability of dividing the record. Following the second procedure, we specify the volume of the mill consumption as zero and the synthetic price level as infinite, prior to the existence of the fiber. The assumption of zero consumption is not unreasonable. Nevertheless it is an assumption, for the actual volume consumed was not zero — a well defined quantity — but rather was nonexistent⁵⁴. The assumption of an infinite price

⁵² See Chapter 5, Section 5.3.6.1.

⁵³ Even if it is possible to devise such an approximation, to encompass structural change it still may be necessary to estimate two separate regression models, one for each of the two sub-periods mentioned above. We do allow for this possibility.

⁵⁴ All other annual fiber consumption studies have been confronted with the same difficulty but have not recognized it as such.

also is not unreasonable; it is the counterpart of a zero quantity in that the infinite price is so high as to preclude any rational purchasing. In effect, we are assuming that the fiber did exist but that its price was so high that its discovery was rendered useless. Alternatively, the high price represents the cost which would have been incurred in developing the fiber prior to its invention. Since the synthetic price variable enters the consumption model for the natural fibers in its reciprocal form, the price variable in the early period has a value of zero⁵⁵.

We emphasize that such approximations are a potential source of misspecification. They do permit, however, the inclusion of important effects which would otherwise have to be ignored.

4.3.5. Excluded Variables and Structural Change

The structure presented to explain consumption behavior provides only a partial description of the forces actually responsible for consumption. It cannot encompass the entire network of sociological, economic, and historical influences ultimately responsible for fiber consumption. Such determinants range from factors which directly affect fiber consumption, but which are difficult to measure, to those which indirectly affect fiber

55

We may assign an arbitrarily large number, but not infinity, and introduce the price level rather than the reciprocal. The estimated coefficient of the price term is a function of the actual level chosen for the approximated price and therefore loses any economic meaning. Experiments with the scheme provide sensible estimates of the other parameters of the model. These other parameter estimates, furthermore, are not sensitive to very large changes in the value of the approximated price. The predetermined value of the price is varied from ten to seventy-five times the actual initial value of the price; in no case does the coefficient value of the other variables wander by more than one half its standard error, and in the overwhelming majority of the cases, the observed variability is much less. Furthermore, as the approximated values are increased, the price coefficient estimates converge. Neither of these results is surprising because of the collinearity between these alternative forms of the approximated price. Finally, the estimates of these other coefficients are comparable to those obtained by specifying the synthetic price in reciprocal form.

consumption through their impact on the economic system. There are several direct factors which have not been included in the specification. Winter heating in buildings and automobiles has reduced the necessity for heavier types of fiber. The insurgence of fashion consciousness has led to a greater turnover in some apparel and in decorative household items and has created additional fiber markets. Suburban living has led to the acceptance of a sport as well as a work wardrobe. Paper, glass, and plastic can be spun into yarn, presenting an additional fiber source. In fact, it has even been argued that fiber consumption behavior cannot be adequately quantified because of the impact of such not-easily-measured factors⁵⁶. There are also more general forces which influence the volume of fiber consumption indirectly; these include patterns of family formation, shifts in the age-sex composition of the population, gradual redistribution of income, and increased average prosperity. Even though such forces may alter very slowly, they still may have sizable effects upon spending patterns.

We cannot hope, even conceptually, to capture deterministically all such direct and indirect determinants of consumption behavior. F. M. Fisher has stated the consequences of the presence of such direct and indirect forces, noting that the parameters of a partial model are likely to be variables of a larger model which explains the more encompassing network of interaction⁵⁷. Thus if these "other" determinants are changing significantly over time, it is possible that the parameters of the partial model are changing, so

⁵⁶ Interorganization Research Program on Prospective Trends in Consumption of Textile Fibers, Prospective Trends in Consumption of Textile Fibers, Part IV (Secretariat of the International Cotton Advisory Committee, Washington, D.C., March, 1962) pp. 5-10 and 52-54.

⁵⁷ Franklin M. Fisher, A Priori Information and Time Series Analysis (North-Holland Publishing Company, Amsterdam, 1966) p. 5.

that the partial model is operational for only a limited time period. Although we have attempted to allow for such "other" influences by adopting a stochastic model, it is possible to overtax the ability of a random error term to capture such forces. We remain aware of the possibility of structural change, recognizing that its presence may seriously hamper the usefulness of the partial explanation.

It is possible to test statistically for the presence of structural change. The procedure is to test a particular hypothesis stating when the structural change may have occurred. We are particularly concerned that a structural break may have occurred with the introduction of synthetic fibers and their rapid expansion in markets previously dominated by the natural fibers. We find that such structural change occurs only in the carpet wool consumption equation. The actual statistical procedure and the results are discussed in the following chapter.

CHAPTER 5

ESTIMATED FIBER CONSUMPTION EQUATIONS

5.1. Introduction

Two first-order autoregressive models of consumption behavior have been constructed, and certain statistical properties of the models have been examined. The parameters of the models are now estimated and the results are employed to provide forecasts of consumption behavior. To understand and evaluate the actual parameter estimates, it is necessary to examine the properties of these estimates and to provide criteria for their evaluation. This is the subject of Section 5.2. The estimated consumption models for the different fiber categories are presented in Section 5.3 and the forecasts appear in Section 5.4.

5.2. Properties of the Estimates

5.2.1. Properties of the Estimates and Their Forecasts

Some properties of the single equation least squares estimates have already been introduced in the discussion of the possible effects of errors in observation, structural changes in the parameters, and feedback between the independent and dependent variable. We now extend the list of properties.

The autoregressive model has the form:

$$(5.1) \quad C_{jt} = a_0 + a_1 C_{jt-1} + \sum_{i=1}^n a_{1+i} X_{ijt} + u_{jt},$$

where C_{jt} is the consumption of fiber j during period t , X_{ijt} is the i^{th} independent variable at time t , and u_{jt} is the random disturbance term. To make meaningful inferences from the estimated form of the model requires certain assumptions about the properties of the variables and the parameters. Since extensive lists of these assumptions and their implications can be found elsewhere,

we list only a few of special interest¹. The parameters of the model are assumed to be time invariant over the period of estimation². It is also assumed that the unobservable residuals are random variables which are distributed independently over time³ and that the X_{ijt} are exogenous and thus statistically independent of the u_{jt} for all j and t ⁴.

The remaining independent variable, C_{jt-1} , is not exogenous⁵. The entire array of independent variables cannot be assumed to be distributed independently of the error term; thus, while the parameter estimates retain the desirable asymptotic properties of

¹ See Carl F. Christ, Econometric Models and Methods (John Wiley and Sons, Inc., New York, 1967), pp. 350-357; J. Johnston, Econometric Methods (McGraw-Hill Book Company, Inc., New York, 1963), pp. 211-221; and Arthur S. Goldberger, Econometric Theory (John Wiley & Sons, Inc., New York, 1964), pp. 272-278.

² Observations can be excluded from the estimation period if it is felt that there has been a parameter shift during that period.

³ That is, u_{jt} is assumed to be a sample from a stationary univariate stochastic process with mean zero, constant variance, σ^2 , and all lag covariances zero.

⁴ The X_{ijt} 's, as well as C_{jt-1} , are assumed to be sample observations from a stationary multivariate stochastic process with a given contemporaneous, nonsingular covariance matrix which is the probability limit of the sample variance - covariance matrix.

⁵ If for every period t each disturbance u_t is statistically independent of all its past values, u_{t-1} , u_{t-2} , etc., then for all t , u_t is statistically independent of C_{t-s} , for all s greater than or equal to zero. That is, the lagged endogenous variable is predetermined. For further discussion, see Christ, op.cit., p. 227.

consistency and efficiency, they are biased^{6,7}.

We are also interested in the statistical properties of the forecasts of the model⁸. From equation (5.1) it is evident that the projection of the dependent variable, C_t , in period t depends upon the value of C_{t-1} , the value of the exogenous variables in period t , and the addition of an unobservable random element, u_t . Forecasts of C_t can be built up either from initial conditions⁹ or, because the partial-adjustment model reduces to a first-order stochastic difference equation, directly from the solution of the equation. A closed form solution to the difference equation cannot be formed without some specification of the behavior of the X_{ijt} 's, for otherwise the nonhomogeneous contribution to the equation will not have a specific derivative. We might, for example, set $\Delta X_{ijt} = h_{ij}$, where h_{ij} is a constant for i and j . However, we choose to build the predictions up from initial conditions, using the least square estimates of the parameters and the actual values, when known, of the exogenous variables or the estimated values, when not known. To discuss the statistical properties of the forecasts, we rewrite equation (5.1). For each

⁶ Hurwitz has studied the existence and the nature of the bias and has found that except for very simple models, it is difficult to determine the strength and the direction of the bias. See Johnston, op.cit., pp. 214-216.

⁷ The asymptotic properties of the estimates of the autoregressive model are discussed extensively elsewhere. See Johnston, op.cit., pp. 266-274, and Christ, op.cit., pp. 372-379.

⁸ We discuss only the statistical aspects of the forecasts. The ability of a particular estimated model to predict depends upon how adequately it specifies economic behavior as well as the statistical properties of the estimates.

⁹ This procedure requires that the X_{ijt} 's be projected for the periods between the present and the period for which the forecast is being made.

fiber,

$$(5.2) \quad C_t = a_1 {}^t C_0 + a_0 \sum_{k=0}^{t-1} a_1^k + \sum_{i=1}^n a_{1+i} \sum_{p=1}^t a_1^{t-p} X_{ip} \\ + \sum_{p=1}^t a_1^{t-p} v_p,$$

where C_0 is the initial value of C_t . \hat{C}_t , the predictor of C_t , is formed by substituting the least square parameter estimates for the coefficients in (5.2). Since the least squares estimates of the parameters of the autoregressive model are biased, so is the least square projection of C_t . The variance of the prediction error, $E\{(C_t - \hat{C}_t)^2\}$, cannot be estimated, but we can discuss some of its properties¹⁰. From (5.2), as the length of the forecast period becomes longer, the contribution of the stochastic part of the model becomes larger, increasing the variance of the forecast error¹¹. Second, if the residual has a finite variance and $|a_1| < 1$, the forecasting variance is bounded (remains finite)¹²; Houthakker and Taylor argue further that the projecting variance for the autoregressive model with $|a_1| < 1$ is bounded above by the projecting variance of the model with $a_1 = 1$ (the corresponding static model)¹³.

¹⁰ See H. S. Houthakker and Lester D. Taylor, Consumer Demand in the United States, 1929-1970, Analysis and Projections (Harvard University Press, Cambridge, Massachusetts, 1966), p. 38.

¹¹ See Christ, op.cit., p. 221.

¹² Ibid., p. 221.

¹³ Houthakker and Taylor, op.cit., pp. 38-39.

5.2.2. Autocorrelation

If the residuals are serially correlated, the lagged dependent variable is no longer predetermined, since it is not distributed independently of the current and forward residuals. The resultant bias can be very serious and unpredictable in both size and sign. The least squares estimates are no longer minimum variance estimates; they will lead to an underestimate of the residual variance. Furthermore, because of the induced interdependence between the current residual and the lagged dependent variable, the least square estimates will also be inconsistent. The existence of serially correlated residuals also leads to an underestimate of the projection variance and to an increase in this variance¹⁴.

The problems of autocorrelated residuals are compounded by the fact that the statistics usually used to test for its presence are not strictly applicable to the autoregressive model. The Durbin-Watson statistic, a test for first-order autocorrelation, is biased toward two, so that it is only possible to reject the hypothesis of serially independent residuals¹⁵. Since the extent of the bias is unknown, it is not possible to accept the null hypothesis and the statistic is used as only an approximation. We consider the statistic acceptable if it lies in the range 1.6 to 2.4; this is a rule of thumb which has been adopted in another study with similar degrees of freedom¹⁶.

¹⁴ Houthakker and Taylor, op.cit., p. 40. For further discussion of the effects of autocorrelation, see Johnston, op.cit., pp. 215-221; also see Houthakker and Taylor, op.cit., pp. 40-42.

¹⁵ Z. Griliches, "A Note on Serial Correlation Bias in Estimates of Distributed Lags," Econometrica, Vol. 29, No. 1, 1961.

¹⁶ See Houthakker and Taylor, op.cit., p. 42.

5.2.3. Simulation

The consumption models are simulated over their period of observation; like the forecasts, the simulated values are built up from the initial observations, using the actual values of the exogenous variables and the simulated value of the lagged dependent variable. The simulated consumption values are compared with the actual values. Discrepancies between the series can point out or help to reinforce other indications of misspecification. To test the conformance of the two series, three descriptive statistics are used: the coefficient of determination between the two series, Theil's coefficient of inequality, which is also disaggregated into its three components, and the number of periods in which the simulated series incorrectly predicts the direction of change of the actual series. The last statistic is labeled as "misses".

5.2.4. Evaluation of the Estimates

The parameter estimates do not have desirable small sample properties, and the usual statistical tests are no longer strictly applicable for small sample estimates¹⁷. Other indicators are used. Two important criteria for evaluating the parameter estimates are the quality of the a priori specification and the plausibility of the estimates¹⁸. A third criterion is to compare them with the

¹⁷ Franklin Fisher has pointed out that the "usual" statistical tests are rarely strictly applicable in econometric work because of the unavoidable and desirable use of a priori information in specifying the model. He argues that it is preferable to have a stable structure, which may require initial scanning of the data, than to have a nonstable structure, even though statistical tests upon the parameters may not be statistically valid. To yield meaningful results it is often necessary to lose precision in the estimates. See Franklin M. Fisher, A Priori Information and Time Series Analysis (North-Holland Publishing Company, Amsterdam, 1966), p.13.

¹⁸ See Stephen M. Goldfeld, Commercial Bank Behavior and Economic Activity (North-Holland Publishing Company, Amsterdam, 1966), p. 37, and Houthakker and Taylor, op.cit., p. 55.

results of similar studies in related areas. Franklin Fisher notes, "the most impressive kind of econometric result is ... that of a striking and plausible pattern in the estimates obtained by treating similar problems in a similar way"¹⁹. A high premium is placed upon the consistency of similar coefficients in the various fiber categories and upon the consistency of these coefficients with those derived with similar models in related areas. Finally, the ability of a particular model to forecast and to simulate is used as an indication of the relevance of the specification. In summary, the final evaluation of the structural equations will be based upon a mixture of criteria including traditional statistical tests, a priori specification and expected parameter values, and the comparison with parameters describing similar phenomenon in similar settings.

5.3. The Estimated Fiber Consumption Functions

5.3.1. Notation

The following notation is used throughout the chapter. The following variables are used in the analysis:

$DCCTN_t$ = Per capita domestic consumption of cotton, year t,

$LDCCTN_t$ = Natural logarithm of the per capita domestic consumption of cotton, year t,

$DCAW_t$ = Per capita domestic consumption of apparel wool, year t,

$DCCW_t$ = Per capita domestic consumption of carpet wool, year t,

$MCRAS_t$ = Per capita mill consumption of cellulosic staple, year t,

$MCRAF_t$ = Per capita mill consumption of cellulosic filament yarn, year t,

$MCSNS_t$ = Per capita mill consumption of synthetic staple fiber, year t,

¹⁹ Fisher, op.cit., p. 16.

- LMCSTP_t = Natural logarithm of the per capita mill consumption of synthetic staple fiber, year t,
- LMCSNF_t = Natural logarithm of the per capita mill consumption of synthetic filament yarn, year t,
- MCSILK_t = Per capita mill consumption of silk, year t,
- YTD_t = Real, per capita disposable income, year t,
- PCE_t = Deflated, per capita, aggregated personal consumption expenditures, year t,
- LYTD_t = Natural logarithm of the real, per capita disposable income, year t,
- LPCE_t = Natural logarithm of the real, per capita level of personal consumption expenditures, year t,
- SEAPC_t = Deflated, seasonal average price of cotton, year t,
- LCTNPC_t = Natural logarithm of the deflated, seasonal average price of cotton, year beginning 12 months prior to preceding October,
- FMPC_t = Deflated, seasonal average domestic price of wool received by farmers, year t,
- AUST_t = Deflated annual average price of fine Australian wool, year t,
- BAPC_t = Deflated price of Buenos Aires coarse wool, year t,
- LBA_t = Natural logarithm of the deflated Buenos Aires price of carpet wool, year t,
- RASPC_t = Deflated price index of cellulosic staple, year t,
- RAFPC_t = Deflated price index of cellulosic filament yarn, year t,
- R150_t = Deflated price index of regular tenacity rayon yarn, year t,
- LSNSPC_t = Natural logarithm of the deflated synthetic staple price index, year t,

$PCSILK_t$ = Deflated price of silk, year t,
 $ACRPC_t^{-1}$ = Reciprocal of the deflated price of Acrilan staple fiber, year t,
 $NYSTP_t^{-1}$ = Reciprocal of the deflated price index of nylon staple fiber, year t,
 $SNSPC_t^{-1}$ = Reciprocal of the deflated synthetic staple price index, year t,
 $NY840_t^{-1}$ = Reciprocal of the deflated price of nylon high tenacity filament yarn, year t,
 $RAYON_t^{-1}$ = Reciprocal of the deflated rayon staple price index, year t,
 WD_t = War dummy variable, year t,
 DD_t = Depression dummy variable, year t,

and

$\Delta LMSTP_t = LMSTP_t - LMSTP_{t-1}$,
 $\Delta LSNSPC_t = LSNSPC_t - LSNSPC_{t-1}$,
 $\Delta YTD_t = YTD_t - YTD_{t-1}$,
 $\Delta LYTD_t = LYTD_t - LYTD_{t-1}$,
 $YTDSM_t = YTD_t + YTD_{t-1}$,
 $\Delta YTDSM_t = \Delta YTD_t + \Delta YTD_{t-1} = YTD_t - YTD_{t-2}$,
 $\Delta PCE_t = PCE_t - PCE_{t-1}$,
 $\Delta PCESM_t = \Delta PCE_t + \Delta PCE_{t-1} = PCE_t - PCE_{t-2}$,
 $\Delta LPCE_t = LPCE_t - LPCE_{t-1}$,
 $MCSNSM_t = MCSNS_t + MCSNS_{t-1}$,
 $SEASM_t = SEAPC_t + SEAPC_{t-1}$,
 $AUSTSM_t = AUST_t + AUST_{t-1}$,
 $BASUM_t = BAPC_t + BAPC_{t-1}$,
 $RASPSM_t = RASPC_t + RASPC_{t-1}$,

$$\text{SNP}^{-1}\text{SM}_t = \text{SNSPC}_t^{-1} + \text{SNSPC}_{t-1}^{-1},$$

$$\text{ACRPC}_t^{-1}\text{SM} = \text{ACRPC}_t^{-1} + \text{ACRPC}_{t-1}^{-1},$$

$$\text{NYSTP}_{t-1}^{-1}\text{SM} = \text{NYSTP}_{t-1}^{-1} + \text{NYSTP}_{t-2}^{-1}.$$

The symbols are defined as follows:

- δ = coefficient of adjustment in the Nerlove specification,
- δ' = coefficient of adjustment in the Bergstrom specification,
- a = intercept of the Nerlove normal equation,
- a' = intercept of the Bergstrom normal equation,
- y_l = long-run income elasticity,
- y_s = short-run income elasticity,
- pc_l = long-run personal consumption expenditure elasticity,
- pc_s = short-run personal consumption expenditure elasticity,
- p_l = long-run own price elasticity,
- p_s = short-run own price elasticity,
- o_l = long-run cross price elasticity,
- o_s = short-run cross price elasticity,
- c_l = long-run other mill consumption elasticity,
- c_s = short-run other mill consumption elasticity,
- \bar{R}^2 = coefficient of multiple determination, corrected for degrees of freedom,
- DW = Durbin-Watson statistic,
- $F_{m,n}$ = F-test statistic with m and n degrees of freedom,
- \hat{X}_t = the estimated value of the variable X, in year t,

U = Theil U statistic, "coefficient of inequality",

U^m = mean component of coefficient of inequality,

U^v = variance component of coefficient of inequality,

U^c = nonsystematic component of coefficient of inequality,

R'^2 = coefficient of multiple determination between the actual and the simulated series,

Misses = the number of periods in which the simulated series incorrectly predicts the direction of change of the actual series.

5.3.2. Domestic Cotton Consumption

Nerlove Consumption Model 1922-1966

$$(5.3) \quad DCCTN_t = 17.858 + .213 DCCTN_{t-1} - 1.045 SEAPC_t \\ - 9.785 SNSPC_{t-1}^{-1} + .572 YTD_t + 1.146 \Delta YTD_t \\ + 5.304 WD_t - 4.322 DD_t^{.20}$$

(10.) (2.6) (3.5)
(5.9) (3.8) (3.4)
(6.9) (5.4)

$$\bar{R}^2 = .92 \quad DW = 2.29 \quad F_{7,37} = 59.74 \quad \delta = .786$$

$$p_1 = .17 \quad y_1 (\Delta YTD=0) = .365 \quad o_1 = .476$$

$$p_s = .13 \quad y_s (\Delta YTD=0) = .287 \quad o_s = .374$$

$$\hat{DCCTN}_{1967} = 23.66 \text{ pounds per capita}^{21}.$$

²⁰The "t" statistics are presented in parentheses.

²¹The forecast is based upon the following data and projections:

$$SEAPC_{1967} = 2.108, SNSPC_{1966} = .888, \hat{YTD}_{1967} = 23.10,$$

$$DCCTN_{1966} = 25.10.$$

The projections for 1967, denoted by the "hat", are extrapolated from first quarter preliminary data.

Bergstrom Consumption Model 1922-1966

$$\begin{aligned}
 (5.4) \quad DCCTN_t &= 20.820 + .086 DCCTN_{t-1} - .623 SEASM_t - 5.660 SNP^{-1} SM_{t-1} \\
 &+ .333 YTDSM_t + .592 \Delta YTDSM_t + 5.965 WD_t - 4.933 DD_t.
 \end{aligned}$$

$$\bar{R}^2 = .887 \quad DW = 2.31 \quad F_{7,37} = 41.49$$

$$\delta' = 1.685$$

$$a' = 22.79$$

$$p_1 = .17$$

$$\hat{DCCTN}_{1967} = 23.86 \text{ pounds per capita.}$$

The Nerlove model (5.3) explains annual movements in domestic cotton consumption well. The signs of the estimated parameters correspond to a priori expectations, and their values are reasonable. Also, while the exact meaning of the standard statistical tests of the significance of the coefficients is in question, the high "t" values support a claim of significance. The \bar{R}^2 , corrected for degrees of freedom, is .92, and the significance of the general linear hypothesis is upheld by the F ratio. The Durbin-Watson statistic, 2.29, is acceptable. The simulation experience of the Nerlove model is impressive, especially with respect to predicting the direction of change.

The Bergstrom model (5.4) is less satisfactory. The corrected coefficient of determination is lower at .887, and the Durbin-Watson is slightly higher²². The coefficient of the lagged endogenous variable is only marginally significant²³. Furthermore, as shown in Table 5.1, the Bergstrom model does not simulate as well as the Nerlove model over the observation period.

Table 5.1. Summary Statistics for Models (5.3) and (5.4).

<u>Model</u>	<u>R²</u>	<u>U (U^m U^v U^c)</u>			<u>Misses</u>
(5.3)	.929	.022(.000	.020	.980)	6
(5.4)	.903	.026(.000	.026	.974)	15

In summary, the Nerlove model is superior to the Bergstrom model in explaining cotton consumption even though the Bergstrom model makes finer theoretical distinctions.

²² The two models assume potentially different residual distributions, so a difference in the Durbin-Watson statistic may be anticipated.

²³ Based upon the pairwise correlation coefficients, the high standard error does not appear to be a result of multicollinearity. This does not eliminate the possibility of a higher-order interdependence.

We discuss the implications of the Nerlove model (5.3) and introduce various extensions. The coefficient of adjustment, derived from the coefficient of the lagged dependent variable, is .786, indicating that the volume of cotton consumed responds quickly to changes in the determinants of normal consumption. The distinction between short-run response and long-run response of consumption to changes in the explanatory variables is not so important here because actual consumption rapidly approaches its "equilibrium" level.

Both the current level and the change in the level of real, per capita disposable income are included in the model. The demand for cotton fiber is derived from that for finished cotton products, which are primarily durable, staple apparel and household items. The disposable income variables are included to reflect the demand for these finished products, under the assumption that the level as well as recent changes in income affect their purchase. The estimated coefficients indicate that cotton consumption is only slightly responsive to changes in the level and in the rate of change of income. The income elasticity of consumption is inelastic in both the short run and the long run, with a short-run elasticity of .287 and a long-run elasticity of .365²⁴. Since cotton is used in the production of staple clothing and industrial items, inelasticity is expected.

The two prices in equation (5.3) are the seasonal average price of domestic cotton and the index of nylon staple, Dacron, and Orlon prices. The cotton price is lagged by six months, since the season begins in August and continues through the following July. The lag is intended to reflect the "time-consuming process involved in [the] movement [of fiber] from the farm to the textile mills".²⁵

²⁴ The income elasticity is estimated assuming that the recent change in income has been zero.

²⁵ James R. Donald, Frank Lowenstein, and Martin S. Simon, "The Demand for Textile Fibers in the United States," Technical Bulletin No. 1301, United States Department of Agriculture, Economic Research Service, Washington, D.C., November, 1963, p.58.

However, neither the exact nature nor the length of the lag between buying and utilization is clear. When an unlagged price is included in the model, the results are almost identical and are only slightly inferior; when the lag is as long as one year, the results are worse. The synthetic price index, on the other hand, is lagged one full period. This specification assumes that changes in the synthetic price will not affect cotton consumption in the current period²⁶. The model thus assumes that mill management will react more quickly to a change in the price of cotton than a simultaneous change in the price of synthetic fiber. Such differential adaptation is highly reasonable. However, an unfortunate aspect of the specification is that the length of these lags must be prespecified.

The signs and the values of the two estimated price coefficients conform to a priori expectations. The own price coefficient is negative, with price elasticities of .13 in the short run and .17 in the long run²⁷. The price elasticity depends in part upon that of clothing and industrial products from which the demand for

²⁶

The initial lag for synthetic fiber has probably become shorter over time as familiarity with the fiber has increased. The inability of the model to determine the length of these lags or to account for their possible variability remains a weakness of the specification.

²⁷

These price elasticities are comparable to those of Donald, who used a double-logarithmic specification over the period 1927-32, 1935-40, 1948-60:

$$(5.5) \quad \text{LDCCTN}_t = .35 + \underset{(.12)}{.42} \text{LYTD}_t + \underset{(.29)}{1.22} \Delta \text{LYTD}_t - \underset{(.09)}{.14} \text{LCTNPC}_t \\ - \underset{(.04)}{.14} \text{LMCSTP}_t, \quad R^2 = .68$$

They suggest that there was difficulty in quantifying behavior in the early fifties and attribute some of it to the Korean War. See Donald, Lowenstein and Simon, op.cit., p. 61.

cotton fiber is derived. While there has been little success in quantifying the price elasticity of such products, a high price elasticity is not expected²⁸. Furthermore, the portion of the total cost of cotton products attributable to the original cost of raw cotton is typically small; this implies, ceteris paribus, a lower elasticity for the derived good. The negative sign of the inverted, lagged synthetic price coefficient implies that synthetic staple and cotton are gross substitutes. The cross price elasticity of consumption is inelastic, as expected, and, interestingly, greater than the own price inelasticity²⁹. The model indicates that in the long run, cotton consumption is more responsive to changes in the man-made fiber price than in its own price, even though the initial response to the synthetic fiber price is very small. This is a reasonable and concise description

²⁸See especially Houthakker and Taylor, op.cit., pp. 68-69, 73, 85; M. Hamburg, "Demand for Clothing," in Consumption and Savings, Friend and Jones, eds., University of Pennsylvania, Philadelphia, Pennsylvania, 1960; Donald, Lowenstein, and Simon, op.cit., pp. 90-100.

²⁹The partial derivative of consumption with respect to the price index of synthetic staple fiber is a function of the level of the price index, and the cross elasticity is measured using the 1966 value.

of the interaction between the two fibers³⁰.

The specification is extended to include the prices of other potential substitutable and complementary fibers, but these experiments are only marginally successful. As an alternative to the staple price index, the prices of high tenacity and of regular tenacity nylon yarn are introduced, but with little success. Thus the interaction between cotton and synthetic staple appears to be more predictable than that between cotton and the filaments.

Second, the rayon-acetate staple and yarn prices are introduced in addition to the synthetic staple price, but neither achieves statistical significance. Each cellulosic price enters with a positive sign, indicating a possible complementary relationship³¹.

³⁰

Two alternative approaches account for the effects of synthetic staple fiber. The staple price variable in (5.3) is replaced either by the actual level of the price index (with a very high value for the years prior to the fiber's existence) or by the level of synthetic staple mill consumption. In Table 5.2, the first alternative model is labeled (5.6), and the second, (5.7). As seen in the table, both forms are less successful than (5.3). Note especially the failure of (5.6) to simulate the mean of the actual series. Interestingly, the coefficients in model (5.6) do not alter by more than one-tenth of their standard deviation when the prespecified value of the synthetic price is varied.

Table 5.2. Summary Statistics for Models (5.3), (5.6), and (5.7).

Model	\bar{R}^2	DW	δ	P1	R ²	U	(U ^m	U ^v	U ^c)	Misses
(5.3)	.92	2.29	.786	.17,	.93	.022	(.00	.02	.98)	6
(5.6)	.89	2.04	.639	.17	.90	.060	(.69	.01	.30)	9
(5.7)	.87	1.83	.490	.31	.85	.037	(.00	.03	.97)	10

³¹

Surprisingly, this is true even for rayon tire cord yarn, which is an outstanding example of direct and vigorous competition.

For example, the reciprocal of the rayon staple price index is introduced into (5.3):

Nerlove Consumption Model 1922-1966

$$\begin{aligned}
 (5.8) \quad DCCTN_t &= 18.361 + .208 DCCTN_{t-1} - 1.021 SEAPC_t \\
 &- 9.79 SNSPC_{t-1} + .517 YTD_t + 1.197 \Delta YTD_t + 5.228 WD_t \\
 &- 4.291 DD_t + .338 RAYON_{t-1}^{-1} \quad ^{32}
 \end{aligned}$$

$$\bar{R}^2 = .917 \quad DW = 2.29 \quad \delta = .792$$

Markham has anticipated these results for the cellulosic fibers, noting that "much of the increased rayon consumption was at the expense of silk ... and that the extent to which rayon consumption has increased at the expense of cotton (and wool) is not so obvious"³³. He points out that cotton is used in many items where "durability, cheapness, and launderability, rather than style and appearance, are decisive factors," and mentions the possibility that cotton consumption may have "benefited from the increase in total demand for textiles that has resulted from the introduction of rayon"³⁴. We conclude that further evidence is needed to make a conclusive statement as to the competition between cotton and cellulosic fiber.

³² Multicollinearity does not appear to be a problem, but it may be responsible for the result in the sense that the independent variation in the independent variable set may have been exhausted by the previously included variables; we have not, for example, investigated the principle components of the data set to get a better idea of their independent variability. As a hedge against this possibility, the model is rerun without the synthetic price variable, but the result is not altered.

³³ Jesse W. Markham, Competition in the Rayon Industry (Harvard University Press, Cambridge, 1952), p. 33.

³⁴ Ibid, p. 34.

Two dummy variables, WD_t and DD_t , are introduced in (5.3) to account for the effect of unusual circumstances upon consumption behavior. Both variables represent a temporary structural shift in the level of autonomous consumption; the war dummy, WD_t , isolates years of large military purchases and related speculative demand, and the depression dummy, DD_t , indicates years of depression and severe textile stock accumulation.

The war dummy variable covers both the Second World War and the Korean War, but not the Vietnam War. Sizable increases in mill consumption occurred during both the Second World War and the Korean War, primarily in the initial stages of the wars; the dummy variable isolates such purchases during 1941-1943 and 1950-1951. During the Vietnam War the military purchases of cotton products were not above normal through 1966; inventories of textile products had not been accumulating, and material used by all branches of the military had become standardized³⁵. In 1966 when Vietnam military buying reached its peak, it represented approximately two percent of total cotton purchases³⁶. The coefficient of the war dummy variable is positive and large. The estimated increase in autonomous consumption during the Second World War is 18% of the total consumption before the War. The coefficient is highly significant, indicating that it is necessary to isolate unusual

³⁵ S. J. Kennedy, "Military Textiles and Clothing: Changing Needs," in Modern Textiles Magazine, Rayon Publishing Corporation, New York, October, 1966, pp. 82-85.

³⁶ Textile Economics Bureau, Inc., Textile Organon, Stanly B. Hunt, ed., New York, Monthly, May 1967, p. 14.

market activity during the period³⁷.

The depression dummy variable covers 1930-1935 and the 1938 recession; during both these periods the entire textile industry suffered a drastic reduction in activity in the face of large stock accumulations³⁸. The negative coefficient of the variable is highly significant and indicates a severe decrease in autonomous consumption, with an estimated decline of 16% of the 1930 consumption level in the early depression. In fact, the estimated percentage decline in autonomous consumption during the depression is almost as great as the estimated percentage increase during the Second World War.

We investigate the possibility of the existence of structural change over the period 1922-1966. The long record provides many degrees of freedom, but as Fisher has observed, long time series

37

It is possible to test whether the three year war dummy has captured the essence of the structural change introduced during the Second World War. A Chow test is conducted by treating the years 1941-43 as additional observations and (allowing for the autonomous shift in consumption during these years) comparing the coefficients estimated during this period with those estimated over the remainder of the record. We are not able to reject the hypothesis that the same structure is operative during these three war years and during the remainder of the period. Thus, the dummy variable appears to capture the structural change adequately. The F statistic is

$$F_{3,34} = .610.$$

The test also supports the related hypothesis that one dummy variable is sufficient for both war periods.

38

For extensive discussion of the inventory movements during these periods, see Hiram S. Davis, Inventory Trends in Textile Production and Distribution (The Textile Foundation, Washington, D.C., and Industrial Research Department, Wharton School of Finance and Commerce, University of Pennsylvania, Philadelphia, 1941).

are not necessarily a panacea because of the increased possibility of structural change³⁹. If some or all of the "true" parameter values have altered over the period of observation, it may be necessary to split the period of observation to gain meaningful estimates. We are particularly concerned that the cotton consumption function may have altered significantly with the introduction of synthetic fibers. Until the introduction and acceptance of synthetic fibers, cotton had been the dominant textile raw material and was the only usable or practical fiber for many products. With the introduction of synthetic fiber, competing products entered the market and the cotton consumption function may have undergone a fundamental shift. We have allowed for a shift in the function by including the synthetic fiber price (or consumption level), but there may have been an even more fundamental change altering all or some of the parameters of the other variables in the function. It is difficult to predict the parameters which would have been affected. This depends, in part, upon the speed and scale with which synthetic products displaced cotton products. If the displacement were slow, orderly, and not too sizable, we might expect the following. First, the cotton price elasticity may become, ceteris paribus, more elastic with the introduction of a substitute⁴⁰. A price increase in cotton would now elicit a greater decrease in the quantity of cotton demanded than before, since mills could use synthetic fiber instead. The income elasticity may be expected to remain the same if the substitute product is not much different from the cotton product. The change in the sign of the coefficient of adjustment is uncertain. However, it is not certain that the entrance of synthetic fiber products was slow or orderly enough to fit this description.

³⁹ See Fisher, op.cit., p. 5.

⁴⁰ J. M. Kuhlman and R. G. Thompson, "Substitution and Values of Elasticities," American Economic Review, Vol. LV, No. 3, June, 1965, pp. 506-510.

G. C. Chow has introduced procedures to test the occurrence of a significant structural break in either all the parameters or in a particular subset⁴¹. The null hypothesis of the test is that the true parameter values in question have remained constant over two subperiods. If we cannot reject the null hypothesis, it indicates that a structural break has not occurred or is not significant enough to obscure the meaning of the estimates computed over the entire observation period. The first step in using the test is to specify which coefficients are likely to have changed. Because of the lack of a well-defined hypothesis here, we allow for a change in all of the parameters. The second step is to state explicitly when the structural break is likely to have occurred. The record is divided into the periods 1922-1954 and 1955-1966. Prior to the mid-1950's, the synthetic fibers had not produced a large impact upon textile markets. Nylon was still in very short supply, with its patent remaining in effect, and the polyester and acrylic fibers, introduced in 1952-53, had not been particularly successful in large scale marketing. After 1954, however, a large reorganization in market shares occurred, and that of synthetic fibers rose rapidly.

Over both subperiods the number of independent variables is less than the number of observations. If the full model is estimated over each subperiod, however, a special case of multicollinearity is encountered, for the value of the depression dummy and of the war dummy is everywhere zero for the second subperiod. To avoid this technical difficulty, two alternative procedures are adopted. The first is to employ an alternative test which is usually used in situations in which the observations

⁴¹ Gregory C. Chow, "Tests of Equality Between Sets of Coefficients in Two Linear Regressions," Econometrica, Vol. 28, No. 3, July 1960, pp. 591-605. For a variation on Chow's work, see Ryutaro Komiya, "Technological Progress and the Production Function in the United States Stream Power Industry," Review of Economics and Statistics, Vol. 44, May, 1962, pp. 156-166.

in one period are less than the number of variables; this test does not require the direct estimation of the full model over the second subperiod. This test is still valid when the observations in each subperiod are greater than the number of variables, but it is less efficient than the regular test, since it "unnecessarily" inflates the numerator of the F statistic⁴². Using this procedure, we are not able to reject the null hypothesis of no structural change. The appropriate F statistics are presented below⁴³. The alternative procedure is to modify (5.3) and (5.4) by deleting the years 1930-1935, 1938, 1941-1943, and 1950-1951, thus eliminating the dummy variables. The model can now be run directly on the two subperiods. Again we are unable to reject the null hypothesis of no structural change⁴⁴. Both tests indicate that the structure over the two prespecified subperiods has not changed significantly and that the inclusion of the synthetic staple price in (5.3) and in (5.4) has represented adequately the impact of synthetic fibers. Thus we need not allow for a more basic alteration in the consumption function. The tests also indicate that the structure has not altered

⁴² See Chow, op.cit., p. 598.

⁴³ Based on the periods 1922-1954 and 1955-1966, for model (5.3), the appropriate F statistic is

$$F_{12,25} = .482.$$

⁴⁴ For the years 1922-1929, 1936-1937, 1939-1940, 1944-1949, and 1952-1966, and based on the subperiods above,

$$\text{for (5.3), } F_{6,21} = .99, \text{ and}$$

$$\text{for (5.4), } F_{6,21} = 1.15.$$

significantly over the forty year period for other sociological-psychological reasons⁴⁵.

5.3.3. Domestic Apparel Wool Consumption

Nerlove Consumption Model 1925-1966

$$(5.9) \quad \text{DCAW}_t = 2.464 + \overset{(8.8)}{.349} \text{DCAW}_{t-1} - \overset{(4.7)}{.135} \text{FMPC}_t - \overset{(3.0)}{.707} \text{ACRPC}_{t-1} \\ + \overset{(8.9)}{1.076} \text{WD}_t - \overset{(6.2)}{.801} \text{DD}_t.$$

$$\bar{R}^2 = .909 \quad \text{DW} = 2.26 \quad F_{5.36} = 71.61 \quad \delta = .651 \\ a = 3.79$$

$$p_1 = .44 \quad o_1 = .542$$

$$p_s = .29 \quad o_s = .353$$

$$\widehat{\text{DCAW}}_{1967} = 1.835 \text{ pounds per capita.}$$

⁴⁵

Observers have expressed concern that aggregate consumption behavior may have altered structurally after the Second World War. See, for example, Chow, op.cit., p. 591, or Houthakker and Taylor, op.cit., p. 32. Early in the analysis we included a dummy variable to allow for a shift in autonomous consumption behavior. The variable was insignificant and dropped from further consideration. Such a procedure does involve a specific specification of the nature of the structural change and so is by no means a rigorous test of the existence of structural change.

Bergstrom Consumption Model 1925-1966

$$(5.10) \quad \text{DCAW}_t = 3.245 + \begin{matrix} (6.4) \\ .202 \end{matrix} \text{DCAW}_{t-1} - \begin{matrix} (2.6) \\ .260 \end{matrix} \text{AUSTSM}_t - \begin{matrix} (3.1) \\ .529 \end{matrix} \text{ACRPC}_{t-1} \text{SM} \\ + \begin{matrix} (8.0) \\ .998 \end{matrix} \text{WD}_t - \begin{matrix} (6.0) \\ .800 \end{matrix} \text{DD}_t.$$

$$\bar{R}^2 = .904 \quad \text{DW} = 2.18 \quad F_{5,36} = 68.17 \quad \delta' = 1.328 \\ a' = 4.065$$

$$p_1 = .536 \quad o_1 = .604$$

$$\hat{\text{DCAW}}_{1967} = 1.883 \text{ pounds per capita.}^{46}$$

The Nerlove model (5.9) and the Bergstrom model (5.10) provide similar descriptions of apparel wool consumption⁴⁷. Both the corrected coefficients of determination and the Durbin-Watson statistics are comparable. The long-run price elasticities, for both the price of apparel wool and of Acrilan staple, are almost identical in the two models. Also, the results of the simulation experiments presented in Table 5.3 are similar, with the R^2 and the coefficient of inequality slightly higher for the Bergstrom model. Finally, both models provide almost identical projections

⁴⁶ The forecasts of wool consumption are based upon the following data and projections:

$$\hat{\text{FMPC}}_{1967} = 4.58, \quad \hat{\text{AUST}}_{1967} = 1.402, \quad \text{ACRPC}_{1966} = 1.039,$$

$$\text{DCAW}_{1966} = 1.940.$$

⁴⁷ Model (5.9) and (5.10) do not include an income term. When the income term is included, its coefficient is insignificant and the other coefficient values are practically unaffected (this is shown later). Since an income variable is included in the a priori specification, its exclusion could alter significantly the other signs, but this is not the case here so the exclusion does not concern us.

of the 1967 consumption level. We do not attempt to distinguish between the two models, so we discuss their properties together.

Table 5.3. Summary Statistics for Models (5.9) and (5.10).

<u>Model</u>	<u>R'²</u>	<u>U</u>	<u>(U^m</u>	<u>U^v</u>	<u>U^c)</u>	<u>Misses</u>
(5.9)	.883	.0399	(.001	.0483	.9511)	11.
(5.10)	.905	.0414	(.000	.0290	.9710)	13.

The coefficients of adjustment are $\delta = .651$ and $\delta' = 1.328$, so that both models are stable; they indicate that apparel wool consumption adjusts fairly quickly toward its steady-state, normal level, but that it does not react so quickly as cotton consumption.

The price of apparel wool included in the Nerlove model is the deflated seasonal average price received by farmers for domestic wool. Like cotton, the wool season runs from August through July. The price included is that of the previous full season, so that it is lagged by six months. The Bergstrom model performs poorly when the seasonal price is used, so the unlagged, annual average price of fine Australian wool has been employed. Because the price variable in the Bergstrom model is not lagged, the implied initial response to a price change is earlier for the Bergstrom model than for the Nerlove model. Both models indicate an inelastic, long-run consumption response to a change in the wool price. The estimated price elasticity in the Nerlove model is .44, which is lower than the .536 Bergstrom

estimate⁴⁸. Both these elasticities are over twice as great as the estimated cotton elasticities. The small contribution that the cost of raw wool makes to the total cost of wool products would imply an inelastic price response, while the comparative "luxury" of woollen goods to cotton goods would indicate a higher elasticity for apparel wool than for cotton.

In both forms of the model the impact of synthetic staple fiber is represented by the price of Acrilan. Acrylic fibers have competed more vigorously with wool than have either polyester or nylon fibers. The estimated long-run cross price elasticities for the Nerlove and the Bergstrom models are .542 and .604, respectively⁴⁹. Both elasticities are inelastic, and the two fibers are gross substitutes. Furthermore, the cross elasticity is greater than the own price elasticity, as is the case for cotton. Apparel wool consumption also appears to be more sensitive to interfiber competition than cotton, but this is not surprising considering the drastic postwar decline in the consumption of apparel wool.

⁴⁸ Of the three previous major wool consumption studies, two have indicated such an inelastic price response. Donald, Lowenstein, and Simon have not produced convincing results with respect to the value of the price coefficient, but the elasticity seems to be less than .50. (See Donald, Lowenstein, and Simon, op.cit., pp. 74-81.) Ferguson and Polasek's analysis of quarterly consumption behavior from 1954-1959 produces an elasticity of .55. (See C. E. Ferguson and Metodey Polasek, "The Elasticity of Import Demand for Raw Apparel Wool in the United States," Econometrica, Vol. 30, No. 4, October, 1962.) The United States Consumption equation in Witherell's model of the world wool market, estimated with annual data for 1949-1964, implies a short-run elasticity near unity and a long-run elasticity of 7.0. These elasticities are very high and surprising. We introduce and discuss his equation below. (See William H. Witherell, "Dynamics of the International Wool Market: An Econometric Analysis," Econometric Research Memorandum 91, Econometric Research Program, Princeton, New Jersey, September, 1967.)

⁴⁹ The elasticities are measured at the 1966 price level.

Other variables can be used to account for the effect of synthetic staple competition. When the level of mill consumption of synthetic staple fiber is included instead of the price, both the Bergstrom and the Nerlove models are less convincing. The coefficients of the own price variables lose their statistical significance. When per capita disposable income is introduced into the models, its coefficient enters with a negative sign. A second procedure is to introduce the actual level of the lagged Acrilan price. The results are similar to (5.9) and (5.10). As in the case of cotton, the coefficient values (except that of the Acrilan price) are practically insensitive to changes in the approximated synthetic price level.

Two dummy variables are included in the models. The war shift variable again covers both the Second World War (1941-46) and the Korean War (1950). The world market was unsettled during 1950 and early 1951, with large speculative waves, so the Korean War component covers both speculative demand and military demand in the early stages of the War. Covariance analysis indicates that the same variable may be used to represent the unusual demand conditions during both war periods. The dummy variable does not cover the Vietnam War, since military purchases had not increased over their normal, peacetime level, remaining below two percent of total woolen goods purchased⁵⁰. The value of the war dummy coefficient is 1.076, which represents a 42% increase in World War II autonomous consumption over the total pre-War consumption level. This increase is much higher than the 18% increase in cotton consumption. As in the case of cotton, the war dummy variable seems to represent adequately the structural

⁵⁰

Textile Economics Bureau, Inc., Textile Organon, op.cit., May, 1967, p. 14.

change in consumption behavior⁵¹. The depression dummy variable isolates the reduced wool activity from 1930-1934 and during 1938. The level of autonomous consumption experiences an estimated decline of 35% of the pre-depression total consumption level. This is much greater than the estimated 16% decline in cotton and is almost as great as the percentage increase during the Second World War. Both these periods definitely experienced unusual consumption patterns.

Models (5.9) and (5.10) do not conform to a priori expectations in one important respect: in both models there is no provision for the effect of disposable income. Attempts to include its effect are indecisive. In the Bergstrom model, the income coefficient enters with a positive sign, but its entrance does not affect significantly the other coefficient values and its coefficient is so decisively insignificant ("t"-value equals .176) that we choose not to base inferences on it. Disposable income appears more influential in the Nerlove model⁵²:

⁵¹ The observations for the years 1941-1946 are treated as additional and their compatibility with the model is tested. For (5.9)

$$F_{6,30} = 2.180.$$

The model with the inclusion of the war dummy appears to describe adequately consumption behavior during the war period.

⁵² It is possible that the failure to isolate convincingly the effect of income may result from multicollinearity between income and the Acrilan price. With postwar data, the pairwise correlation coefficient between the variables is $-.74$, which is not alarmingly high, but the possibility does remain.

Nerlove Consumption Model 1925-1966

$$(5.11) \quad \text{DCAW}_t = 2.273 + .285 \text{DCAW}_{t-1} - .143 \text{FMPC}_t - 1.029 \text{ACRPC}_{t-1} \\ + 1.033 \text{WD}_t - .744 \text{DD}_t + .0318 \text{YTD}_t.$$

$$\bar{R}^2 = .910 \quad \text{DW} = 2.20 \quad F_{6,35} = 59.13 \quad \delta = .715$$

$$p_1 = .44 \quad o_1 = .69 \quad y_1 = .27$$

$$p_s = .31 \quad o_s = .49 \quad y_s = .19$$

$$a = 3.18$$

$$\hat{\text{DCAW}}_{1967} = 1.917 \text{ pounds per capita}^{53}.$$

Table 5.4. Summary Statistics for Models (5.9) and (5.11).

Model	\bar{R}^2	R'^2	U	(U ^m U ^v U ^m)	Misses
(5.9)	.909	.883	.0399	(.001 .048 .951)	11.
(5.11)	.910	.893	.0395	(.000 .041 .959)	9.

The corrected coefficient of determination has risen only slightly, and the augmented model appears to simulate only a little better. The disposable income coefficient does not meet the standard test of statistical significance, but its sign and its implied elasticities are compatible with a priori expectation. Also, the inclusion barely alters any of the conclusions of model (5.9). While there is some indication that the level of disposable income is a determinant of apparel wool usage, its importance remains questionable. Other observers have encountered similar difficulty

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When the change-in-income variable is added to (5.11), the other coefficient values are not altered greatly and its own coefficient is very insignificant. By itself, the change variable is inferior to the level variable.

in capturing the influence of disposable income. Neither Donald, Lowenstein, and Simon nor Witherell has described convincingly the nature or the magnitude of the effect^{54, 55}.

It is possible that the apparel wool specifications are not detailed enough to isolate the effects of disposable income. Such factors as the increase in interior and automobile heating and the increased use of lightweight clothing are probably partly responsible for the secular decline in per capita apparel wool consumption during the postwar period⁵⁶. Once such influences are quantified and accounted for explicitly, the effect of per capita disposable income may appear stronger and more significant.

⁵⁴ Donald, Lowenstein, and Simon, op.cit., pp. 74-81.

⁵⁵ See Witherell, op.cit., pp. 151-155. Witherell's consumption equation, estimated by two-stage least squares, is

$$(5.12) \quad C_t = 419.931 + .897 C_{t-1} - 4.250 P_t + .167 Y_t \\
\begin{matrix} (388.9) & (.228) & (1.176) & (1.105) \end{matrix} \\
+ 9.298(Y_t - Y_{t-1}) - .210 NS_t + 266.329 KWD_t. \\
\begin{matrix} (1.716) & (.15) & (94.4) \end{matrix} \\
R^2 = .85 \quad DW = 2.12 \quad \delta = .121.$$

C_t is net consumption and includes both apparel and carpet wool. The wool price, P_t , is an average world seasonal price and NS_t is the mill consumption of synthetic staple fiber, recorded since 1953. Y_t is the current, deflated income level and KWD_t is a Korean War dummy variable. The variables are not stated in per capita terms and the equation does not include a population variable; thus it is likely that both synthetic consumption and income are picking up some of the population effect. Under such circumstances, one would expect an even stronger income effect. The lack of significance of the income variable, however, may result from multicollinearity between the income variable and the level of synthetic staple mill consumption. Their partial correlation coefficient is over .9; the author is fully aware of this situation.

⁵⁶ See especially, Markham, op.cit., p. 34.

We conclude that the role of income in the consumption of apparel wool is an unsettled question, that the relationship does not appear to be particularly strong and may be a manifestation of multicollinearity, and that usage is probably more sensitive to synthetic staple competition and to population growth than to income.

Again it is necessary to test whether the parameter values have altered over the period 1925-1966. We test the hypothesis that the introduction of synthetic fibers may have altered fundamentally the consumption function of apparel wool. The record is divided into the periods 1925-1956 and 1957-1966 under the assumption that synthetic staple did not begin to displace apparel wool until the mid-1950's. The two forms of the test introduced above are used. For both we cannot reject the null hypothesis of no structural change, so that models (5.9) and (5.10) appear to represent adequately the effects of the competition provided by synthetic staple fiber⁵⁷.

⁵⁷

The results of the covariance analysis for the two procedures are as follows:

- a) For the subperiods 1925-1956 and 1957-1966, versus 1925-1966, the F statistic for model (5.9) is

$$F_{10,26} = .213.$$

- b) When the models are modified to exclude the war and depression years:

$$\text{for (5.9), } F_{4,21} = .214,$$

$$\text{for (5.10), } F_{4,21} = .381,$$

$$\text{for (5.11), } F_{5,19} = .344.$$

5.3.4. Domestic Carpet Wool Consumption

Bergstrom Consumption Model 1937-1966

$$(5.13) \quad DCCW_t = \begin{matrix} (1.37) \\ .346 \end{matrix} + \begin{matrix} (3.9) \\ .433 \end{matrix} DCCW_{t-1} + \begin{matrix} (2.2) \\ .0159 \end{matrix} YTDSM_t - \begin{matrix} (2.0) \\ .150 \end{matrix} BASUM_t \\ - \begin{matrix} (3.1) \\ .0649 \end{matrix} MCSNSM_t - \begin{matrix} (5.7) \\ .485 \end{matrix} WD_t.$$

$$\bar{R}^2 = .70 \quad DW = 2.176 \quad F_{5,24} = 14.549 \quad \delta' = .791 \\ a' = .610$$

$$p_1 = .494 \quad y_1 = 1.19 \quad c_1 = .195$$

$$DCCW_{1967}^A = .5008 \text{ pounds per capita}^{58}.$$

Only the Bergstrom specification is presented. The Nerlove model, with the same explanatory variables, has been estimated, but it performs considerably worse, with many of the coefficients only marginally significant and some with unreasonable signs⁵⁹. The Bergstrom model (5.13) presents a reasonable description of the determinants of consumption behavior, but accounts for only seventy percent of the variation in consumption. The explanatory power of the model is considerably less for carpet wool than for any other fiber⁶⁰.

⁵⁸ Behavior before 1937 is not investigated because of the lack of a reliable, continuous price series. Series extending back before 1937 do exist but since have been discontinued; we have chosen not to extrapolate backward the Buenos Aires series.

⁵⁹ The sign of the own price coefficient is repeatedly negative for different formulations of the Nerlove model. Because of the distinct possibility of simultaneous equation bias in the carpet wool equation, some difficulty had been anticipated.

⁶⁰ We considered three alternative specifications (linear, double-logarithmic, and a stock adjustment model in logarithms), but all met with limited success and had less explanatory power.

The model includes the mill consumption of synthetic staple rather than the staple price as an independent variable⁶¹. Originally, as in the previous fiber equations, the staple price was introduced; however, there was strong evidence of structural change. We introduce and discuss this particular model later in the section. Model (5.13) does not exhibit such structural change, even though it does have other potential problems, which were introduced in Chapter 4.

The coefficient of adjustment is .791, indicating that carpet wool consumption reacts slowly to changes in its economic determinants and reacts even more slowly than apparel wool. This result is consistent with the hypothesis that previously purchased stocks of finished textile products deter consumption of these products, particularly since rug stocks are more durable, on the average, than clothing stocks.

Disposable income appears to be a major determinant of carpet wool consumption (although its importance for apparel wool is questioned). Changes in income have a small initial impact upon consumption since carpet wool usage reacts slowly to its economic determinants, but in the long run, the effect is sizable. The long-run income elasticity, 1.19, is much higher than that of cotton, .37, or apparel wool, .27. This difference in the income elasticities is expected because of the sizable growth of the carpet industry in the last fifteen years, with the introduction of stylistic fashion elements on a large scale. The estimated difference in the income elasticities has precedent, for Donald, Lowenstein, and Simon estimated elasticities of .87 and .34 for carpet and apparel wool⁶².

⁶¹ The difficulties with such a specification have been discussed in Chapter 4, Section 4.3.4.

⁶² Donald, Lowenstein, and Simon, op.cit., p. 81 and p. 88.

The estimated, long-run own price elasticity for carpet wool is .49, which is comparable to the estimate for apparel wool, .43. While there is a difference in the long-run income elasticity between the two classes of wool, this is not the case for the own price elasticity. The reliability of the carpet wool estimate is questionable because of the possible simultaneity resulting from the dependence of the price upon the level of United States consumption. In defense of the single equation specification, it has been argued that wool production is very insensitive to current market conditions so that the supply of wool reacts to current price changes only after a considerable lag⁶³. However, carpet wool can also be supplied from producer stocks and from the stockpiles of countries with wool price stabilization schemes.

The war dummy includes the years 1942-1945 and 1951. The coefficient of the variable is -.485, indicating a large average decrease in autonomous consumption during the war years. In World War II, the decrease was approximately 50% of the prewar level of consumption. Carpet wool is not a military good, and the negative coefficient reflects both a decreased demand and a decrease in fiber imports. The size and the significance of the variable indicates a sharp and distinct drop in consumption which should be analyzed independently of the general model. Tests indicate that the dummy variable adequately isolates such independent behavior⁶⁴.

⁶³ Witherell, op.cit., p. 77.

⁶⁴ A Chow test is used to determine if (5.13) is appropriate for the years 1942-1945, and we cannot reject the hypothesis that it is:

$$F_{4,20} = 1.305.$$

However, for (5.15), introduced later, $F_{4,19} = 3.89$.

The coefficient of the synthetic mill consumption variable is negative, indicating that on the average the two groups of fibers are gross substitutes⁶⁵. The long-run cross elasticity is .195, so that a 10% increase in synthetic staple consumption will lead to an eventual decrease in carpet wool consumption of 1.95%⁶⁶. The elasticity must be interpreted carefully. First it reflects the manner in which carpet wool consumption has decreased in the past in response to an increase in the consumption of a particular mix of synthetic staple fibers. Since the synthetic staple group includes fibers which do not compete with carpet wool, use of the synthetic consumption coefficient for prediction presupposes that the future increase in staple fiber will retain a similar mix of competing and noncompeting fibers. Second, the strength of the competition is understated because a pound of synthetic fiber provides more carpeting than a pound of wool fiber; the Textile Economics Bureau has estimated that a pound of synthetic staple provides the same coverage as two and one-half pounds of wool⁶⁷.

The above results indicate that the consumption behavior of carpet and apparel wool has several differences. The reaction of carpet wool to its normal level is slower. The two fibers experienced opposite movements during the war periods. Also, there is a difference in both the significance and the magnitude of each of the fiber's reactions to a change in the level of disposable income. Such differential behavior justifies an independent investigation of the consumption behavior of each of

⁶⁵ This does not preclude the possibility that individual fibers may complement carpet wool.

⁶⁶ The pairwise correlation coefficient between the level of income and synthetic mill consumption is .765 (the other pairwise correlation coefficients in the model are well below .30), and multicollinearity does not appear to influence the value of the coefficient.

⁶⁷ See Donald, Lowenstein and Simon, op.cit., p. 128.

the two classes of wool fiber. By distinguishing between the classes, we better understand the forces influencing aggregate wool consumption behavior.

Interesting complications arise when model (5.13) is extended to include the price index of synthetic staple fiber instead of the level of mill consumption. Both Nerlove and Bergstrom models are estimated; the former again has a positive own price coefficient and a low Durbin-Watson statistic of 1.58, while the own price coefficient and the estimated constant term of the Bergstrom model are very insignificant. Interestingly, neither model provides a reasonable estimate of future consumption levels: the Bergstrom model predicts a per capita consumption level of .8564 pounds per capita in 1967, requiring approximately a 40% increase in consumption over its 1966 level of .600 pounds per capita; the Nerlove prediction is only slightly better at .7472 pounds per capita. The estimated residuals for both models show a large, systematic upward deviation in recent years, and the 1967 forecasts appear to be a continuation of this tendency.

In recent years consumption behavior may have deviated from its previous pattern, as the structure of the demand function may have altered. The history of carpet wool consumption reinforces this suspicion. Until the early sixties, wool remained the major fiber in the carpet industry, even though both cellulosic and synthetic fiber carpets were being manufactured. Then synthetic carpet sales began to surge. In the early sixties, wool was able to match this growth, but in 1964 wool's sales position began to deteriorate. As early as 1964, industry sources were projecting a sharp upturn in both nylon and acrylic fiber, with no significant growth potential in wool⁶⁸. Since 1964, per

⁶⁸

Peter W. Sherwood, "The Outlook for the New Man-Made Fibers," Modern Textile Magazine, Rayon Publishing Corporation, New York, June, 1965, p. 51.

capita carpet wool consumption has dropped sharply, falling from .779 pounds per capita in 1964 to .600 pounds per capita in 1966.

Even though there are indications of structural change with the altered pace of synthetic competition, its existence is an empirical question. The appropriate Chow tests indicate that, in the models including the synthetic price, we cannot accept the hypothesis of no structural change (at the 5% level)⁶⁹. This strongly indicates that the coefficients estimated over the entire period are averages over different structures, so the models are of limited usefulness.

The original model (5.13) provides reasonable projections of future consumption, and tests indicate that there is no structural break. A possible explanation of the difference between the models is that the synthetic staple mill consumption variable in (5.13) is able to account implicitly for the altered pace of synthetic carpet fiber consumption.

Rather than reject the models including the synthetic price, we amend the specification to account directly for the structural change. Specifically, we argue that the "true" value of the synthetic staple price coefficient has shifted, assuming that the variable proxies other competitive aspects which have become especially effective since 1964⁷⁰. We account explicitly for the price coefficient shift by including a multiplicative dummy

⁶⁹ The record is divided into the periods 1937-1964 and 1965-1966: for the Bergstrom model, $F_{2,22} = 3.974$ and for the Nerlove model, $F_{2,22} = 3.760$.

⁷⁰ Industry sources indicate that man-made fiber producers were beginning to reap the rewards of their large promotional and quality improvement campaigns of the early sixties. See, for example, Lowell P. Weicker, "Record Carpet Sales Expected," in Modern Textile Magazine, op.cit., January 1964, pp. 21-22; Jordan P. Yale, "The Strategy of Nylon's Growth: Create New Markets," Modern Textile Magazine, op.cit., January 1964, pp. 32-33; Peter W. Sherwood, op.cit., pp. 50-51.

variable^{71, 72}. It is emphasized that this attempt to account for the structural change is based upon the specific assumption that the other price coefficient has altered with the introduction of other elements of fiber competition.

Neither the Bergstrom nor the Nerlove amended model produces a very successful description of consumption behavior, since both have a positive own price coefficient⁷³. The Bergstrom

⁷¹ The multiplicative dummy is a zero-one variable, which, when multiplied by the synthetic price, forms an additional variable.

⁷² Alternatively, one could argue that the structural shift occurred in the constant term and that this variable should be altered to account for the additional elements of fiber competition. This is a reasonable, but different, hypothesis, which yields similar results. The record of recent experience is so short that the data cannot distinguish between these two alternatives. In fact, other dummy schemes would probably produce very similar results because such dummies would be highly correlated. The short series also probably precludes the inclusion of more than one multiplicative dummy.

⁷³ The Bergstrom form of the amended model is presented.

Bergstrom Dynamic Model 1937-1966

$$\begin{aligned}
 (5.14) \quad DCCW_t = & \begin{matrix} (.63) & (3.5) & (3.2) & (.07) \\ -.216 & + .374 DCCW_{t-1} & + .0324 YTD SM_t & + .0057 BASUM_t \\ & (3.2) & -1 & (2.7) \\ & -.294 NYSTP_{t-1} SM & -.123 NYSTP_{t-1} SM & * BD_{t-1} \\ & (6.3) & & \\ & -.637 WD_t & & \end{matrix}
 \end{aligned}$$

$$\bar{R}^2 = .74 \quad DW = 2.4 \quad F_{6,23} = 14.6 \quad \delta' = .912$$

$$y_1 = 2.03$$

$$R'^2 = .32 \quad U = .18$$

$$\hat{DCCW}_{1967} = .623 \text{ pounds per capita.}$$

BD_{t-1} is a dummy variable which is equal to zero from 1937-1964, unity in 1965, and two in 1966. The dummy variable is multiplied by the nylon staple price variable to form a new variable.

model has a Durbin-Watson statistic of 2.4, indicating that the results may be unreliable⁷⁴. However, the amended models do produce forecasts of future consumption which are more reasonable than those of their original counterparts, and the residuals for recent periods no longer deviate consistently. While the procedure improves the reasonableness of the model, the specification is not superior to (5.13), especially with respect to the own price coefficient, the plausibility of the 1967 forecasts, and the possibility of serial correlation. However, recent experience may be too short for this procedure to be successful; when more data are accumulated, the latter approach may provide a more informative and more complete description of consumption behavior.

5.3.5. Rayon and Acetate Staple Mill Consumption

We investigate the consumption patterns of the man-made fibers, beginning with rayon and acetate staple. There are two major classes of man-made fiber, rayon-acetate fibers (the cellulose) and the synthetic fibers. The man-made fibers are produced primarily in two forms, staple and filament yarn.

Nerlove Consumption Model 1938-1966

$$(5.15) \quad \text{MCRAS}_t = \overset{(2.3)}{2.125} + \overset{(4.0)}{.621} \text{MCRAS}_{t-1} - \overset{(2.1)}{3.042} \text{RASPC}_t + \overset{(1.3)}{.203} \Delta \text{PCE}_t.$$

$$\bar{R}^2 = .883 \quad F_{3,25} = 62.93 \quad \delta = .379$$

$$p_1 = 1.46 \quad \Delta pc_1 = .086 \quad a = 5.610$$

$$p_s = .554 \quad \Delta pc_s = .033$$

$$\hat{\text{MCRAS}}_{1967} = 4.074 \text{ pounds per capita.}$$

⁷⁴ We have not corrected for possible negative serial correlation because we are not convinced of the usefulness of the model.

Bergstrom Consumption Model 1938-1966

$$(5.16) \quad \text{MCRAS}_t = 2.518 + \begin{matrix} (2.7) \\ \end{matrix} .556 \text{MCRAS}_{t-1} + \begin{matrix} (3.4) \\ \end{matrix} - 1.792 \text{RASPSM}_t + \begin{matrix} (2.5) \\ \end{matrix} \\ + \begin{matrix} (.89) \\ \end{matrix} .097 \Delta \text{PCESM}_t.$$

$$\bar{R}^2 = .884 \quad \text{DW} = 2.081 \quad F_{3,25} = 63.46 \quad \delta' = .571$$

$$p_1 = 1.47 \quad \Delta pc_1 = .067 \quad a' = 5.680$$

$$\hat{\text{MCRAS}}_{1967} = 4.021 \text{ pounds per capita}^{75}.$$

The simulation results for the two models are reported in Table 5.5.

Table 5.5. Simulation Results for Models (5.15) and (5.16).

<u>Model</u>	<u>R²</u>	<u>U</u>	<u>U^m</u>	<u>U^v</u>	<u>U^c</u>	<u>Misses</u>
(5.15)	.889	.0763	.003	.026	.971	11.
(5.16)	.902	.0765	.003	.026	.971	9.

Both the Nerlove model (5.15) and the Bergstrom model (5.16) describe staple mill consumption patterns well and provide almost identical explanations. We do not attempt to differentiate between the specifications, so we discuss their properties together. The overall explanatory power of both models is high, with corrected coefficients of determination of .883 and .884. Both models also simulate well over the period of observation.

⁷⁵

The forecasts for models (5.15) and (5.16) are based on the following figures:

$$\text{MCRAS } 1966 = 4.118, \hat{\text{PCE}} \text{ } 1967 = 22.0, \hat{\text{RASPC}} \text{ } 1967 = .273,$$

$$\hat{\Delta \text{PCE}} \text{ } 1967 = 1.10.$$

The R^2 for both forms is acceptable, but the U statistic is a little high; however, the components of the U statistic reflect no systematic forecast error. The Durbin-Watson statistics are within the acceptable range and are similar; the similarity is somewhat surprising, for near equality is expected only under very special assumptions, but it may be due to the bias implicit in the estimated statistics. Both models have reasonable coefficient estimates.

Neither model adequately explains consumption in 1949 and 1960, since the estimated residuals are large and positive. Observation error appears to be partially responsible for these outliers, arising because the man-made consumption series measures shipments while the model explains usage. There were unusually large discrepancies between shipments and usage in 1949 and 1960, due to the large stock accumulations prior to these years. The presence of the outliers, however, does not hamper seriously the explanatory power of the models.

The reaction coefficients for the two models are $\delta = .397$ and $\delta' = .571$ and indicate that cellulosic staple usage reacts very slowly to changes in economic conditions. The initial reaction of rayon and acetate staple consumption is slower than that of any of the natural fibers, including carpet wool whose $\delta' = .791$.

The long-run price elasticity for both models is almost identical and is greater than unity (approximately 1.46). Even though consumption reacts slowly to changes in the price level (the short-run elasticity is only .55), the eventual response is considerable and is much larger than that for any natural fiber. Since the demand for the fiber is derived in part from that for luxury and fashion items, we expect the price elasticity to be greater than those for the natural fibers, but the estimated elasticity of 1.46 seems high. Actually, the price elasticity is probably not comparable to those of the natural fiber prices, since the man-made fiber price variable likely has more of a tendency than the natural fiber price to proxy other effects besides the

list price; in doing so, the coefficient probably overstates the effect of just the list price. First, the price variable may be accounting for the joint effect of other elements of fiber competition, especially since the list price has had a downward trend over time, while many of these other aspects have increased in importance. Second, the price variable may be accounting for some of the influence of per capita personal consumption expenditures, for when this variable is added to the models, there is indication of multicollinearity: the own price coefficient is very insignificant (and positive) and the pairwise correlation coefficient between the price and the personal consumption expenditure variable is $-.955$. The model may not be able to discriminate between the effects of the own price and per capita consumption expenditure, and the coefficient of either, when entered separately, may represent the combined effect of the variables. Thus the price coefficient proxies other effects and likely overstates the response of mill consumption to a change in the list price.

Income effects are included by introducing the annual change in the level of per capita personal consumption expenditures. Its estimated coefficient is positive, but it is only marginally significant. Its effect is not particularly strong, even in the long run, and is less than the similar response of cotton.

Neither model includes the prices of alternative fibers. Cellulosic staple fiber competes with cotton and wool and commonly is blended with these fibers in apparel and household products. The extent to which staple has replaced the natural fibers is not obvious; by providing softer and stronger blends, cellulosic staple may have created additional outlets for the natural fibers. Attempts to isolate empirically the effect of other fibers upon cellulosic consumption indicate a weak relationship with no conclusive evidence of either gross substitutability or complementarity. Both cotton and the synthetic staple fibers repeatedly appear to be complements of the cellulosic staple, but the other

price coefficients are consistently insignificant, with t-values below unity. Indications of substitutability are found only when carpet and apparel wool prices are introduced, but again, these variables rarely attain even marginal significance. Furthermore, the inclusion of these variables does not alter the implications of models (5.15) and (5.16). Evidence of gross substitutability or complementarity is weak; if there are substitutes, they are more likely wool fibers (especially carpeting), and if there are complements, they are more likely cotton and synthetic staple fiber.

The period of observation begins in 1938 and continues through 1966. Cellulosic staple was first marketed in the early thirties, but only in small volume. By 1938 cellulosic staple fiber was still undergoing a period of experimentation and promotion and was therefore not marketed widely. In the early stages of development, technological innovations and promotion were instrumental determinants of the consumption level, and we exclude these years from the record⁷⁶. The period of observation includes both the Second World War and the Korean War, although we do not include a war dummy variable or make some similar correction. Such corrections should be made only when it appears that special conditions may have temporarily distorted the consumption pattern. Such distortion may not have occurred, since the volume consumed during the Second World War and the Korean War did not deviate greatly from its pre-War pattern and the fiber was not used in large quantities by the military. However, the existence of structural change during the war years is an empirical question, and the appropriate Chow tests are conducted. The tests indicate that the same structure is operative during the entire period,

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Later analysis has indicated that it is possible to continue the observation period back to the early thirties without encountering structural change; the resultant estimates and their implications are similar to those above.

thus supporting the decision to include the war years without special recognition⁷⁷.

5.3.6. Rayon and Acetate Filament Yarn Mill Consumption

Nerlove Dynamic Model 1933-1966

$$(5.17) \quad \text{MCRAF}_t = \overset{(2.5)}{2.661} + \overset{(5.8)}{.688} \text{MCRAF}_{t-1} - \overset{(2.1)}{1.350} \text{RAFPC}_t + \overset{(1.3)}{.147} \Delta \text{YTD}_t \\ - \overset{(2.5)}{.625} \text{NY840}_{t-1}^{-1}$$

$$\bar{R}^2 = .885 \quad F_{4,29} = 55.99 \quad \text{DW} = 2.476 \quad \delta = .312$$

$$R'^2 = .6604$$

$$U = .0537 \quad U^m = .007 \quad U^v = .246 \quad U^c = .747$$

Previously, the dynamic consumption model has been successful in accounting for the autocorrelation often observed in static fiber models. Here the estimated Durbin-Watson statistic, 2.476,

⁷⁷

A Chow test is conducted to test the null hypothesis that the population parameters ruling during the period 1942-1946 are equivalent to those operating over the entire period. The models are estimated over the two separate periods and their performance is compared to models (5.15) and (5.16). For

$$(5.15) \quad F_{4,21} = 1.37, \text{ and for}$$

$$(5.16) \quad F_{4,21} = 1.43.$$

Also tested is the model including the reciprocal of the synthetic price index. It is necessary to employ the Chow test for a limited additional sample. Again, the null hypothesis cannot be rejected:

$$F_{5,19} = .976.$$

indicates the possible presence of negative serial correlation⁷⁸. This suspicion of serial correlation is reinforced by the discrepancy between the variance of the simulated series and of the actual series. This is the second example of poor simulation of the variance when there is some hint of autocorrelation.

When the residuals are negatively autocorrelated, they switch from positive to negative. Such movement may result from measurement error in the dependent variable. The model is specified to explain the use of the fiber, while the data used as the dependent variable are the shipments of the fiber to the mill. The model, in explaining consumption, fails to allow explicitly for the movement of the raw fiber stock component of the shipment data. This movement may impart a negative serial correlation scheme to the residuals. A comparison of the movement of the residuals and the mill stocks may help to determine the importance of this possible source of autocorrelation, but stock data do not exist in a continuous series; some information can be obtained from trade journals, but these report exceptionally large movements rather than the average level of the stocks from year to year. Similar residual behavior has not been observed in the cellulosic staple consumption series, and we cannot explain why filament stocks should misbehave more than staple stocks. A second possible explanation of the implied serial correlation is that the residuals are following the "textile cycle." Model (5.17) may be explaining only the long-run, average trend of consumption and not the short-run, two-to-three year oscillations which may be left in the residuals. The specification may be unable to account for such a phenomenon

⁷⁸

It is interesting that the implied first-order autocorrelation is negative, since positive correlation is typically encountered in economic data; see C. W. J. Granger, "The Typical Spectral Shape of an Economic Variable," Econometrica, Vol. 34, No. 1, January, 1966, pp. 150-161.

because it aggregates over the production and inventory decisions along the production-marketing sequence⁷⁹.

Regardless of the nature of the misspecification, serial correlation in the residuals reduces the usefulness of the estimates. In order to secure a more meaningful explanation, we assume that the residuals follow a first-order Markoff scheme and reestimate the coefficients^{80,81}. The residuals of the transformed model (5.18) appear not to be serially correlated:

Nerlove Consumption Model 1934-1966 AGLS₁

$$(5.18) \quad \text{MCRAF}_t = 3.591 + \begin{matrix} (3.8) \\ .633 \end{matrix} \text{MCRAF}_{t-1} - \begin{matrix} (6.6) \\ 2.077 \end{matrix} \text{RAFPC}_t + \begin{matrix} (3.4) \\ .134 \end{matrix} \Delta \text{YTD}_t + \begin{matrix} (1.5) \\ -.839 \end{matrix} \text{NY840}_{t-1}^{-1}$$

$$\bar{R}^2 = .94 \quad \text{DW} = 2.204 \quad F_{4,28} = 119.3 \quad \delta = .367$$

$$p_1 = 1.47 \quad o_1 = .67 \quad a = 9.77$$

$$p_s = .54 \quad o_s = .25$$

$$R'^2 = .9955$$

$$U = .0473 \quad U^m = .005 \quad U^v = .000 \quad U^c = .995$$

$$\hat{\text{MCRAF}}_{1967} = 3.625 \text{ pounds per capita}^{82}$$

⁷⁹The nature of the textile cycle is studied extensively in Chapter 7 and the cellulosic data are studied specifically. We find that, interestingly, the cellulosic data have slightly more of a tendency to exhibit short cycles than the other fiber categories.

⁸⁰See Johnston, *op.cit.*, p. 194. This process approximates generalized least squares estimation and so is labeled AGLS₁. The subscript 1 denotes that only the first-order autocorrelation coefficient of the residuals is estimated in the transformation procedure. It has not been necessary to reiterate the procedure.

⁸¹Emphasis is placed entirely upon the Nerlove dynamic model; methods exist for dealing with the serial correlation problem in the Bergstrom model; see Houthakker and Taylor, *op.cit.*, pp. 42-52.

⁸²The values used in the projection for 1967 are $\hat{\text{MCRAF}}_{1966} = 3.968$, $\hat{\text{RAFPC}}_{1967} = .6735$, $\hat{\Delta \text{YTD}}_{1967} = .40$, $\hat{\text{NY840}}_{1966}^{-1} = 1.29$.

Models (5.17) and (5.18) are summarized in Table 5.6.

Table 5.6. Summary Statistics for Models (5.17) and (5.18).

Model	\bar{R}^2	DW	R' ²	U	U ^m	U ^v	U ^c	δ	Misses
(5.17)	.885	2.476	.6604	.0537	(.007	.246	.746)	.312	11.
(5.18)	.940	2.204	.9955	.0473	(.005	.000	.995)	.367	10.

The Durbin-Watson statistic for (5.18) is closer to 2.0 and within the acceptable range. Also, the model no longer simulates a systematic bias in the projection variance.

The coefficient of adjustment in (5.18) is .367, suggesting that cellulosic filament consumption reacts slowly to changes in its economic determinants. Filament consumption's reaction is comparable to that of cellulosic staple, with $\delta = .379$, and is slower than any of the natural fibers.

The short-run price elasticity is .54, while the long-run elasticity is 1.47; given a sufficient period of time, the consumption response to a change in the own price is large. Again, the own price coefficient probably overstates the influence of just the list price. First, the filament price index may account for other competitive effects. The price series itself exhibits a general decline which is larger in the initial stages, where technological and educational programs may have had their greatest impact upon consumption behavior. Second, the own price coefficient may account for some of the influence of per capita disposable income upon consumption; when per capita disposable income is introduced into (5.18) there is strong indication of multicollinearity: both the income and the price variable are insignificant and their pairwise correlation coefficient is -.906. The data may not distinguish between income and own price movements so that one may be a proxy for both.

Unlike cellulosic staple consumption, filament yarn activity is influenced significantly by movements in the price of synthetic fiber. The deflated price of nylon, high tenacity tire cord yarn

is included. Synthetic yarn has competed with rayon yarn, especially in the tire cord industry⁸³. As expected, nylon filament yarn is a gross substitute for cellulosic filament. The percentage response is inelastic both in the short run, .25, and in the long run, .67. Cellulosic filament is even more responsive than cotton to the change in synthetic filament price.

We have also tested for the influence of the price of cotton yarn and silk but have not found a significant relationship. Rayon yarn became established before the Second World War by replacing silk and by gaining a large share of the cotton tire cord market⁸⁴. When the price of either cotton or silk yarn is included in (5.18), the estimated relationship is insignificant⁸⁵.

The relationship between cellulosic filament and silk can also be investigated by estimating the effect of the filament price on silk consumption. We estimate a silk equation from 1922-1940. Attempts to extend the period after the Second World War produce insignificant results. This is not surprising, for silk has since become a luxury fiber with a very small market and its consumption is probably best explained by style trends. The prewar equation indicates that silk and cellulosic filament were gross substitutes:

⁸³ Since nylon tires develop "flat spots" if continual pressure is exerted on one area, they have not been used for original equipment. If "flat spotting" is remedied, nylon may tighten its hold on the market even further. Cellulosic tire yarn also will be affected by activity in other synthetic yarns, such as polyester and glass fibers.

⁸⁴ Markham, op.cit., pp. 31-33.

⁸⁵ Because we are dealing with gross, rather than net, substitutability, (or complementarity), it is possible to derive an asymmetric relationship between two particular fibers. In the cotton equation we find that cotton and rayon tire yarn may be gross complements, and in the rayon equation we find evidence of substitutability. The relationships in both the equations are too weak, however, to give meaning to the coefficient signs.

Nerlove Dynamic Model 1922-1940 AGLS₁

$$(5.19) \quad \text{MCSILK}_t = \begin{matrix} (1.45) \\ .0828 \end{matrix} + \begin{matrix} (10.9) \\ .83 \end{matrix} \text{MCSILK}_{t-1} - \begin{matrix} (1.48) \\ .0078 \end{matrix} \text{PCSILK}_t \\ + \begin{matrix} (3.3) \\ .0074 \end{matrix} \text{R150}_{t-1} \quad 86$$

$$\bar{R}^2 = .936 \quad \text{DW} = 2.30 \quad \delta = .17$$

Because of the early competition between cellulosic filament and silk, substitutability is reasonable. The implied but insignificant relationship in the cellulosic equation may be due to misspecification; the inability to isolate the post-war determinants of silk consumption suggests that the silk price coefficient in the cellulosic filament equation may have shifted after the War, so that until such a shift is allowed for, the true price effect is obscured.

The period of observation in model (5.18) is 1933 through 1966. Filament yarn was produced before 1933, but it did not have a large impact upon the United States fiber market until the late twenties⁸⁷. The period of early expansion is excluded to avoid specifying technological determinants. The depression years are also deleted in order to eliminate obvious observation error in the price and possibly in mill consumption data. The record includes the early fifties when synthetic filament yarn was introduced. As in the case of apparel wool and cotton, we ask whether we have represented the competition of synthetic filament adequately or whether its introduction and rapid growth

⁸⁶ The pairwise correlation coefficient between the cellulosic and the silk price is .905; this may be partially responsible for the marginal significance of the silk price coefficient. The income variable is excluded from (5.19); when it is included, it enters with a very insignificant coefficient and hardly alters the magnitude of the other coefficients, so we are not concerned about its absence.

⁸⁷ See Markham, op.cit., p. 14.

may have induced a fundamental shift in the consumption function. We test the hypothesis that the function did not experience structural change over the subperiods 1933-1954 and 1955-1966. The tests do not reject the null hypothesis, indicating a common structure over the observation period⁸⁸.

The observation period also includes both the Second World War and the Korean War, although the model does not allow for special consumption behavior during these periods. The consumption data do not exhibit a sizable increase during either of the war periods, even though cellulosic filament has many industrial uses and was the major tire cord fiber by the early fifties⁸⁹. As in the case of cellulosic staple, we test the advisability of including the World War II years without special recognition, and again, there appears to have been no significant change in the structure during the period⁹⁰.

⁸⁸ Model (5.17) is compared with a similar specification for the periods 1933-1954 and 1955-1966. The estimated F statistic is

$$F_{5,24} = 1.883.$$

⁸⁹ However, nylon tire cord yarn was preferred for military uses, especially for airplane tires.

⁹⁰ The Chow test compares the structures over the two periods, 1933-1966 and 1933-1941, 1947-1966. The estimated F statistic for (5.17) is

$$F_{5,24} = .895,$$

and the null hypothesis cannot be rejected at the 1% level. The Chow test is conducted on the model before it is transformed and reestimated.

5.3.7. Synthetic Staple Mill Consumption

Several alternative specifications of synthetic staple consumption models have been estimated over the period 1949-1965. Two forms of the Bergstrom and Nerlove dynamic models have been used, along with linear and double logarithmic static specifications. The static models have very low explanatory power and exhibit significant first-order autocorrelation (at the five percent level). It was hoped that the static logarithmic first difference model, which accounts for short-run deviations about a growth trend, would indicate the effect of relative prices and income, even if technological forces were largely responsible for the growth trend, but the results are unsatisfactory⁹¹. Only the dynamic models produce encouraging results. Both linear forms, used in the previous five sections, and double logarithmic forms are estimated⁹². The linear forms yield unreasonable elasticities, poor overall explanation, and often produce coefficients of the wrong sign. Also, they are all unstable (the Nerlove reaction coefficient is greater than unity and the Bergstrom coefficient is less than zero)⁹³. This result

⁹¹ Static Consumption Model 1949-1966

$$(5.20) \quad \Delta \text{LMCSTP}_t = \begin{matrix} (2.4) \\ .2014 \end{matrix} - \begin{matrix} (.12) \\ .096 \end{matrix} \Delta \text{LSNSPC}_t + \begin{matrix} (1.4) \\ 3.47 \end{matrix} \Delta \text{LPCE}_t.$$

$$\bar{R}^2 = .126 \quad \text{DW} = .96.$$

⁹² For a discussion of the properties of the double logarithmic dynamic consumption functions, see Marc Nerlove, "Distributed Lags and Estimation of Long-Run Supply and Demand Elasticities: Theoretical Considerations," Journal of Farm Economics, Vol. XL, No. 2, May, 1958, pp. 304-306.

⁹³ The models may have the further problem of multicollinearity because the coefficient values are difficult to interpret and the regressors are highly correlated.

prompted the investigation of the logarithmic forms of the dynamic model, which allow for the technologically and economically oriented growth rate in the background. The logarithmic version of the Nerlove model is stable and provides the only encouraging results in the estimation of synthetic fiber equations.

Nerlove Dynamic Model 1949-1965

$$(5.21) \quad \text{LMCSTP}_t = - \overset{(3.4)}{11.13} + \overset{(6.7)}{.50} \text{LMCSTP}_{t-1} - \overset{(1.01)}{.47} \text{LSNSPC}_t + \overset{(3.5)}{4.0} \text{LPCE}_t \\ + \overset{(1.9)}{.21} \text{LBA}_{t-1}. \quad \bar{R}^2 = .99 \quad \text{DW} = 2.84$$

The coefficient estimates have the expected signs and the model is stable; however, there are several difficulties with the specification. There are indications of multicollinearity: the high coefficient of determination, the marginal significance of the own price coefficient, and high pairwise correlation coefficients between the logarithms of lagged fiber consumption, synthetic staple price, and aggregate personal consumption expenditure. Also, the estimated Durbin-Watson statistic, 2.84, lies outside the "acceptable" range⁹⁴.

In an attempt to avoid possible autocorrelation, model (5.21) is transformed as above, and the parameters are re-estimated:

⁹⁴ The "acceptable" range applies to models estimated with thirty to forty observations rather than just sixteen, so perhaps it should be expanded in this case.

Nerlove Dynamic Model 1950-1965 AGLS₁

$$(5.22) \quad \text{LMCSTP}_t = - \overset{(3.8)}{8.642} + \overset{(10.2)}{.490} \text{LMCSTP}_{t-1} - \overset{(2.4)}{.823} \text{LSNSPC}_t \\ + \overset{(4.1)}{3.166} \text{LPCE}_t + \overset{(1.43)}{.111} \text{LBA}_{t-1}.$$

$$\bar{R}^2 = .994 \quad \text{DW} = 2.65 \quad \delta = .510$$

$$p_1 = 1.61 \quad pc_1 = 6.22 \quad o_1 = .22$$

$$p_s = .82 \quad pc_s = 3.16 \quad o_s = .11$$

$$R'^2 = .942 \quad U = .0340 \quad U^m = .04 \quad U^v = .17 \quad U^c = .79$$

$$\hat{\text{LMCSTP}}_{1966} = 1.713 \text{ pounds per capita,}$$

$$\hat{\text{MCSTP}}_{1966} = 5.54 \text{ pounds per capita.}$$

The Durbin-Watson statistic, 2.65, still lies outside of the acceptable range, although it is lower than that of the original model. The simulation results further indicate that autocorrelation is present in (5.22), for there is a systematic discrepancy between the variance of the actual series and that of the simulated series, a discrepancy which has been observed in other consumption models where autocorrelation is indicated. (Serial correlation and the simulation difficulty may not be the same problem, for when the own price variable is deleted, the Durbin-Watson statistic drops to 2.27 from 2.65, but the variance component of Thiel's inequality coefficient is reduced only to .14, from .17.) Because autocorrelation still may be present, model (5.22) is transformed again, and the parameters are estimated; however, the new model is rejected because the Durbin-Watson statistic increases. Thus we adopt (5.22), but we interpret its coefficients carefully, for there is indication of autocorrelation.

The model indicates that economic forces have affected the growth of synthetic staple consumption; both the aggregate personal consumption expenditure and the synthetic staple price index have a strong, significant effect⁹⁵. The short-run and the long-run income elasticities are greater than unity. The long-run income elasticity, 6.22, is greater than that for either the natural fibers or the rayon-acetate fibers. A high income elasticity is expected for the synthetic fibers, which have created markets for new products and introduced additional stylistic competition, especially in carpeting. But the income coefficient may be acting partially as a proxy for other factors such as quality improvement and successful promotion, suggesting that the income effect may be disguised and less elastic. The own price elasticity is inelastic in the short run, but is elastic in the long run, 1.61. Because of the gradual decrease in the synthetic price variable, it may proxy other elements of the price vector, so again the price coefficient may not represent the effects of just the list price.

The Buenos Aires price coefficient of carpet wool has a positive sign, indicating the gross substitutability evidenced earlier in the carpet wool equation. The long-run relationship is inelastic, .22. Attempts to introduce the prices of cotton, apparel wool, and cellulosic staple fiber are not so successful.

The coefficient of adjustment is .510, which is lower than those of the natural fibers and is comparable to that for the other man-made staple category. The constant term is extremely

⁹⁵

This is a significant result in itself and is contrary to the assertions of others. See, for example, W. Witherell, op.cit., p. 145; and Alan Powell and Metodey Polasek, "Wool Versus Synthetics: An International Review of Innovation in the Fiber Market," Australian Economic Papers, Vol. III, June-December, 1964, pp. 49-64.

small and lies outside the observed range of values for the dependent variable. Although its value is small, its contribution is significant. Finally, the model does not allow for possible special behavior during the Korean War. Synthetic staple consumption does not appear to have been affected appreciably, although a specific test of possible structural change has not been conducted.

5.3.8. Synthetic Filament Yarn Mill Consumption

Economic determinants of the consumption of synthetic filament yarn are not so influential as they are in the case of synthetic staple. Several different specifications of the consumption functions are estimated. The static models have low explanatory power and serious autocorrelation problems, while the linear dynamic models are unstable. Again, the dynamic logarithmic specification is the most successful, but it does not isolate reasonable price effects for either the own synthetic price or for the price of other fibers. The own price coefficients are consistently positive, although insignificant, and the other price coefficients are also insignificant. The failure to isolate own price effects is disturbing and may be due either to multicollinearity or to misrepresentation by the price variable. The own price variable is highly correlated with the level of per capita disposable income, so that the data may be unable to isolate its individual effect. Alternatively, the particular price variable used may misrepresent the average movement of filament prices. For example, the price of high tenacity, tire cord fiber is used to represent the price of both high tenacity and regular tenacity yarn. If the tire cord price does not proxy regular tenacity prices, the price variable may not isolate the price effects. The yarn consumption data may be disaggregated into their high tenacity and regular tenacity components in order to increase the representativeness of the price variables. The disaggregation,

however, does not correct the own price difficulty, so we return to an aggregate model. In the model, the own price is excluded; its inclusion produces an insignificant coefficient and does not alter the other coefficient values, so we conclude that its effect is weak or indeterminate and that its inclusion is non-essential. The consumption function for the combined regular and high tenacity synthetic filament yarn has the form:

Nerlove Consumption Model 1947-1965

$$(5.23) \quad \text{LMCSNF}_t = -4.17 + \overset{(2.6)}{.73} \text{LMCSNF}_{t-1} + \overset{(2.7)}{1.53} \text{LYTD}_t.$$

$$\bar{R}^2 = .99 \quad \text{DW} = 2.17 \quad \delta = .27$$

$$y_l = 5.7$$

$$y_s = 1.5$$

$$R'^2 = .951 \quad U = .057 \quad U^m = .463 \quad U^v = .038 \quad U^c = .499$$

$$\hat{\text{LMCSNF}}_{1966} = 1.7474 \text{ pounds per capita,}$$

$$\hat{\text{MCSNF}}_{1966} = 5.74 \text{ pounds per capita.}$$

The estimated coefficients are all significant and have the expected signs. The coefficient of adjustment, .27, is much lower than that of synthetic staple, but is comparable to that estimated for rayon-acetate filament yarn, .37. Both the short-run and the long-run income elasticities are greater than unity, suggesting that a large impact occurs even in the short run. The long-run income elasticity, 5.7, indicates a strong income effect. The simulation experience is unique, with a systematic bias in the mean value of the simulated series. The residuals between the actual and the simulated series illustrate a tendency to simulate high. In the previous discussion of the properties of the projectors, the existence of a bias was noted. Interestingly, such strong indications of a bias are experienced only here, but this does not preclude

the existence of sizable bias in the consumption projections for the other fibers⁹⁶. In conclusion, the model is not so satisfactory as that for synthetic staple, since it does not isolate own and other price movements. It does provide some insight into the consumption process, indicating a large, although slow, response of consumption to the level of disposable income.

In future research, we plan to use a different approach to study synthetic fiber consumption. Rather than develop models to explain the growth process and to isolate the impact of various determinants, we describe the historical pattern of the growth process. Specifically, we fit a logistic trend to time series of the staple and the filament yarn consumed in their various end uses; this enables a systematic description of the product areas in which synthetic fiber made its initial inroads, where it has grown the fastest, and where it is likely to grow in the future in the absence of major technological change. We also test rigorously whether there is significant difference between the growth pattern in the different end use categories. The results will provide a concise description of

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Such a discrepancy between the means of the simulated and the actual consumption series is also evidenced in one of the cotton consumption equations. The equation includes as the other price the actual level of synthetic staple price, proxied by a high, constant price during the prewar period. The indication of bias here, however, is not so strong as it is above.

the growth pattern of synthetic fiber over the textile products industries⁹⁷.

5.4. Forecasts of Future Fiber Consumption

The ability of a model to predict behavior is a crucial test of its effectiveness. Since the evaluation of the forecasts requires the collection of additional, unavailable observations, only a few comments can be made about the accuracy of the predictions. The forecasts also provide additional insights into consumption movements, summarizing certain implications of the model in a concise and easily understandable form. Two sets of forecasts are examined here. The first predicts consumption in the year immediately following the period of observation: 1967 for the natural and the cellulosic fibers and 1966 for the synthetic fibers. These predictions are presented in Table 5.7. The second set projects consumption for each of the five years beyond the period of observation.

⁹⁷

Others have used the logistic trend to describe environments involved in technological change. (See Zvi Griliches, "Hybrid Corn: An Exploration in the Economics of Technological Change," Econometrica, Vol. 25, No. 4, October, 1957, pp. 501-522; Gerhard Tintner, Econometrics (John Wiley and Sons, Inc., New York, 1952) pp. 208-211; Polasek and Powell, op.cit., pp. 49-64; Metodey Polasek, Alan Powell, and Harry T. Burley, "Synthetic Fibers in the Wool Textile Industry: A Study of the Role of Price in Technological Adjustment," Australian Journal of Agricultural Economics, Vol. 7, December, 1963, pp. 107-120). A priori, the logistic trend may be expected to fit the data in such circumstances, but there is no reason why other trends could not be fitted; that is, there is no real significance to be placed on the result that one trend line fits better than another trend line.

Table 5.7. Short-Run Consumption Forecasts.

	Estimated Consumption Level 1967	Actual Consumption Level 1966	Estimated Change in Consumption Level 1967-1966	Estimated Change as Percentage of 1966
<u>Natural Fibers</u>				
Cotton (5.3)	23.661	25.10	-1.34	- 5.34%
(5.4)	23.862		-1.24	- 4.94%
Apparel				
Wool (5.9)	1.835	1.940	- .105	- 5.42%
(5.10)	1.883		- .057	- 2.70%
(5.11)	1.917		- .023	- 1.20%
Carpet				
Wool (5.13)	.501	.600	- .99	-16.50%
(5.14)	.623		+ .02	
<u>Man-Made Fibers</u>				
Cellulosic				
Staple (5.15)	4.074	4.118	- .004	- .10%
(5.16)	4.021		- .097	
Cellulosic Filament				
Yarn (5.18)	3.625	3.968	- .343	- 8.65%
	Estimated 1966	Actual 1965	Estimated Change 1966-1965	Change as Percentage of 1965
Synthetic				
Staple (5.22)	5.540	3.905	+1.635	+42.0%
Synthetic Filament				
Yarn (5.23)	5.740	4.768	.972	+20.4%

The one year predictions are constructed from the estimated consumption functions, using either the actual values of the independent variables (if known) or the predicted values. The values of the independent variables were determined in early 1968, so that the 1967 and some of the 1966 values are approximated. Preliminary data were available to indicate the direction of change of the independent variables. More recently issued preliminary data indicate that the independent variable estimates have the correct signs and reasonable magnitudes.

The short-run forecasts project a decline in the consumption of the natural and rayon-acetate fibers in 1967 and an increase in synthetic consumption in 1966. The projected domestic consumption level for cotton, using model (5.3), is 23.66 pounds per capita, or a 5.3% decrease from its 1966 level of 25.10 pounds per capita. The projected mill consumption level is even lower because the raw cotton content of imports is larger than that of exports; with preliminary 1967 import and export figures, predicted mill consumption is 22.32 pounds per capita, or a decrease of 5.15% from the 1966 level of 23.54 pounds per capita. The predictions account for the elimination of the equalization payment in the own price variable. The forecasts do not recognize explicitly the large increase in 1967 Vietnam expenditures to almost 4% of total cotton consumption⁹⁸. (The military expenditures still are not sizable when compared to those in previous war periods.) The predicted decline in 1967 conforms to the preliminary reports of the Department of Agriculture, which indicate a decline of 4.2%⁹⁹. Because of the

⁹⁸ United States Department of Agriculture, Cotton Situation, Economic Research Service, Washington, D.C., bimonthly, May, 1967, pp. 14-17.

⁹⁹ United States Department of Agriculture, Cotton Situation, op.cit., July, 1967, and December, 1968.

distinct possibility of observation error, this preliminary estimate is regarded as only very approximate. The estimate is in the same direction but is slightly less severe than the forecast of model (5.3). It is encouraging that the model is able to predict the apparent decrease in consumption which follows three years of increases.

Both apparel wool models (5.9) and (5.10) predict a downturn in 1967, with the Nerlove model indicating a slightly sharper decline. The Nerlove model predicts a 1967 domestic consumption level of 1.835 pounds per capita, or using preliminary export and import data, a per capita mill consumption level of 1.313 pounds per capita, which represents a 3% decrease from the 1966 level of 1.345 pounds per capita. Again, the projection does not explicitly recognize Vietnam usage, which has increased 50% over the 1966 level¹⁰⁰. The Department of Agriculture has issued preliminary 1967 mill consumption data for apparel wool, which indicate a drop in consumption possibly as large as 14% of the 1966 level¹⁰¹. This is much greater than the 3% decrease predicted by our models¹⁰².

The predicted level of carpet wool domestic consumption, using (5.13), is .501 pounds per capita, or 16.5% below the 1966 level of .600 pounds per capita. This sizable decrease follows the trend of the last few years. The projected mill consumption level, based upon preliminary export and import data, is .462 pounds per capita, a 12.3% decrease from the 1966 level.

¹⁰⁰ United States Department of Agriculture, Cotton Situation, op.cit., May, 1967, pp. 14-17.

¹⁰¹ United States Department of Agriculture, Wool Situation, Economic Research Service, Washington, D.C., quarterly, October, 1967, and February, 1968.

¹⁰² Model (5.11) which includes the income variable explicitly projects a slightly smaller decrease in mill consumption.

Preliminary reports of the Department of Agriculture indicate a decrease in 1967 in carpet wool mill consumption of perhaps 19%¹⁰³. The carpet wool projections are comparable to the Department's preliminary reports, and the models may have predicted carpet wool consumption better than apparel wool consumption.

The rayon-acetate staple model (5.15) projects a very slight downturn in 1967. Preliminary reports indicate that rayon and acetate staple consumption has declined from its 1966 level, even though it began to rise in late 1967¹⁰⁴. Further evidence of a decline is presented by the Department of Agriculture, which indicates that cellulosic staple consumed on the cotton spinning system (accounting for about 50% of the fiber consumed) has declined approximately 10%.

The 1967 prediction of cellulosic filament yarn consumption, using model (5.18), is 3.652 pounds per capita, which is a decline of 8.65% from the 1966 level of 3.968 pounds per capita. This large decline amplifies the gradual downturn of 1966; the decline is even larger than that for apparel wool consumption. Preliminary data are not available to assess the accuracy of the projection.

The one year projections for the synthetic staple and filament yarn consumption levels are for the year 1966. The estimated mill consumption for synthetic staple is 5.54 pounds per capita, which represents approximately a 40% increase over the 1965 level. Based upon preliminary data of the synthetic staple consumed on the cotton spinning system, the estimated increase in consumption is only 16%¹⁰⁵. The projection seems

103

Ibid.

104

United States Department of Agriculture, Cotton Situation, op.cit., July, 1967.

105

United States Department of Agriculture, Cotton Situation, op.cit., July, 1967.

high, which reinforces previously expressed reservations about the explanatory ability of the staple model. The synthetic filament projection conforms better to ex post experience. The predicted mill consumption level is 5.74 pounds per capita, which represents a 20% increase in consumption over 1965. Preliminary data indicate that the 1966 level was slightly lower, at 5.50 pounds per capita¹⁰⁶. Both models predict a continued increase in synthetic mill consumption, but the synthetic staple model does not behave as satisfactorily as the filament yarn model.

The short-run forecasts, in summary, indicate a downturn in fiber consumption in 1967 for both the natural and the rayon-acetate fibers. Carpet wool consumption is predicted to experience the greatest decline, followed by cellulosic filament, apparel wool, cotton, and then cellulosic staple. According to preliminary reports, the forecasts project correctly the direction but not always the magnitude of the change. This is especially true for apparel wool, with its small predicted decline. The short-run forecasts for synthetic fibers indicate a consumption increase in 1966 (when all other fibers but cellulosic filament and carpet wool increased). The projection for synthetic filament yarn consumption is more reasonable than that for synthetic staple. Later we present estimates for the 1967 synthetic consumption levels which indicate a further increase in synthetic consumption; this increase is opposite to the downturn in the natural and rayon-acetate fibers but is supported by sparse preliminary data. Thus, the fiber consumption models suggest a continued increase in both synthetic staple and filament yarn consumption during 1966 and 1967, with a decline in natural and cellulosic fiber consumption during 1967.

¹⁰⁶ Ibid., July 1967.

A second set of forecasts predicts the consumption level for each of the five years beyond the period of estimation¹⁰⁷. The projection procedure is similar to the simulation procedure. The predicted fiber consumption level in the first period beyond the estimation record is based on the actual consumption level during the previous period; the subsequent fiber consumption levels are based on the predicted level in the previous period. The predictions also use the values of the current or lagged exogenous variables for each of the future periods. Because these future values are typically unknown, it is necessary to predict or to assign them. In order to generate the exogenous variables, we fit a linear trend to each of the variables over the last ten years and then project these trends over the next five years. The exogenous variable projections indicate how these variables would behave if their average trends over the last ten years were to continue over the next five. Forecasts based on other assumptions about the behavior of the exogenous variables could be devised.

The projections for the individual fibers are presented in the figures and the tables below. The figures illustrate the actual consumption levels recorded during the period of estimation and the projected levels for the future five years. The actual levels are represented by "X"'s; the projected levels, by "N" or "B", referring to the Nerlove or the Bergstrom model. The tables record both the predicted levels and the predicted market shares; the 1966 levels are the actual values, while the 1967-1970 values are predicted by the models¹⁰⁸. Tables 5.8 and 5.9 present numbers for only the four major classifications of

¹⁰⁷ For the natural and rayon-acetate fibers, the projection period is 1967-1971; for the synthetic fibers, the period is 1966-1970.

¹⁰⁸ We predict synthetic fiber consumption for 1967-1970, using a preliminary value as the "actual" 1966 value.

fiber: cotton, wool, cellulosic, and synthetic, but a supplementary table is presented to indicate the relative shares of subdivisions in the last three major categories¹⁰⁹.

Cotton consumption is predicted to decline in 1967 but then to rise through 1971, resuming the upward trend of the middle sixties. The increase in the second half of the sixties, however, is predicted to be more gradual than that of the first half. Even though there is a predicted increase in per capita consumption, the projected market share of cotton drops from 53.2% in 1967 to 48.3% by 1970¹¹⁰.

Figure 5.3 indicates that carpet wool consumption will decline between 1967 and 1971 and decline more rapidly after 1969. Apparel wool consumption is also predicted to decline (see Figure 5.2), but the decline will tend to level off. Thus total wool consumption is predicted to decline as seen in Table 5.8. The predicted market share of aggregate wool also declines, from 4.2% in 1967 to 3.4% in 1970. Table 5.10 indicates that the decrease in the market share will be sharper for carpet wool consumption than for apparel wool consumption. Summarizing, the predictions imply that the 1967 downturn may not be just a

¹⁰⁹

The tables are presented in terms of mill consumption, but the cotton, apparel wool, and carpet wool projections are in terms of domestic consumption. Mill consumption figures are used so that the per capita consumption of the natural fibers and of the man-made fibers can be compared and market shares computed. To convert the natural fibers' domestic consumption projections into mill consumption figures, the 1967 ratio between domestic and mill consumption is assumed to continue through 1970. The use of the 1967 ratio represents a potential source of inaccuracy if the upward trend in imports over exports continues. The distortion should be small, however, especially over a four year period.

¹¹⁰

The pattern of the exogenous variables used in the prediction is as follows: the own price decreases by 15% from its 1967 level; the synthetic staple price index, 10.9%; and the level of personal disposable income increases by 8.85%.

Figure 5.1. Actual and Projected Domestic Cotton Consumption, 1962-1971.

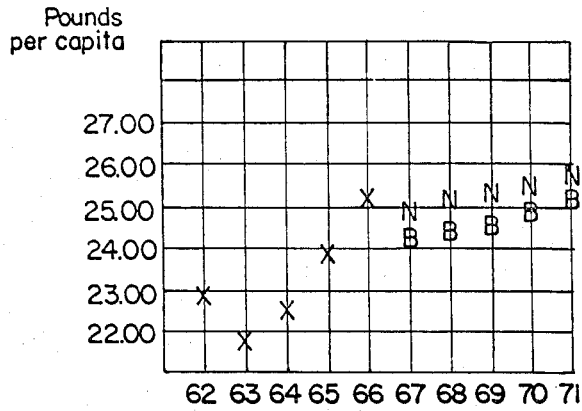


Figure 5.2. Actual and Projected Domestic Apparel Wool Consumption, 1962-1971.

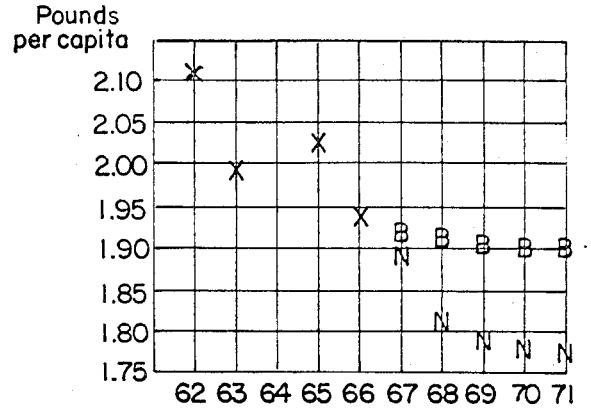


Figure 5.3. Actual and Projected Domestic Carpet Wool Consumption, 1962-1971.

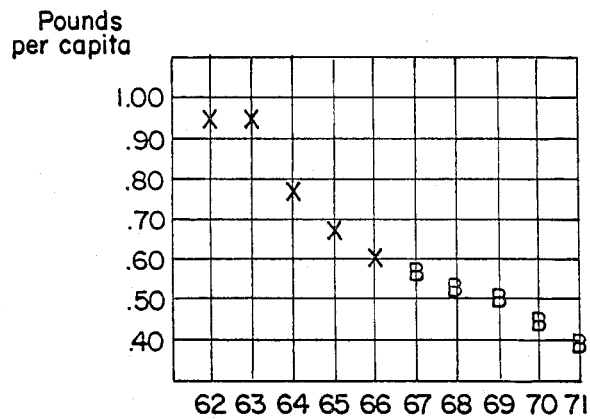


Figure 5.4. Actual and Projected Cellulosic Staple Mill Consumption, 1962-1971.

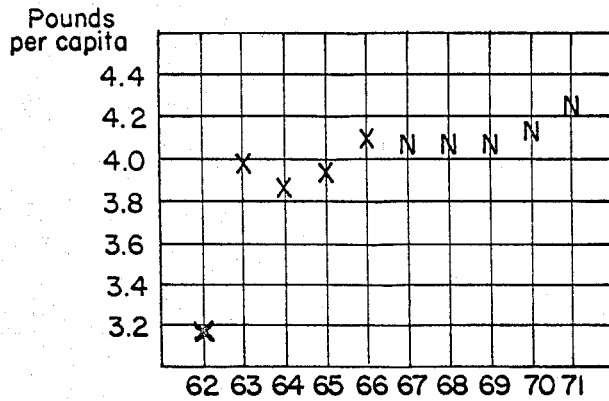


Figure 5.5. Actual and Projected Cellulosic Filament Yarn Mill Consumption, 1962-1971.

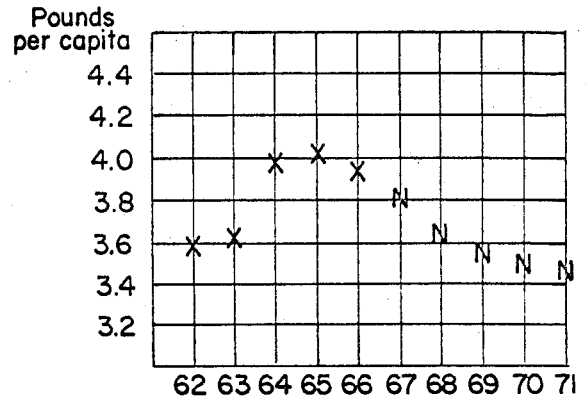


Figure 5.6. Actual and Projected Non-Cellulosic Staple Mill Consumption, 1962-1970.

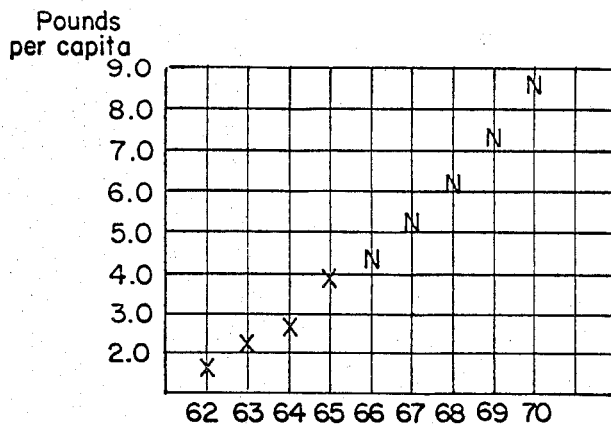


Figure 5.7. Actual and Projected Non-Cellulosic Filament Yarn Mill Consumption, 1962-1970.

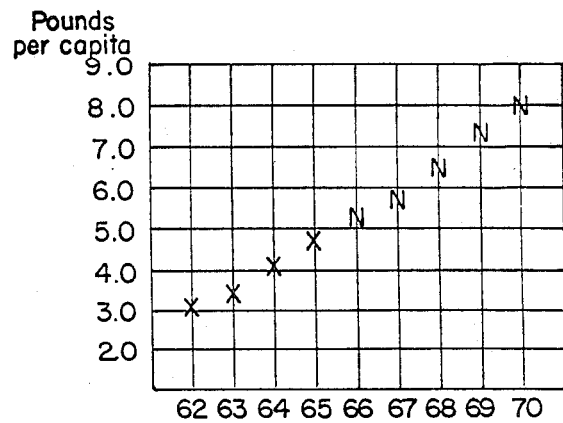


Table 5.8. Projected Per Capita Mill Consumption by Fiber Category.

	<u>1966^a</u>	<u>1967</u>	<u>1968</u>	<u>1969</u>	<u>1970</u>
Cotton	23.54	23.46	23.62	23.84	24.36
Wool	1.88	1.87	1.81	1.75	1.69
Cellulosic	8.09	7.85	7.73	7.67	7.65
Non-Cellulosic	10.03	10.97	12.57	14.50	16.78
Total Fiber Consumption	43.54	44.15	45.73	47.76	50.45

a. Actual levels, based on preliminary data.

Table 5.9. Market Shares: Projected Percentage of Total Fiber Consumption Attributable to Each Fiber.

	<u>1966^a</u>	<u>1967</u>	<u>1968</u>	<u>1969</u>	<u>1970</u>
Cotton	54.10	53.15	51.60	49.99	48.25
Wool	4.32	4.23	3.97	3.65	3.35
Cellulosic	18.54	17.77	16.90	16.06	15.16
Non-Cellulosic	23.04	24.85	27.45	30.40	33.30

a. Actual levels, based on preliminary data.

Table 5.10. The Projected Relative Shares of Apparel and Carpet Wool and Man-Made Staple and Filament Yarn.

	<u>1966^a</u>	<u>1967</u>	<u>1968</u>	<u>1969</u>	<u>1970</u>
<u>Apparel Wool</u>	72.1	71.3	72.3	73.7	75.5
Total Wool					
<u>Cellulosic Staple</u>	51.0	51.8	52.6	53.4	54.2
Total Cellulosic					
<u>Non-Cellulosic Staple</u>	45.1	46.8	48.9	50.4	52.3
Total Non-Cellulosic					

a. Actual levels, based on preliminary data.

temporary phenomenon and may continue through the latter half of the sixties. It should be mentioned that the projections are based on a slightly increasing apparel wool price and a very slowly decreasing carpet wool price, so that if the prices adjust radically downward, as they appear now to be doing, the decline should be less severe^{111,112}. On the other hand, since the projections are based on average trends over the last ten years and since the sharp downturn in carpet wool consumption has occurred only recently, the wool decline may be understated.

The projections of cellulosic staple consumption indicate a slight decline followed by a gradual increase. The consumption of cellulosic filament yarn decreases through 1971, leveling off in the early seventies. The total consumption of cellulosic fiber decreases gradually over the four year period, with the eventual increase in staple almost offsetting the decrease in filament yarn. The predicted share of cellulosic fiber also declines gradually through 1970, from 17.8% in 1967 to 15.2% in 1970, with staple increasing relative to filament yarn and commanding 54% of the cellulosic market. Thus, while total consumption of rayon-acetate fiber is predicted to decline gradually, cellulosic staple appears to have more growth potential than filament yarn¹¹³.

¹¹¹ This assumes, of course, that the synthetic price decreases have not been underestimated.

¹¹² The projected exogenous variables for the apparel wool consumption prediction represent a 3.38% increase in the own price and a 2.29% decrease in the deflated price of Acrilan. The projections likely underestimate the fall in the synthetic price and a possible fall in the own price. The projected decrease in the carpet wool price is 2.09% and the projected increase in synthetic staple mill consumption is 37.2%. Again, these may be too small.

¹¹³ For the cellulosic predictions, cellulosic staple price decreases by 7.52%, filament yarn price decreases by 4.0%, and the deflated level of nylon tire cord yarn price decreases by 14.4%. The latter decrease may be a little high, which would lead to a less sharp decline in cellulosic filament.

The estimated per capita consumption levels for the synthetic fibers increase continuously through 1970, with synthetic staple consumption rising more rapidly and to a higher level than synthetic filament yarn consumption. The market share of the combined levels of staple and filament yarn consumption is predicted to rise from 24.9% in 1967 to 33.3% in 1970, with staple climbing from 47% to 52% of synthetic's market share¹¹⁴. The predictions may overstate the growth potential of the synthetic fibers if past consumption increases are based upon technological advances which are not continued in the future. For the next few years the overstatement should be small, but this possibility should be recognized for longer-run projections.

To summarize the above projections, the market shares of the natural fibers and of the man-made cellulose are all predicted to decline through 1970. Even though the level of cotton consumption is predicted to increase slightly, its market share is expected to decline and finally to fall below 50%. The level of total wool consumption and wool's market share are predicted to decrease, with the market share declining by 21%. The decline in wool consumption could be somewhat lessened by a sharp drop in the price of wool. Both the consumption level and the market share of rayon-acetate fiber are predicted to decrease, but only gradually, since cellulosic staple consumption begins to climb in the late sixties. The consumption of synthetic fibers has the greatest growth potential in the late sixties and early seventies; it is predicted to rise throughout the period, with a market share rising from 25% to 33% by 1970.

¹¹⁴

The projections of synthetic staple no longer appear inflated as they did in the one year predictions above.

The projections are based on specific assumptions about the behavior of the exogenous variables, indicating the consumption response if exogenous conditions continue to trend as they have in the past ten years. The projections possibly understate the decline in carpet wool consumption and overstate the increase in synthetic consumption for the more distant future.

CHAPTER 6

AN OVERVIEW OF THE FIBER CONSUMPTION MODELS

6.1. Introduction

We put the estimates of the previous chapter in a broader framework, summarizing the results and evaluating the overall success of the dynamic models. In Section 6.2, the regression estimates for the different fiber consumption models are summarized. Some clearly recognizable and interesting patterns emerge. In Section 6.3, we summarize the ability of both the Nerlove and the Bergstrom dynamic models to explain consumption behavior, to account for serial correlation, and to simulate over the period of observation. In Section 6.4, we discuss the existence of structural change in the parameters of the different fiber models.

6.2. Comparison of the Fiber Equation Estimates

The estimated models indicate that economic factors are important determinants of fiber consumption. Changes in these factors do not necessarily alter usage immediately, due to psychological, institutional, and technological rigidities in consumption behavior, but their eventual influence can be very sizable. Economic factors are important determinants even for the synthetic fibers, although their effects are not so convincing as for other fibers. The most powerful economic determinants are per capita disposable income and the own price. One important exception is the inability of income to explain variation in apparel wool usage. A third determinant is the price of various synthetic fibers, which affects the consumption of the three natural fibers and the rayon-acetate fibers. This dependence likely reflects both economic and technological factors. Interfiber competition is not so important between the cellulosic fibers and the natural fibers or between the

various classes of natural fibers. In fact the prices of alternative fibers generally are not so important as originally thought.

While economic factors affect fiber consumption, there are significant and interesting differences in their impact and importance. These differences are most noticeable between the man-made fibers and the two natural fibers, apparel wool and cotton; the remaining natural fiber, carpet wool, lies inbetween. First, the impact of economic factors is slower for the man-made fibers than for either apparel wool or cotton, so that technological and habitual rigidities appear to be more stringent for the man-made fibers. Second, the eventual effect of a change in the level of both per capita disposable income and the own fiber price is much more sizable for the man-made fibers. Both the disposable income and the own price elasticities are greater than unity for the man-made fibers and are less than unity for apparel wool and cotton (although the income elasticities for cellulosic fiber consumption are only tentative). However, the man-made own price coefficients are not strictly comparable to the natural fiber price coefficients, since the man-made fiber prices may proxy promotional and technological developments, and, in the case of cellulosic fiber, cannot be distinguished from per capita disposable income because of multicollinearity problems. Interesting differences also appear between the two classes of wool, apparel and carpet, and between man-made staple and filament yarn fiber. Thus it is useful to distinguish between different classes of fiber; this reinforces the earlier decision to disaggregate.

The coefficients of the individual fiber equations are presented in Table 6.1. The starred equations in each fiber category are those that provide the best overall description; the other equations are included for supplementary information. The first of five major divisions in the table contains the coefficients of adjustment, δ for the Nerlove model and δ' for the Bergstrom model. The second and third divisions present the

TABLE 6.1. FIBER CONSUMPTION COEFFICIENT ESTIMATES.^a

	δ_N	δ'_B	Y_L	Y_S	P_L	P_S	Other Fiber Price	O_L	O_S	Other Mill Consump- tion	C_L	C_S	WD_t	DD_t	WD as % of 1940	DD as % of 1930	
Natural Fibers																	
Cotton (5.3)*	.786		.365	.287	.17	.13	Synthetic Staple	.48	.37				5.30	-4.32	18%	16%	
(5.4)		1.685			.17		Index Synthetic Staple Index						5.97	-4.93			
Apparel Wool (5.9)*	.651				.44	.29	Acrylican	.54	.35				1.08	-.80	42%	35%	
(5.10)*		1.328			.54		Acrylican	.60					1.00	-.80			
(5.11)	.715		.27	.19	.44	.31	Acrylican	.69	.49				1.03	-.74			
Carpet Wool (5.13)*		.791	1.19		.49					Synthetic Staple							
(5.14)		.912	2.03								.195						
Man-Made Fibers																	
Cellulosic Staple (5.15)*	.379				1.46	.55											
(5.16)		.571			1.47												
Cellulosic Filament Yarn (5.17)	.312				1.47	.54	Nylon High Tenacity	.67	.25								
(5.18)*	.367						Carpet Wool	.22	.11								
Non-cellulosic Staple (5.22)*	.510		6.22	3.16	1.61	.82											
Non-cellulosic Filament Yarn (5.23)*	.270		5.70	1.50													

^aThe standard errors of the estimates are not presented, but it is important to note that the entries are statistics.

income elasticities and the own price elasticities. The fourth division contains the cross price elasticities and the cross fiber consumption elasticities. In the column entitled "other fiber price" is the name of the particular fiber whose price is entered in the equation. Summary information concerning the dummy variables is included in the remaining columns.

The first two columns contain the estimated coefficients of adjustment, which indicate how extensively the level of fiber consumption reacts to a change in one of the determinants of its desired level. The reaction coefficients can be roughly divided into three ranges: the highest coefficients of adjustment are found for the two traditional natural fibers, cotton and apparel wool, with cotton reacting even more quickly than wool. The medium range contains carpet wool, rayon-acetate staple, and synthetic staple. The least volatile fibers are the rayon-acetate and the synthetic filament yarn. The breakdown is especially interesting because the fibers in each category have definite similarities. The first category includes the oldest established fibers; the second, the man-made staples and competing carpet wool; and the third, both types of man-made filament yarn. As F. M. Fisher points out, consistency in estimates is one of the most impressive kind of econometric results¹. The relative magnitudes of the estimated coefficients of adjustment also conform to a priori expectations. The slower reaction of the man-made fibers than of the natural fibers is anticipated because of the reluctance of the public to use and then to identify with new products, and because of the technical difficulty of first learning to weave man-made fiber. The carpet wool result is also reasonable, because the public is likely to be

¹ See Franklin M. Fisher, A Priori Information and Time Series Analysis (North-Holland Publishing Co., Amsterdam, 1966), p. 16.

very hesitant about discarding previously purchased rugs². The difference between the man-made staple and filament yarn is not readily explained, but the difference, except for synthetic filament, is not very large.

Columns 3 and 4 contain both short-run and long-run estimated income elasticities. The short-run elasticities indicate the initial response of consumption to a change in income and are of interest to the forecaster responsible for short-run projections. The long-run response is an indication both of the growth potential of the fiber and of the eventual impact of changes in the level of income³. The long-run income elasticities are well above unity for the man-made fibers and well below unity for the natural fibers, cotton and apparel wool. Carpet wool is a special case with an elasticity of 1.19. The pattern of the elasticities is reasonable, since the more established fibers are used in staple items, and the newer synthetic fibers

² For a discussion of this property of durable products, see H. S. Houthakker and Lester D. Taylor, Consumer Demand in the United States, 1929-1970, Analyses and Projections (Harvard University Press, Cambridge, Massachusetts, 1966), p. 9. The existence of the consumer stock motive also helps to explain the lower reaction coefficient for apparel wool (relative to cotton), since apparel wool is used more intensively than cotton in the apparel industry.

³ Nerlove argues that only long-run elasticities can be meaningfully compared, because the short-run elasticities are not unique but depend upon the time interval. See Marc Nerlove, Distributed Lags and Demand Analysis (U.S. Department of Agriculture Marketing Service, Washington, D.C., June, 1958), p. 15.

have experienced tremendous growth⁴.

The next two columns contain the long-run response of fiber consumption to a change in its own price. The elasticities of the natural fibers are below unity, while those of the man-made fibers are greater than unity. Cotton consumption is very unresponsive, and that of apparel and carpet wool is only slightly more so. The natural fiber price is only a small percentage of the total cost of end products, and these products are typically staples. The price elasticities for rayon-acetate filament and staple and for synthetic staple are approximately 1.5 (price effects for synthetic filament are not available). Since the man-made fiber price elasticity may proxy other competitive effects besides the list price and may include some of the influence of per capita disposable income, it may not reflect the influence of just the list price. Thus, the estimated elasticity is not strictly comparable with those of the natural fiber equations and is expected to be larger. While the response of man-made fiber to a change in only its list price has not been isolated, we would expect it to be as large as, and possibly larger than, the wool elasticities, since man-made fiber products are typically more luxurious than cotton products.

The cross price elasticities in the next six columns outline the extent and the strength of fiber interaction. The only significant interaction is between the synthetic fiber prices and the consumption of both the natural and the rayon-acetate fibers. The rayon-acetate prices do not seem to have a strong effect on the consumption of the natural fibers, and there

⁴ When the constant term is deleted from the cellulosic fiber equations (both staple and filament yarn), measures of per capita income enter significantly with implied long-run elasticities of 1.57 for staple and 1.72 for filament yarn. These estimates fit nicely into the pattern developed above. They are greater than unity, like the other man-made fibers, but they are not so great as for the synthetic fibers, which is reasonable.

appears to be no significant cross price effects between the natural fibers. The inability to uncover more significant fiber interaction is disappointing.

The price of synthetic staple is an important determinant of the consumption of cotton and apparel wool. The estimated cross price elasticities indicate that both fibers are gross substitutes of synthetic staple. For both fibers, the initial impact of the synthetic price is negligible, but the long-run impact is greater than that of the own price. We are unable to measure the synthetic staple cross price elasticity of carpet wool consumption, but it appears that the two fibers are significant gross substitutes. The price of synthetic filament yarn significantly influences the consumption of cotton and rayon-acetate filament. The coefficients indicate the fibers are gross substitutes; the cross elasticities are less than unity and comparable to those above.

The final four columns illustrate market disruptions which occurred during the thirties and the later war periods. The mill usage of both cotton and apparel wool declined dramatically during the early thirties and in 1938. While the estimated average decline in autonomous per capita cotton consumption, -4.322, is five times as great as that of apparel wool, the 16% decline in cotton is only one half that of the apparel wool percentage. Unusual activity is also isolated in the World War II and the Korean War periods. Consumption of the natural fibers showed the greatest sensitivity to special market conditions existing during the wars; autonomous consumption of apparel wool increased by 42%, while that of cotton increased by only 18%, even though the absolute cotton increase was much greater. Autonomous consumption of carpet wool experienced a large decline of approximately 50%. There is no evidence of significant structural change in the consumption of cellulosic fiber during the war periods.

For the dynamic fiber models, the coefficient estimates are statistically significant and have signs and magnitudes which conform to a priori expectation. The coefficient values for the different equations fit into reasonable patterns, and such consistency is impressive. One shortcoming of the dynamic specification is that it is not able to isolate fiber interaction so fully as originally hoped. Reasonable, consistent, and significant estimates over the set of equations is an important indication that the models are successful.

6.3. Further Comments on the Performance of the Dynamic Specifications

A second set of statistics, presented in Table 6.2, describes the ability of the model to explain consumption, to account for serial correlation, and to simulate. These statistics provide additional information as to the overall effectiveness of the consumption equations. Two alternative formulations of the stock adjustment process have been introduced, one which views consumption as taking place at discrete time intervals, and one which represents consumption as taking place continually. The two models do not always behave identically nor do they yield indistinguishable inferences. Their explanations are similar for apparel wool, cellulosic staple, and cellulosic filament, but not for cotton or carpet wool. The Nerlove model is better for cotton, and the Bergstrom model is better for carpet wool. We discuss the performance of only the more successful specification.

Column 1 of Table 6.2 contains the corrected coefficients of determination, which indicate the explanatory power of the models. The coefficients are all greater than .70 and are typically between .88 and .94⁵. Carpet wool consumption is the

⁵ This is not so impressive as it may seem, for the models are estimated in terms of levels rather than in terms of first differences.

Table 6.2. Fiber Consumption Summary Statistics.

	\bar{R}^2	DW	R'^2	U	U^m	U^v	Missed Direction of Change
<u>Natural Fibers</u>							
Cotton (5.3)*	.92	2.29	.93	.022		.020	6/45
(5.4)*	.89	2.31	.90	.026		.026	15/45
Apparel							
Wool (5.9)*	.91	2.26	.88	.040		.048	11/42
(5.10)*	.90	2.18	.91	.041		.029	13/42
(5.11)	.91	2.20	.91	.040		.041	9/42
Carpet							
Wool (5.13)*	.70	2.18	.74	.086		.066	6/29
(5.14)	.74	2.40	.32	.177		.200	8/29
<u>Man-Made Fibers</u>							
Cellulosic							
Staple (5.15)*	.88	-	.89	.076		.026	11/28
(5.16)	.88	2.08	.90	.077		.026	9/28
Cellulosic							
Filament							
Yarn (5.17)	.89	2.48	.66	.054		.246	11/33
(5.18)*	.94	2.20	.99	.047		.000	10/33
Synthetic							
Staple (5.22)*	.99	2.65	.94	.034	.040	.170	
Synthetic							
Filament							
Yarn (5.23)*	.99	2.17	.95	.057	.463	.038	

most difficult to explain, since the highest \bar{R}^2 associated with a reasonable explanation is .70. This difficulty in quantifying carpet wool behavior has appeared in previous textile studies. The high \bar{R}^2 's indicate that the overall explanatory power of the dynamic models is good, although in some cases it is better for one form of the model than another.

In columns 3 through 6 we introduce statistics which describe how well the model is able to simulate over its period of observation; the simulated series is constructed from the original value of the lagged endogenous variable and the actual

sample values of the exogenous variables. The simulation ability of the model is measured by three statistics: a coefficient of determination estimated from the actual and the projected values of the dependent variable (labeled R'^2), Theil's coefficient of inequality and its various components, and the frequency with which the simulation incorrectly predicts the direction of change of the actual series. The models which simulate best, as measured by these criteria, also have the highest corrected squared multiple correlation coefficient, \bar{R}^2 . In the estimates in Table 6.2, Theil's U is less than .04 and R'^2 is greater than .88 for both cotton and apparel wool. The cotton consumption model performs better, with the lower value of U and the remarkable record on simulating turning points. The remaining natural fiber, carpet wool, does not perform so well, with a high Theil's U of .086 and a low R'^2 of .74. The simulation inaccuracy parallels the lower explanatory power of the carpet wool model as measured by the coefficient of determination. The rayon-acetate fiber models, which exhibit high explanatory power, also simulate well. The R'^2 is high for both staple and filament yarn, and there is little indication of systematic variation in the simulation experience. However, both cellulosic models do exhibit U coefficients which are greater than those of the natural fibers, with that for cellulosic staple as high as .076.

There are several simulation experiences which do not merely confirm the success of the explanation as measured by the corrected coefficient of determination, \bar{R}^2 . These include the synthetic fiber models and special cases of the natural and cellulosic fiber models. The synthetic filament yarn model, (5.29), uncovers a bias in the projection of the mean of the usage series, even though both the R'^2 and Theil's U are acceptable. The forecasts of this equation may be more seriously biased than those of the other fiber categories. The synthetic staple model (5.22) exhibits a sizable systematic discrepancy between the variance of the actual series and that of the simulated series. This phenomenon is observed in two other

fiber models, (5.17) for rayon and acetate filament yarn and (5.14) for carpet wool consumption⁶. Interestingly, in all three cases there is also an indication of serial correlation in the residuals. In these three models, autocorrelation may be affecting the projections by increasing their variability⁷. In conclusion, the ability of the autoregressive model to simulate over its period of estimation conforms generally to its explanatory ability as measured by the squared multiple correlation coefficient, but in specific instances the projection experience has helped to uncover or to reinforce suspicion of possible weakness in the overall quality of the estimates.

Finally, as indicated in column 2 by the Durbin-Watson statistics, the autoregressive model has avoided most of the serial correlation difficulties encountered in the static models of fiber consumption⁸. The dynamic specification occasionally encounters autocorrelation. Two examples have just been discussed. A third example, cellulosic filament yarn equation (5.21), apparently has been corrected by the Durbin procedure. A fourth example is equation (5.28) for synthetic staple; here there is strong indication of negative first-order serial correlation.

⁶ The U^V statistics for the three models are .17, .246, and .20, which are much higher than those for any other equations.

⁷ It is interesting that here the U statistic is large only for the carpet wool equation; the values of U for the cellulosic filament model and for the synthetic staple model are .054 and .04, respectively.

⁸ The Durbin-Watson statistic is biased for the models and is used only as an approximation. The arbitrary acceptable range of 1.6 - 2.4, adopted by Houthakker and Taylor, has been used - see Chapter 4, Section 4.2.

6.4. Evidence of Structural Change Over Time

In Chapter 4 the dynamic model is described as a partial explanation of consumption, and the proposition is advanced that the parameters of the partial model are variables of an even larger model. These parameters, as variables of the larger model, may alter over time, especially if the period of observation is long. If significant structural change does occur over the period of observation, then estimates based on the entire period are meaningless averages over different structures. In such a case, it is necessary to separate the periods or to incorporate the nature of the structural change into the specification. Finally, we note that covariance analysis provides statistical techniques to test particular hypotheses about where a structural break may have occurred.

We are especially concerned that the introduction and rapid growth of synthetic fibers may have caused a structural break in the natural and the cellulosic fiber equations. We allow for the effects of this innovation by including either the price or the level of the mill consumption of synthetic fiber in the consumption functions of the older fibers; however, a more fundamental shift in these functions may have occurred, affecting the other parameters. We look for evidence of a structural break in the cotton, apparel wool, and cellulosic filament yarn functions in the mid-1950's when synthetic fibers were introduced in large volume. In the carpet wool equation, we look for evidence of a break in 1964. Only for carpet wool is there strong, significant evidence of structural change, and we have had to correct for this change by altering the specification. It is not surprising that the carpet wool equation has not remained stable with the large and especially rapid growth of man-made carpeting. In the cotton, apparel wool, and rayon-acetate filament yarn equations, the inclusion of the synthetic fiber price apparently is sufficient to capture the impact of the synthetic revolution, so that we do not split the time period or make some other correction.

Finally, there is also evidence of structural change in both the Second World War and in the depression of the early thirties. Zero-one dummy variables are introduced to account for such change. A war dummy variable has not been included in either the cellulosic staple or the filament yarn equation because we do not feel that there was a significant change in the functions. We test directly whether a structural break did occur over the war periods, and it appears that there was no such break. We also test the adequacy of a war dummy variable to represent structural change in the natural fiber equations; the dummy is adequate. We do not test the depression dummy.

CHAPTER 7

THE TEXTILE CYCLE

7.1. Introduction

Several observers have argued that production in the textile industry is subject to short-run, cyclical oscillations, which are exhibited in series that measure the level of activity in the industry. These fluctuations have been termed the "textile cycle." We employ spectral analysis of textile time series to examine whether or not a textile cycle does exist and to describe its physical characteristics. The final product of this analysis is a rigorous, empirical description of the properties of the cycle. We then comment briefly on possible explanations of the cyclical behavior.

Claims that a textile cycle exists are common in the industry literature. For example, in 1941 Markham stated that while the phenomenal regularity with which this cycle occurs in textile consumption data has never been adequately explained, the phenomenon is beyond dispute¹. Davis noted in 1958 that the existence of a specific textile cycle has long been recognized and is clearly demonstrated². In 1964 Zymelman cited the cyclical tendencies³. Business reports and discussions frequently mention the cycle⁴. It is a phenomenon of concern recognized

¹ Jesse W. Markham, Competition in the Rayon Industry (Harvard University Press, Cambridge, 1952), p. 113.

² Thomas Jeff Davis, Cycles and Trends in Textiles (U.S. Department of Commerce, Business and Defense Services Administration, Washington, D.C., 1958), p. 1.

³ Manuel Zymelman, "A Stabilization Policy for the Cotton Textile Cycle," Management Science, Vol. 11, No. 5, March, 1965, p.572.

⁴ See, for example, Robert C. Shook, "What to Expect in the Coming Months," Modern Textile Magazine, Rayon Publishing Corporation, New York, Monthly, February, 1959, pp. 20,26,28.

by the industry.

The cycle is described as a subcycle, which lasts two to three years and occurs in the major sectors of the industry. It supposedly has a larger amplitude than fluctuations in end use demand and is unrelated to movements in raw material prices or production. It is reported to have a greater amplitude and to recur more regularly than oscillations in other industries. Finally, it may have dampened since the Second World War.

The description of the "textile cycle" has been largely a result of observation rather than statistical demonstration⁵. The purpose of this analysis is to provide a rigorous description of the cycle. The methodology is to test statistically various hypotheses that have been advanced to describe the cycle. By establishing which hypotheses can and cannot be rejected, we will have a clearer idea of the nature of the cycle. The tests are conducted using the powerful tools of spectral analysis. The analysis itself deals with three of the major sectors of the textile industry: cotton, wool, and cellulosic fiber. The series used are the monthly fiber consumption data, the price of cotton print cloth, and the Federal Reserve Board's Indices of Apparel Production and Total Industrial Production. The data record includes monthly observations from 1923 through 1965 and is divided into prewar (1923-1941) and postwar (1947-1965) periods.

⁵ An important exception is the investigation of cyclical tendencies in the Australian apparel wool fiber prices by S. Peter Burley, "Fluctuations in the Australian Economy: Viewed by Frequency Techniques," Research Memorandum No. 94, Econometric Research Program, Princeton, New Jersey, March, 1968, pp. 74-88. Spectral analysis of wool prices and wool mill consumption is also done by William H. Witherell, "Dynamics of the International Wool Market: An Econometric Analysis," Research Memorandum No. 91, Econometric Research Program, Princeton, New Jersey, September, 1967, Chapter 8.

The series used in the analysis are transformed into the first differences of their logarithms prior to the estimation. The transformed series represent the percentage rate of change in the original series and thus approximate the rate of growth. The data are transformed because the original series exhibit an irregular growth trend violating the assumption of second-order stationarity⁶. On taking logarithms, the series trend upward, indicating an approximately constant growth rate. When the trend is removed by first differencing, the transformed series are homogeneous in the sense that different segments of the series are similar. The series now conform better to the prerequisite stationarity assumption⁷. Furthermore, the choice of the transformation is dictated analytically, given the nature of the environment we are describing⁸. In examining a series with an irregular growth trend, we would not expect to find cycles in the level of activity. That is, we would not expect to find activity rising and then falling back to approximately the same level. Rather, we may expect to find the pace of activity growing systematically more quickly and then more slowly as it continues on a path of irregular growth. The "first difference of logarithms" transformation permits isolation of systematic "growth cycles".

⁶ Second-order nonstationarity and some of its implications are discussed in Appendix A.

⁷ As Burley points out, "This condition (second-order stationarity) is never likely to hold exactly for economic data collected over time, but provided it holds approximately, reasonable estimates can be obtained..." See Burley, op.cit., p. 10.

⁸ For excellent discussion of this point, see Franklin M. Fisher, A Priori Information and Time Series Analysis (North-Holland Publishing Company, Amsterdam, 1966), pp. 21-26; Burley, op.cit., pp. 7-13; Michael D. Godfrey, C. W. Granger, and Oskar Morgenstern, "The Random-Walk Hypothesis of Stock Market Behavior," Kyklos, Vol. XVII, 1964, pp. 1-28.

The remaining sections provide a systematic description of the cycle and indicate possible explanations. Section 7.2 presents the major hypotheses which have been advanced to describe the fluctuations. Section 7.3 introduces definitions and discusses specific problems encountered in using and interpreting the spectral results. In Section 7.4, we test the hypotheses presented in Section 7.2. In Section 7.5, the description is summarized and explanations of the cyclical activity are introduced.

7.2. The Hypotheses Advanced to Describe the Textile Cycle

7.2.1. The Existence of the Textile Cycle

The initial hypothesis to be tested states that there is a cycle in the rate of growth of textile mill activity. Because fluctuations have been observed is no guarantee that a cycle actually exists. Fluctuations are cyclical only when they exhibit regularly recurring, but not necessarily periodic, movement. Dips and recovery can be a reality and a concern without the characteristic of being a cycle.

A second issue related to the existence of the cycle is whether the cyclical movement is periodic or just regularly recurrent. Periodic movement repeats itself exactly period after period. The use of the word periodic is unfortunate in the discussion of economic cycles; in 1950 W. C. Mitchel warned against the use of the concept in the description of economic fluctuations⁹. Nevertheless, claims of a periodic cycle do exist in the literature¹⁰. Most other observers represent the cycle as nonperiodic but still rhythmic; this is more consistent with a priori economic reasoning.

⁹ Arthur F. Burns and Wesley C. Mitchell, Measuring Business Cycles (National Bureau of Economic Research, Inc., New York, 1946), p. 3.

¹⁰ Zymelman, op.cit., p. 572, and T. M. Stanback, Jr., "The Textile Cycle: Characteristics and Contributing Factors," The Southern Economic Journal, Vol. 25, No. 2, October, 1958, p. 181.

7.2.2. The Length of the Textile Cycle

The second hypothesis to be tested is that the length of the oscillation is comparable to that of Ruth Mack's two-to-three year subcycle and that the length of the cycle may have increased after World War II^{11,12}. Zymelman has commented that discrepancies in the reported length may be due to the length of the period, to peculiarities of the specific time series observed, and to the different techniques employed¹³.

7.2.3. The Relative Nature of the Textile Cycle in Different Sectors of the Industry

A third hypothesis is that the textile cycle affects the primary activity in all of the major fiber sectors. Also, further suppositions are that cyclical tendencies are more pronounced in the cotton textile industry and that variations in the woolen and worsted industry tend to follow those in the cotton and man-made fiber industries^{14,15}.

¹¹ See Thomas Jeff Davis, op.cit., p. 1; Edwin F. Dakin and Edward R. Dewey, Cycles - The Science of Prediction (Henry Holt and Co., New York, 1947), p. 136; Stanback, op.cit., p. 181; and Frank Lowenstein, "Seasonal Adjustments in Cyclical Movements for the Ratio of Stocks to Unfilled Orders for Cotton Broadwoven Goods," The Cotton Situation, C.5-186, United States Department of Agriculture, Agricultural Marketing Service, Washington, D.C., January, 1960.

¹² Lowenstein, op.cit., p. 24, and Stanback, op.cit., p. 182.

¹³ W. H. Miernyk and Manuel Zymelman, Inventories in the Textile Cycle (U.S. Department of Commerce, Business and Defense Services Administration, Washington, D.C., 1961), p. 4.

¹⁴ Miernyk and Zymelman, op.cit., p. 11.

¹⁵ The hypothesis has been referred to by Miernyk and Zymelman (Ibid., p. 4) but has not been found elsewhere.

7.2.4. Amplification of the Textile Cycle Over End Use Demand

We also test the assertion that the rate of change of textile mill activity oscillates much more widely than that of purchases of finished textile products¹⁶. Theoretical descriptions of the source of such magnification are contained in the work of Ruth Mack and that of Meirnyk and Zymelman¹⁷. In her discussion of the hide, leather, shoe sequence, Ruth Mack illustrates how inventory policies can magnify impulses as they are passed back through a sequence of operations. The Department of Commerce has supported simulation studies of the textile-apparel sequence which indicate that a small variation in end use demand can be amplified greatly as the impulses are passed along the production-marketing chain. These models specify inventory objectives and allow for converter speculation. The models themselves are deterministic (non-stochastic) and incorporate some unrealistic assumptions so that they cannot be accepted as explanatory; however, they do illustrate that such magnification is possible. The analysis below is not so ambitious; we test only whether magnification has occurred.

7.2.5. The Textile Cycle Compared With Other Industry Cycles

Hypotheses characterizing the textile cycle include comparisons of the regularity and the amplitude of the textile cycle with those of other industry cycles. First, it is claimed

¹⁶ See Stanback, op.cit., p. 181, and Miernyk and Zymelman, op.cit., p. 33.

¹⁷ Ruth P. Mack, Consumption and Business Fluctuations (National Bureau of Economic Research, Inc., New York, 1956); Ruth P. Mack, "Notes on Subcycles in Theory and Practice," American Economic Review, Papers and Proceedings, Vol. XLVII, No. 2, May, 1957; Ruth P. Mack and Victor Zarnowitz, "Cause Consequence of Changes in Retailers' Buying," American Economic Review, Vol. XLVIII, No. 1, March, 1958; Miernyk and Zymelman, op.cit.; and Zymelman, "A Stabilization Policy for the Cotton Textile Cycle," op.cit.

that no major industry in the economy exhibits a more regular cycle than do textiles¹⁸. Stanback claims, "The unique characteristic of the textile industry ... is not that it develops short periodic movements but that it develops them more consistently than any other industry"¹⁹. Second, there is general agreement that the magnitude of textile industry fluctuations is large relative to that of other industries²⁰.

7.2.6. Possible Supply Domination of the Textile Cycle

The cycle may result from movements in the supply of the agricultural raw materials. Abramovitz has emphasized the role of agricultural raw material in production cycles of manufactured products²¹. He argues that agricultural products must be liquidated quickly because of physical or economic spoilage; thus production activity utilizing such raw materials will be governed by their current availability. For example, with an outward shift in the supply schedule, the ceteris paribus fall in price will permit lower mill product prices and lead to expanded production. If the production of agricultural products is primarily a function of noneconomic factors, then producer activity will tend to have unique movement which is not closely related to occurrences elsewhere in the economy. Of course, to the extent that agricultural supply is coincident with general economic activity, related movement would be expected.

Two factors reduce the plausibility of the supply-oriented theory. First, as Stanback notes, cotton and wool are staple

¹⁸ Miernyk and Zymelman, op.cit., p. 3.

¹⁹ Stanback, op.cit., p. 181.

²⁰ Miernyk and Zymelman, op.cit., p. 4.

²¹ Moses Abramovitz, Inventories and Business Cycles (National Bureau of Economic Research, Inc., New York, 1950); pp. 240-241.

fibers which can be stored²². Second, if there is cyclical activity in the man-made fiber sector, lateral propagation from the natural fiber to the man-made fiber sector must be implied.

7.3. A Discussion of Properties of Spectra and Cross-Spectra

We concentrate on a few specific problems in the interpretation and the use of spectral and cross-spectral techniques²³. We begin with a short discussion of those properties of the cycle which the spectral density function identifies and find that it is very similar to the economist's conception of recurring, but not necessarily periodic, movements. We then turn to two specific and important problems encountered in the analysis. The first is the difficulty of assessing the statistical significance, and thus the reliability, of spectral estimates. The second is that of determining how severe and disruptive a particular cycle is, for even if a cycle is statistically distinct, it may involve only a slight loss in efficiency for the industry. The section concludes with an introduction of the statistics of cross-spectral analysis; these statistics permit the comparison of cyclical movements in two related series.

Since the analysis deals with economic cycles, it is important to begin by specifying what is meant by the word cycle

²²

T. M. Stanback, Jr., Postwar Cycles in Manufacturers' Inventories, (National Bureau of Economic Research, Inc., New York, 1962), pp. 61-65.

²³

Many of the properties of spectral and cross-spectral density functions are still unfamiliar to economists. We mention several sources; see especially G. M. Jenkins, "Some Examples and Comments on Spectral Analysis," Proceedings of the IBM Scientific Computing Symposium on Statistics (IBM Data Processing Division, White Plains, New York, 1963); Marc Nerlove, "Spectral Analysis of Seasonal Adjustment Procedures," Econometrica, Vol. 32, No. 3, July, 1964; C.W.J. Granger, "The Typical Spectral Shape of an Economic Variable," Technical Report No. 11, Department of Statistics, Stanford University, Stanford, California, January, 1964; Burley, op.cit.; Witherell, op.cit., Chapter 8.

and to isolate the properties of the cycle which the spectral density function identifies. The use of the word cycle in the description of economic phenomenon is unfortunate because it connotes periodic movement, oscillation which repeats itself exactly period after period. Such a representation is not useful in describing movements in the economy, which do not recur in the same form with the same period and the same severity. More useful is the concept of nearly periodic oscillations with an average duration. Spectral analysis incorporates this idea of nearly periodic movements. The spectrum groups fluctuations with nearly equal periods, allowing for possible changes in both the duration and the amplitude of the fluctuations which leave the average length constant. This latitude in the characterization of the cycle provided by spectral analysis is consistent with a priori economic notions.

The spectral density function identifies cyclic variation by first decomposing a time series into several component series, all with different average periods (or frequencies); it then asks which components seem to account for the actual variation observed in the time series. Any series which is assumed to be generated by a stationary process can be expressed in the form

$$x(t) = \int_0^{\infty} \cos \omega t \, du(\omega) + \int_0^{\infty} \sin \omega t \, dv(\omega),$$

where $x(t)$ is a random function of t about which inferences are to be made and where $du(\omega)$ and $dv(\omega)$ are random functions of the frequency, ω . $x(t)$ is represented as a superimposition of sine and cosine waves of different random amplitudes and frequencies, so that this function is simply a transformation between the time domain and the frequency domain. The total variation in the series $x(t)$ is a combination of the variations in the various component series as they move through time at their respective frequencies, and when the variance contributions of all the frequency components are summed, the result is the

variance of the original series. It is the variance contribution of a particular range of frequency bands which the spectrum uses to isolate cyclical movements in the data. If, for example, there is a predominant two year cycle in textile mill activity, the contribution to the variation of mill activity of this component would be both large and distinct from other bands; if on the other hand, there is strong evidence of short-term oscillations with varying periods ranging from twenty-four to forty months, the variance contribution over the region would be large, but it would be dispersed as a flatter spectrum.

The use of the spectral density function to discuss cyclical variation is not straightforward. One major problem is the difficulty of assessing the statistical significance of particular estimates. It is difficult to determine whether a particular spectral estimate is significantly different from that of an adjacent frequency band or nearby bands, so that an apparent peak in the spectral density function may not be statistically distinguishable from adjacent estimates. This difficulty in assessing statistical independence is complicated since the variability of a particular estimate is a function of the maximum lag employed in the estimate of the lagged correlation function. That is, the spectral density function can be made to appear more smooth or more jagged by decreasing or increasing the maximum number of lags²⁴. To determine whether a peak is significant, then, requires careful consideration. Useful criteria are both the plausibility of particular estimates, based on a priori knowledge of the environment being studied, and the consistency of the estimates with those for other series in similar environments.

²⁴ For a discussion of spectral estimation and the properties of the Parzan "window" used in the estimation, see Burley, op.cit., pp. 14-26.

An additional problem in the interpretation of spectral peaks is in determining the cost of a particular fluctuation to an industry. Consider two industries which produce the same volume of goods over the same time period, where one receives orders at a uniform rate and the other experiences alternative periods of heavy and then slack ordering. If the period is too long to permit effective production smoothing, the second industry may be forced to use some obsolete equipment and pay overtime rates and then to carry surplus capital and labor (or release and then repurchase, and possibly retrain, factors). The second industry may incur greater costs than the first in producing the same volume of goods. It is the level of such additional costs which determines the importance of the cycles to the industry. To determine the costs of short-term oscillations requires knowledge of the industry's economic environment and its costs over time, thus requiring the analyst to go beyond the spectral density function. We have not attempted to measure the actual reduction in efficiency in the textile industry. However, we do look for indications of such reduction in efficiency. We consider the remarks and complaints raised by the industry. Also, we compare the movements in the textile industry with movements in similar industries. If the textile mill activity exhibits wider swings than the production of the remaining nondurable manufacturing industries, it at least indicates that these movements may be economically significant.

Spectral analysis also provides the means with which to study the relationship between two time series. We use the cross-spectral density function, which is the Fourier transform of the lagged cross-covariance function between two series. The cross-spectral density function is complex valued, but its real and imaginary parts can be combined with the spectral density functions of the individual series to form useful statistics describing the relationship between the two series. These statistics are the coherence, the gain, and the phase. The coherence, $C_{12}(\omega)$, is analogous to the coefficient of

Determination between the two series; it measures the squared correlation between the series at each frequency and indicates the extent to which the series move together at a particular frequency²⁵. The gain, $G_{12}(\omega)$, measures the relative amplitude of the fluctuations of the two series at a particular frequency²⁶. It is analogous to the regression coefficient between the two series, measuring the magnitude of the response of one variable to the other; the statistic presupposes that movements in one series result from movements in the other. Since the series have been transformed to approximate the percentage rate of change, the gain estimate is independent of the units of measurement of the individual series²⁷. Thus a gain statistic of 2.0 at a particular frequency indicates that a percentage rate of change of 3% in the independent variable is translated into a 6% rate of change in the dependent variable. The phase, $\phi_{12}(\omega)$, expresses the lead-lag relationship between the series in the

²⁵

The coherence for the two series is equal to the squared modulus of the cross-spectral density function divided by the product of the spectral density functions of the individual series, f_{11} and f_{22} :

$$C_{12}(\omega) = \frac{|f_{12}(\omega)|^2}{f_{11}(\omega)f_{22}(\omega)}, \quad (0 \leq \omega \leq \pi).$$

For an introduction to the interpretation of the coherence estimate, see Burley, op.cit., pp. 30-33.

²⁶

The gain of series X_1 on series X_2 (X_1 as a function of X_2) is measured by

$$G_{12}(\omega) = \frac{|f_{12}(\omega)|}{f_{22}(\omega)}, \quad (0 \leq \omega \leq \pi).$$

²⁷

In the estimation of the gain statistic, the Princeton University Time Series Analysis program uses the series normalized on unit standard deviation so that the gain estimates below have been corrected for the standard deviations of the two series.

different frequency ranges²⁸. The phase angle indicates the extent to which fluctuations in one series lead or lag behind fluctuations in the other series²⁹.

The latter two statistics, the gain and the phase, presuppose a specific relationship between the two series. One series is considered as the input series and the other, as the output series³⁰. The series are assumed to be related by a time invariant, linear relationship which operates on the input series to produce the output series. The gain, then, refers to the amplitude gain in the output series over that of the input series. The phase angle has a similar interpretation. The gain

²⁸

The phase angle measures the lag in series X_1 behind series X_2 ; it is positive for a positive lag and negative for a negative lag. Formally, it is the arc tangent of the imaginary part of the cross-spectral density function, $q_{12}(\omega)$, divided by the real part, $c_{12}(\omega)$.

$$\phi_{12}(\omega) = \arctan \frac{q_{12}(\omega)}{c_{12}(\omega)}, \quad 0 \leq \omega \leq \pi.$$

The lag at a particular frequency can be stated in units of time with the following relationship:

$$\text{lag}(\omega) = \frac{\phi_{12}(\omega)}{\omega}, \quad \text{for all } \omega.$$

²⁹

Since these three parameters are statistics, confidence intervals should exist. Intervals for the gain and phase angle of the "filter" require knowledge of the coherence, which in actual estimation must be replaced by the estimated value of the coherency. Such replacement hampers the utility of the limits.

³⁰

Furthermore, with respect to the gain estimate, the choice of the independent variable is not arbitrary, since

$$\left| \frac{f_{12}(\omega)}{f_{11}(\omega)} \right| \neq \frac{f_{22}(\omega)}{\left| f_{12}(\omega) \right|}.$$

and the phase statistics require a very specific relationship between the series and assume a one-way relationship, not allowing for possible feedback through the surrounding economic system.

7.4. An Empirical Description of the Textile Cycle

7.4.1. Introduction

In this section we use both spectral and cross-spectral techniques to test the hypotheses advanced in Section 7.2. By determining which hypotheses can and cannot be rejected, we develop both a rigorous description of the growth cycle in fiber mill consumption and a concise picture of the relationship between these fluctuations and those in other industries. Single spectra are used to determine the existence and the length of cycles in the three major sectors of the industry. Cross-spectral techniques are used to describe the relationship between the movement in the different fiber sectors, to detect possible magnification in mill activity over end use purchases, to study the comparative intensity between movements in the textile industry and other industries, and to assess the influence of raw material supply.

7.4.2. The Estimated Spectral Functions

The estimated spectral density functions of the transformed cotton, wool, and cellulosic consumption series are presented below³¹. The series have been divided into prewar and postwar periods, and their spectral density functions are presented separately. The scale of the abscissa has been adjusted so that

³¹ The mill consumption series are similar to those referenced in Chapter 4, except that here monthly data are used. The data are reported in various issues of Textile Economics Bureau, Inc., Textile Organon, Hunt, Stanley B., ed., New York, Monthly.

the frequency 1.0π corresponds to annual fluctuations. The period in months which corresponds to a particular frequency can be calculated with the transformation:

$$\text{period (in months)} = 12\pi/\omega.$$

Thus for $\omega = 1.0\pi$, the period is twelve months; for $\omega = .5\pi$, the period is twenty-four months. Seasonal movements in consumption behavior are not reported. The maximum number of lags used for the discussion is 70, which is approximately 30% of the total observations, 227. As the number of lags approaches 100, the spectral density functions begin to become "unstable"³². Seventy lags appear to provide good definition without excessive variability in the estimates.

The prewar spectral density functions are presented in Figures 7.1, 7.2, and 7.5. Each has a relative peak about the frequency range $.5\pi$, which corresponds to two year fluctuations. The peaks are not spiked, but are rounded, demonstrating that the fluctuations are not strictly periodic. The peaks are moderately prominent and appear different from surrounding estimates, indicating that before the Second World War there was some two year movement in the growth rate of textile activity. While there is evidence of a short subcycle, it is not so prominent as might be expected from the industry reports. The spectral density functions also have peaks at the annual frequency, 1.0π , illustrating the yearly seasonal component in fiber consumption data found by Witherell³³. Finally, the peak for wool is more

³²

For a discussion of the choice of the maximum number of lags, see Burley, op.cit., pp. 17-18, and Nerlove, op.cit., pp. 253-256.

³³

Witherell, op.cit., p. 246.

Figure 7.1. Spectral Density Function for Cotton Mill Consumption, Monthly, 1923-1941.

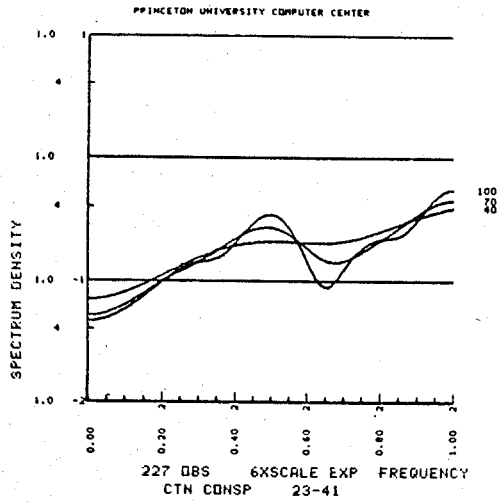


Figure 7.2. Spectral Density Function for Wool Mill Consumption, Monthly, 1923-1941.

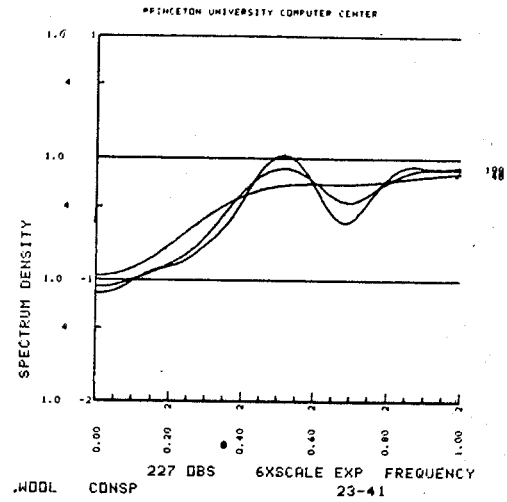


Figure 7.3. Spectral Density Function for Cotton Mill Consumption, Monthly, 1947-1965.

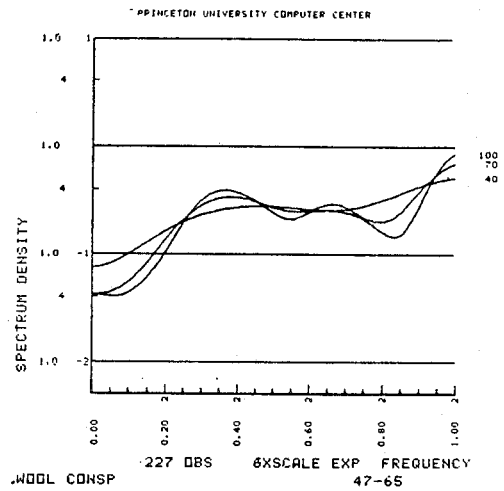
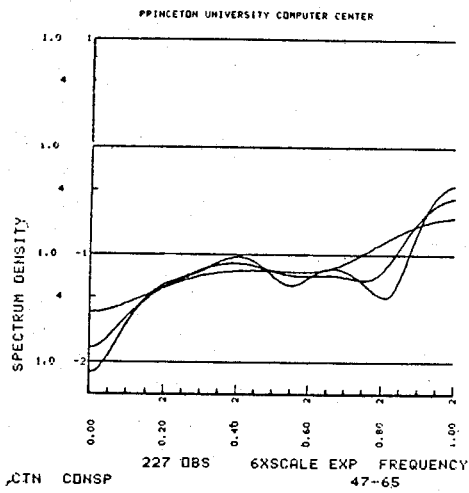


Figure 7.5. Spectral Density Function for Cellulosic Mill Consumption, Monthly, 1924-1941.

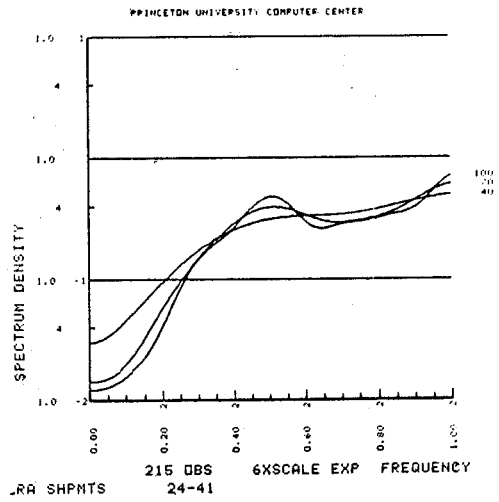
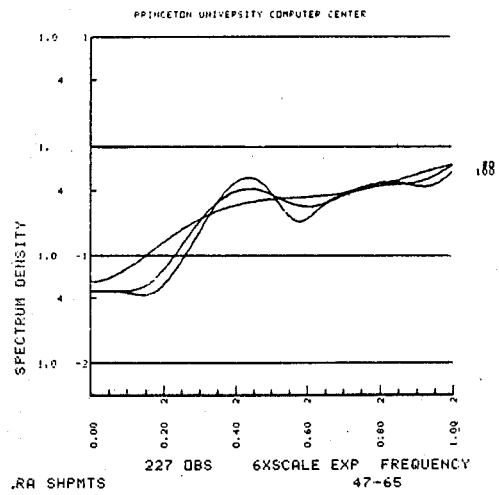


Figure 7.6. Spectral Density Function for Cellulosic Mill Consumption, Monthly, 1947-1965.



pronounced than that for either cellulosic or cotton fiber³⁴.

The postwar spectral density functions are presented in Figures 7.3, 7.4, and 7.6. These functions also exhibit relative peaks in the subcycle frequency range. The wool consumption series has a peak between the thirty-two and thirty-three month frequency range, while the cotton and cellulosic series have peaks at twenty-eight and twenty-nine months, respectively. With the apparent exception of the cellulosic fiber, the subcycle peak in the postwar functions is not nearly so prominent as that in the prewar and is less powerful than the postwar annual peak. For the natural fibers, wool and cotton, the short-term movements of the textile cycle appear to have lengthened and become much less prominent since the war. The pattern for cellulosic fiber, however, is not much different before and after the War. Finally, as in the prewar, the peak of cotton consumption is less pronounced than those of the other fibers.

From the discussion of the prewar and postwar spectral density functions, we conclude that there is evidence of subcyclic movement in the textile consumption data. In the prewar, the movement is prominent, but not sharply peaked or clearly dominant. In the postwar the movement for the natural fibers is much less prominent, with some weak indication of longer subcyclical activity. However, the postwar fluctuations in cellulosic consumption are similar to those in the prewar. Finally, while the subcycle activity extends through at least three of the four major fiber categories of the industry in both the prewar and the postwar, it is apparently least strong in the cotton fiber sector.

³⁴

The individual spectral estimates indicate that subcyclical activity is shared by all three major sectors of the industry. This is reinforced by the high coherence estimates between the series, presented later in Table 7.2, which indicate that the textile cycle has penetrated the different fiber sectors of the industry, both before and after the Second World War.

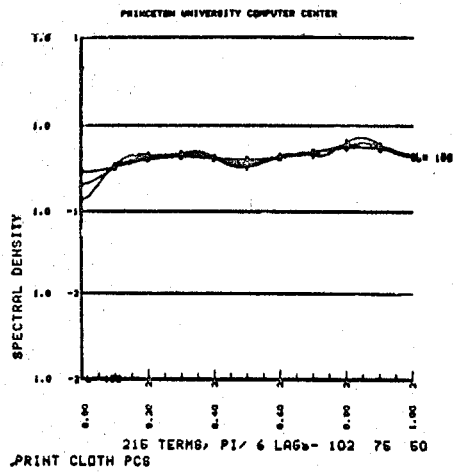


Figure 7.7. Spectral Density Function for Cotton Print Cloth Prices, Monthly, 1923-1941.

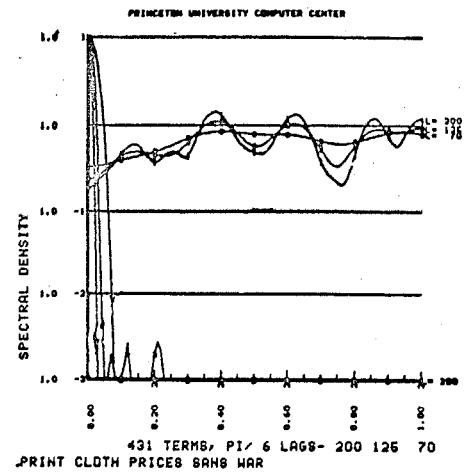


Figure 7.8. Spectral Density Function for Cotton Print Cloth Prices, Monthly, 1923-1941 and 1947-1965.

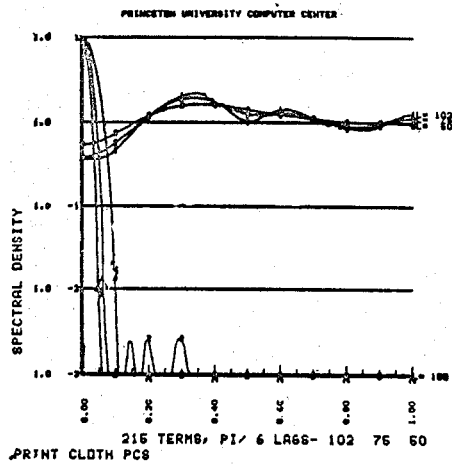


Figure 7.9. Spectral Density Function for Cotton Print Cloth Prices, Monthly, 1947-1965.

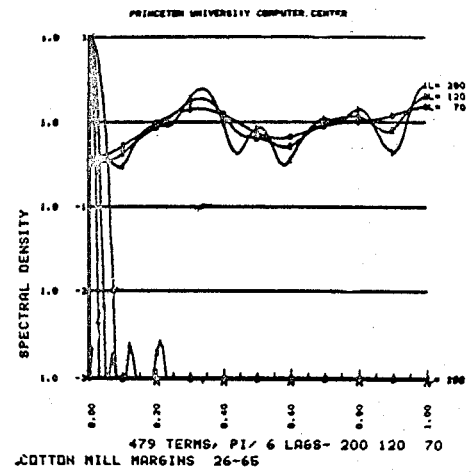


Figure 7.10. Spectral Density Function for Cotton Mill Margins, Monthly, 1926-1965.

There is no indication of growth cycles in either the cotton print cloth price series or the cotton mill margin series, which represents the difference between the average price of cloth and the price of cotton. The spectral density functions of the transformed monthly series are presented in Figures 7.7 through 7.10. Only the print cloth price series has been divided for the prewar and the postwar. The abscissa has been transformed as above, so that the unit frequency corresponds to an annual cycle. The three print cloth price spectral density functions are similar, with little indication of movement in the subcycle frequencies. These spectral functions are very similar to those of "white noise," estimated for other economic price series, especially stock market prices³⁵. The cotton mill margin series does have a rounded peak in the forty month frequency range; the peak is not very prominent, but it does indicate some long-run movement.³⁶

We investigate whether the fluctuations in mill consumption have reduced the productive efficiency of the industry over time. Ideally, we would analyze the costs of production and their variation over the cycle³⁷. We do not have the necessary data

³⁵ See Godfrey, Granger, and Morgenstern, op.cit.

³⁶ The monthly print cloth price index is compiled by the Bureau of Labor Statistics and is reported in United States Department of Labor, Wholesale Prices and Price Indexes, Bureau of Labor Statistics, Washington, D.C. The cotton mill margin series is reported in various issues of United States Department of Agriculture, Cotton Situation, Economic Research Service, Washington, D.C., bimonthly.

³⁷ Howrey has suggested the specification of a dynamic cost function, but the idea has not been pursued.

and thus look to other possible indicators of reduced efficiency. One indication is that the fluctuations have been highly publicized and are a source of complaint in the industry³⁸.

A second indication is that similar movements in other industries are less severe than the textile fluctuations. Specifically, we compute the gain in the textile consumption series over that of the Federal Reserve Board Index of Total Industrial Production³⁹. The Index of Industrial Production is used to represent the average cyclical behavior in the economy. The prewar and postwar cross-spectral statistics are presented in Table 7.1. The Index of Total Industrial Production is considered as the exogenous variable. For both the prewar and the postwar, the gain statistics are greater than unity, indicating

³⁸

For example, see Robert C. Shook, *op.cit.*, p. 22; Miernyk and Zymelman, *op.cit.*; and Hiram S. Davis, "Inventory Trends in Textile Production and Distribution" (The Textile Foundation, Washington, D.C., and Industrial Research Department, Wharton School of Finance and Commerce, University of Pennsylvania, Philadelphia, 1941).

³⁹

The Index of Total Industrial Production has been used to represent the productive activity in other industries. The index itself is averaged over durable and nondurable manufacturing and mining and utilities. One difficulty in using the series is that textile production is a component of the index, so that there is automatically some simultaneity between the series. We have also used the Federal Reserve Board's Index of Nondurable Manufacturers' Production to represent activity in other industries. The gains of fiber consumption over aggregate nondurable production are presented in Table 7.1. These gains are greater than those over the Total Production Index, but these statistics must be interpreted cautiously because of the simultaneity between the nondurable production and the fiber consumption series. Total textile production represents about 8% of the nondurable manufacturing, although the percentage for the individual fibers is less. The uncommonly high phase angle estimates for the series, however, reinforce the suspicion of disruptive simultaneity. Both indices are reported in various issues and statistical supplements to Board of Governors of the Federal Reserve System, Federal Reserve Bulletin, The Federal Reserve System, Washington, C.D.

TABLE 7.1. COHERENCE, PHASE ANGLE, GAIN: TEXTILE FIBER MILL CONSUMPTION AND INDICES OF INDUSTRIAL PRODUCTION, MONTHLY, PREWAR AND POSTWAR.

PREWAR 1923-1941			PREWAR			POSTWAR					
Dependent Variable	Independent Variable	Coherence	Phase Angle ^a (in months)*	Gain ^b	Frequency	Dependent Variable	Independent Variable	Coherence	Phase Angle (in months)	Gain	Frequency
Cotton Consumption	Total Index of Industrial Production	.80	1.0	1.41	.5 π	Cotton Consumption	Index of Nondurable Manufacturing	.91	.2	2.04	.5 π
Wool Consumption	Same as above	.82	1.0	3.10	.5 π	Wool Consumption	Same as above	.82	.4	3.88	.5 π
Cellulosic Consumption	Same as above	.60	1.6	2.12	.5 π	Cellulosic Consumption	Same as above	.77	1.4	2.94	.5 π
POSTWAR 1947-1965			POSTWAR			POSTWAR			POSTWAR		
Cotton Consumption	Total Index of Industrial Production	.80	.2	1.12	.425 π	Cotton Consumption	Index of Nondurable Manufacturing	.57	5.4	1.73	.425 π
Wool Consumption	Same as above	.86	1.1	2.42	.375 π	Wool Consumption	Same as above	.80	5.3	4.55	.375 π
Cellulosic Consumption	Same as above	.88	1.1	1.94	.45 π	Cellulosic Consumption	Same as above	.60	3.7	3.21	.45 π

^a A positive sign indicates that fiber consumption leads the independent variable.

^b The gain estimates have been corrected for the standard deviations of the transformed series.

that the subcycles in the rate of growth of textile activity have a greater amplitude than those experienced on the average in the economy. A comparison of the prewar and postwar statistics indicates that since the War the severity of the textile subcycle has diminished relative to the average fluctuations elsewhere in the economy, although the postwar textile fluctuations are still more severe than those in the production index. In the different sectors in the industry, fluctuations in cotton consumption are not much greater than the economy average, while those in wool and cellulosic fiber consumption are decidedly more severe than those in the production index. Wool consumption experiences the greatest volatility with a prewar gain of 3.10 and a postwar gain of 2.4. Cellulosic fiber is less volatile with gains near 2.0. Finally, the coherence between the series is extremely high, indicating that the above "regressions" have a good fit.

We also investigate the magnitude and the timing of the fluctuations in the different sectors of the textile industry, examining the gain and the phase angle between the various series at the subcycle frequency. The gain statistic is estimated with cotton consumption as the independent (input) variable and with wool or cellulosic fiber consumption as the dependent variable. As in regression analysis, the choice of the input and output variable is not arbitrary and should be specified. However, there is little evidence that wool consumption, for example, should be a function of cotton consumption and not vice versa⁴⁰. This possible source of simultaneity limits the appropriateness of the following gain discussion. Table 7.2 presents the cross-spectral statistics.

⁴⁰

The choice of cotton as the dependent variable is suggested by Miernyk and Zymelman, op.cit., p. 4, in their discussion of the propagation of the cycle over the industry.

Table 7.2. Coherence and Gain: Textile Fiber Mill Consumption, Monthly, Prewar and Postwar.

Prewar 1923-1941		Postwar 1947-1965					
Dependent Variable	Independent Variable	Coherence ^b	Gain ^a	Dependent Variable	Independent Variable	Coherence	Gain
Wool Consumption	Cotton Consumption	.73	1.75	Wool Consumption	Cotton Consumption	.78	1.83
Cellulosic Consumption	Cotton Consumption	.86	1.40	Cellulosic Consumption	Cotton Consumption	.84	1.53

at frequency = $.5\pi$

at frequency = $.42\pi$

^aThe gain statistics have been adjusted for the standard deviations of the transformed series. The gain statistics do not exhibit much fluctuation in the adjacent subcycle frequency range not recorded.

^bThe estimated coherence has its peak in the subcycle frequency range. The high coherence indicates that the gain and phase angle estimates are more reliable. Also, the phase angle does not alter in the subcycle range; this increases the creditability of the coherence estimate.

The gain statistics are all greater than unity, both before and after the War, so that the cotton textile industry experiences the least severe fluctuations. This result is contrary to the argument presented above that the cotton industry experiences wider fluctuations. The phase angle estimates are close to zero, so that it is difficult to determine whether the fiber consumption series lead or lag each other at the subcycle frequencies. The claim that cotton textile activity leads the others seems to be inaccurate.

Cross-spectral techniques also are used to test the proposed magnification of fluctuations in mill consumption over those in end use purchases^{41,42}. We do not attempt to explain the source of such amplification, which would require a general equilibrium model to encompass the simultaneous effect of the interactions along the marketing chain. Rather, we determine with cross-spectral techniques whether the proposed magnification takes place.

One problem with testing the hypothesis is the unavailability of orders data at the apparel and retail levels. The Federal Reserve Index of Apparel Production is used to proxy the orders placed by the cutters⁴³. To the extent that apparel production is to order and not from stock, the production series will reflect the orders series, with a possible lag. Since the

⁴¹ The major participants along the production-marketing sequence have been described in Chapter 2.

⁴² See especially Stanback, op.cit., p. 181; Miernyk and Zymelman, op.cit., p. 33.

⁴³ The Apparel Production Index is compiled by and reported in Board of Governors of the Federal Reserve System, op.cit., various issues and statistical supplements.

cutters are under pressure for rapid delivery, it is possible that the lag is short⁴⁴.

To test the hypothesis of amplification, we compare the magnitude of the fluctuation in mill fiber consumption with that in apparel production, computing the gain between the two series. The Apparel Production Index is used as the independent variable, although apparel production may depend somewhat upon fiber usage. While we cannot test the strength of the possible feedback, we do note that the observation period of one month is so short that the relationship may be recursive rather than simultaneous. However, one month is a long time span when compared to apparel seasons; second, orders are placed by telephone and can be done very quickly.

The cross-spectral statistics indicate that fluctuations in textile mill consumption do have a greater amplitude than those in apparel production. The gains in the consumption of the three major fiber categories over the level of apparel production are all greater than unity. The gain in wool is 2.85, but this probably exaggerates the amplitude of wool fiber usage over wool apparel production⁴⁵. Also, the distinct possibility of

⁴⁴ The original plan of the analysis was to investigate the gain in the percentage rate of change of the apparel production series over that of retail sales and the gain of fiber consumption over apparel production. This would indicate where and to what extent fluctuations in the sales of finished textile products are amplified as their impulses are passed down the line to the mills. The retail sales series, however, produces very inconclusive results and the coherence is so low that it precludes meaningful gain estimates. We are unable, then, to interpret the relationship between movements in retail sales and apparel production.

⁴⁵ Since the apparel production series is not disaggregated according to fiber content, not too much significance can be attached to the relative gain of the different fiber groups, since the apparel production for that particular group may be (and most likely is) fluctuating more than the average represented by the Apparel Production Index.

TABLE 7.3. COHERENCE, PHASE ANGLE, GAIN: TEXTILE FIBER MILL CONSUMPTION, INDEX OF APPAREL PRODUCTION, AND PERSONAL DISPOSABLE INCOME, MONTHLY, POSTWAR.

POSTWAR 1947-1965											
Dependent Variable	Independent Variable	Coherence	Phase Angle (in months)	Gain	Frequency	Dependent Variable	Independent Variable	Coherence	Phase Angle (in months)	Gain	Frequency
Cotton Consumption	Index of Apparel Production	.75	-.2	1.33	.425 [#]	Cotton Consumption	Personal Disposable Income	.75	1.2	2.9	.425 [#]
Wool Consumption	As above	.77	.0	2.85	.375 [#]	Wool Consumption	As above	.65	2.4	4.9	.375 [#]
Cellulosic Consumption	As above	.71	.2	2.28	.450 [#]	Cellulosic Consumption	As above	.77	2.0	5.3	.450 [#]

simultaneity may be affecting the estimates in an unpredictable manner.

Table 7.3 also presents the coherence and the phase angle between the transformed fiber consumption and apparel production series. The coherences are between .71 and .77, indicating that the subcyclical frequency movement in both series is highly correlated. The textile cycle, then, appears in the apparel production series but with reduced severity⁴⁶. The estimated phase angles indicate that apparel production may lead cotton consumption very slightly and may lag behind cellulosic shipments. The phase angles are probably not different from zero, so it is impossible to establish whether apparel production leads or lags fiber consumption. A priori, it is not certain whether there should be a lead or a lag, since production in the textile mill is both to order and to stock.

We comment briefly on the regularity of the textile cycle versus other industry cycles, comparing the spectrum of the Total Industrial Production Index with that of each of the fiber consumption series. The prewar and postwar spectral density functions of the transformed production indices are presented in Figures 7.12 through 7.15 (the coherence estimates are contained in Table 7.1). Again the abscissa of the spectral density functions has been transformed so that the annual frequency is 1.0π . The prewar density functions for the Index of Total Production has a very slight peak at the twenty-four month frequency, but the peak is not prominent and does not appear to differ from the power in adjacent frequency bands. Second, the peak is not nearly so prominent as those in the prewar fiber consumption functions. Thus the prewar textile cycle is

⁴⁶

Figure 7.11 presents the spectral density function for the transformed apparel production series. There is indication of some independent movement in the neighborhood of thirty-three months.

Figure 7.11. Spectral Density Function for Apparel Production Index, Monthly, 1947-1965.

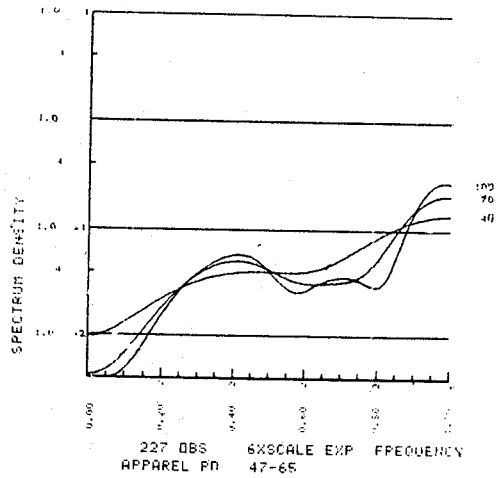


Figure 7.12. Spectral Density Function for Total Production Index, Monthly, 1923-1941.

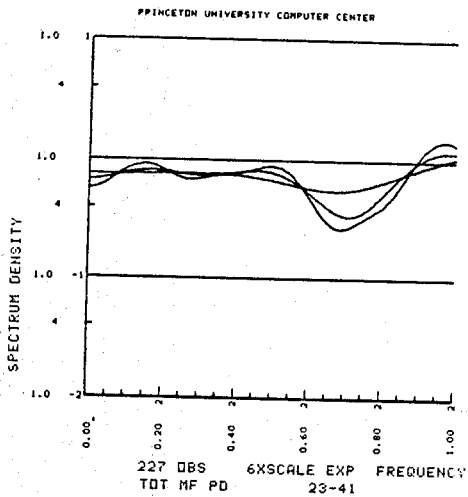


Figure 7.13. Spectral Density Function for Total Production Index, Monthly, 1947-1965.

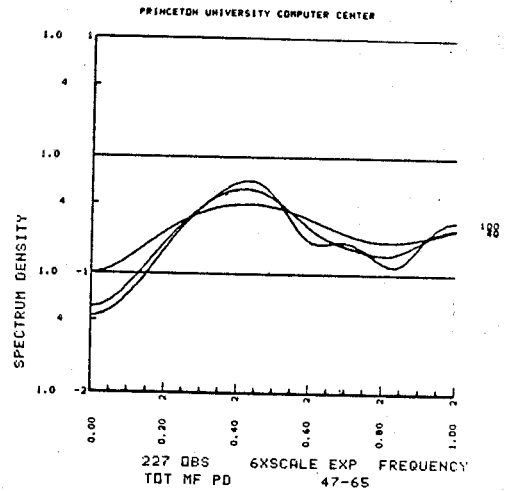


Figure 7.14. Spectral Density Function for Non-durable Manufacturing Production Index, Monthly, 1923-1941.

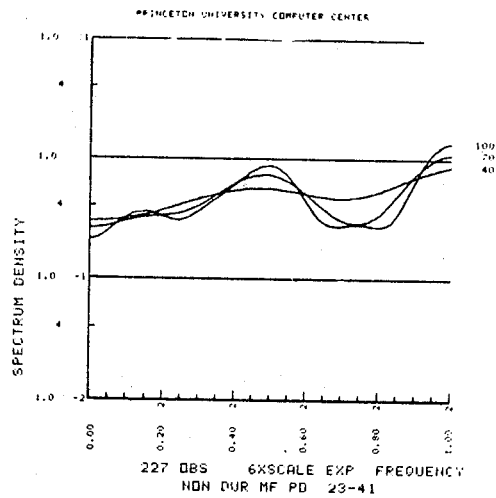
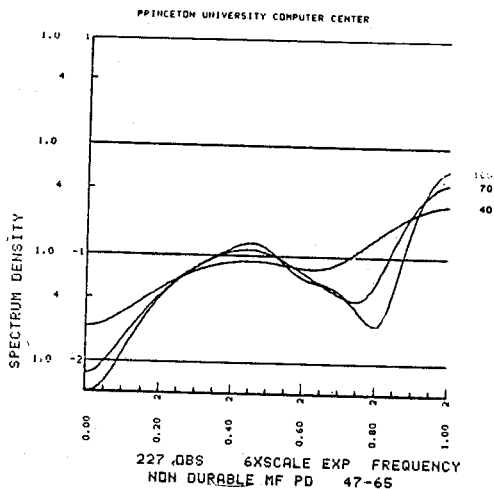


Figure 7.15. Spectral Density Function for Non-durable Manufacturing Production Index, Monthly, 1947-1965.



apparently more regular than average industrial movement. In the postwar the industrial production spectral density function has prominent power in the subcyclical frequency range, with a smoothed peak centered at $.42\pi$, corresponding to a period of twenty-nine months. Furthermore, the peak is more prominent than the subcycle peak in each of the cotton, wool, and cellulosic fiber functions. No longer does the textile cycle appear to be more regular than movements in productive activity elsewhere in the economy⁴⁷.

Finally, by investigating the coherence between fiber consumption and various measures of aggregate purchasing behavior, we examine somewhat superficially whether the textile cycle is supply oriented. If the level of raw material supply is determined exogenously, we would not expect a high coherence; however, the coherence between fiber consumption and the Index of Total Industrial Production is almost always greater than .8, and that between fiber consumption and disposable income is greater than .65. However, movements in the level of the raw material supply still may generate or perpetuate mill production cycles, since supply level movements may coincide with those in the aggregate indicators. Also, a low coherence would not necessarily indicate supply domination; low coherence would be compatible with several other hypotheses, including that of internal regeneration which states that the cycle has little or nothing to do with ultimate sales of finished textile goods.

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In both the prewar and postwar spectral density functions of the Index of Nondurable Production, there is indication of prominent, subcyclical fluctuations. (See Figures 7.14 and 7.15). In both the prewar and the postwar, the textile cycle does not appear to be more regular. The tendency for subcycles to appear more strongly in nondurable production than in total industrial production may in part be due to the fact that the nondurable series includes textile production as a much larger component.

and is generated and perpetuated by expectations held by producers along the production-marketing sequence⁴⁸.

7.5. Overview of the Textile Cycle

Several hypotheses describing short-term cycles in the percentage rate of change of textile productive activity have been presented and subsequently tested with spectral and cross-spectral techniques. The final product of the exercise is a rigorous description of the textile cycle. There is evidence of short-term subcycles in the percentage rate of change of wool, cotton, and cellulosic fiber consumption. During the prewar, subcycle fluctuations are prominent in all the fiber categories, indicating the existence of a clearly delineated textile cycle. In the postwar, the fluctuations in only cellulosic fiber consumption are as prominent as those in the prewar, since the spectral density functions for the two natural fibers have less prominent peaks in the postwar than in the prewar. Also, the postwar oscillations are individually different and have a greater average length; in the prewar, the cycles are all twenty-four months in length, while in the postwar, the wool subcycle has lengthened to thirty-three months and the cotton subcycle, to twenty-eight months. Finally, while the cycle occurs in the three major sectors investigated, its amplitude is not the same in each sector but is weakest for cotton and strongest for wool.

Growth subcycles are observed not only in mill activity but also in the Total Industrial Production and Apparel Production Indices. The textile cycle is different from these other subcycles, since it has a greater amplitude than both. Second, it is more regular than that in total industrial production during the prewar but is less regular during the

⁴⁸ Mack, "Notes on Subcycles in Theory and Practice," op.cit., pp. 183-185, and Stanback, op.cit.

postwar. The lead-lag relationship between the total production and textile consumption series indicates a slight lead in the fiber series, but the result is inconclusive.

Several features of the above description deserve particular attention because they point to possible explanations of the cycle. A prominent feature of the textile cycle is that similar subcycle activity is shared by total industrial production, disposable income, and apparel production. The high correlation is reinforced by the regression results which indicate that annual movements in disposable income affect those in fiber consumption. The textile cycle appears to be a generalization of subcycles in the economy, and the ubiquity of the cycle throughout the major sectors of the industry may stem from the sectors' mutual dependence upon the motion of the economy. This feature of the cycle is compatible with theories which stress the sensitivity of mill activity to movements in demand for final textile products⁴⁹. The result is less compatible with theories which stress either raw material movements or internal generation due to speculation^{50, 51, 52}.

A second prominent feature of the textile cycle is that its amplitude is greater than that of the subcycles in both the

⁴⁹ See Miernyk and Zymelman, op.cit.

⁵⁰ See Abramovitz, op.cit.

⁵¹ See Stanback, op.cit.

⁵² The high coherence does not eliminate the possibility of the operation of any of the three mechanisms. For example, movements in raw material supply may coincide with those in aggregate economic activity, or, likewise, the subcycles generated in textile activity and elsewhere in the economy may have nothing to do with each other. The point here is that we must be careful not to equate correlation (coherence) and causality.

Total Industrial Production Index and the Apparel Production Index. This result indicates that the cycle is accentuated by the production, inventory, and sales decisions along the production-marketing sequence and especially between the apparel producers and the mill. The result of increased amplitude, along with that of high coherence, is compatible with the explanation that oscillations in mill activity are by and large responses to the stimuli of general business conditions, but that they are amplified through the internal reactions within the chain of producers which manufacture textile products⁵³. It suggests that a model of the textile cycle must encompass both dependence upon end use demand and the intricacies of the market structure, the ways in which goods move from plant to plant, the time lags that are involved, expectations as to prices, and management responses to internal conditions. The further result that fluctuations in cotton activity are less than those in wool or rayon-acetate activity detracts somewhat from the plausibility of such a model, since theories which have stressed the internal reaction of the industry have focused on the cotton sector. In the cotton industry, internal reaction is supposedly most influential because there is an active (but declining) grey cloth market and because the market structure is relatively more intricate and less constrained by buyer-seller relationships.

A third prominent feature of the textile cycle is that during the postwar it has lengthened slightly and, for cotton and wool consumption, is much less clearly perceivable. The recent dampening is compatible with an explanation which stresses market structure changes including more sophisticated inventory control and production policies, the decreasing importance of the converter with increased integration, increased emphasis on diversified products, and secular decline in overcapacity.

⁵³ See Miernyk and Zymelman, op.cit.

Stanback has suggested that such forces have been influential⁵⁴.

A fourth prominent feature of the subcycle is that it is experienced both in the natural and in the man-made fiber sectors. This result is compatible with theories which need not stress the peculiarities of raw material supply and indicates that the increased market share of man-made fibers need not necessarily diminish the fluctuations.

Appendix 7.A. The Typical Spectral Shape

It is mentioned in the text that for certain technical and analytical reasons, transformed data have been used in the analysis. The decision to use transformed data can be better understood by examining the problems encountered in attempting to interpret the spectral density functions estimated for the levels of fiber consumption. These functions tend to have extremely high power at the very low frequencies (or the very high periods). The existence of such high power is not uncommon for economic data; in fact, Granger has observed that much economic data possess this property and has called it the "typical spectral shape"⁵⁵. Possible causes of this high power are the existence of a trend in the data or nonsystematic shifts resulting from special market conditions. Since we are not interested here in movements with such long periods, we would like to ignore this frequency range and concentrate on the higher ranges of interest. Unfortunately, the existence of the high power complicates the interpretation of the power in the higher frequencies. First, the high power may distort the spectral estimates in the higher frequency ranges. Second, its existence raises the question of whether the power in the higher ranges is so relatively small that it is unimportant and represents small and unnoticed ripples.

⁵⁴ See Stanback, op.cit., p. 181.

⁵⁵ See Granger, "The Typical Spectral Shape of an Economic Variable," op.cit.

The high power concentrated in the low frequency ranges may bias the spectral estimates of the higher frequencies considerably⁵⁶. This source of bias, called leakage, is normally confined to adjacent frequencies, but when the intensity is a thousand times as great at the low frequencies, the estimated spectral density function may differ significantly from the theoretical density function at high frequencies⁵⁷. The power in the low frequencies can almost be a nuisance; it provides information about which only tentative conclusions can be made and it complicates the reliability of information which is potentially useful. Fortunately, it is possible to remove the ill effects of these low frequency components; granted, this will limit the scope of the analysis to short-term movements (here, four years and less), but it is these movements which most interest us. One method is to actually remove the low frequencies by first fitting a polynomial to the data and then investigating the remaining deviations about this "trend". Both linear and logarithmic trends are fitted to the textile

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Nerlove explains that the window through which one looks at a spectrum does not concentrate all its weight at a designated frequency, but disseminates some of this weight, however small, at all other frequencies. This phenomenon is called leakage. This permits the possibility that extremely high power at some frequencies will distort spectral estimates at other frequencies, some of which possibly being quite distant from those at which the high power is present. This problem can be severe in economic time series. It is compounded by the limited number of observations in most series which limits the number lags which can be taken and thus the potential shrinkage of the window; see Nerlove, op.cit., pp. 251-257.

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Another possible source of spurious power is called aliasing. Because observations are taken at discrete intervals, harmonic components of the series with periods shorter than twice the period of observation cannot be discerned. But even if these high frequency components are of no particular interest they may cause spurious power at frequencies less than one-half cycles per unit time, power operating well above the observable frequency range. See Nerlove, op.cit., p. 251.

series; the rationalization for this procedure, that the polynomial trend is an element of nonstationarity, complies with intuitive notions about the progression of the economy. These operations, however, do not significantly alter the spectra of many of the textile series. The long-term tendencies in the industry cannot be defined so simply. A second approach involves abstracting from these long-term movements by taking first differences, disregarding the wandering of the series. Gradual long-run changes in the level of the series will be reflected in the first difference series but will be deemphasized. The use of first differences (of the series or of the logarithms of the series) is generally successful in removing the contaminating influence of the low frequencies. The series no longer represent the levels of industrial activity but rather the rate of change, or, in the case of logarithmic first differences, the percentage rate of change (which approximates the rate of growth) of mill activity.

CHAPTER 8

CONCLUDING REMARKS

8.1. Summary of the Major Results

The analysis of textile fiber consumption behavior has two major points of focus. The first is to specify and to estimate two dynamic models to explain fiber mill consumption. The analysis uses both prewar and postwar annual data for the individual fiber categories of cotton, apparel wool, carpet wool, rayon-acetate filament yarn, rayon-acetate staple, synthetic filament yarn, and synthetic staple. The second focal point is the spectral analysis of monthly consumption time series to investigate hypotheses that have been formulated about short-run cycles in textile activity.

The dynamic models are very successful in explaining fiber consumption behavior. Economic factors are major and important determinants, although their impact is tempered by habitual, technological, and institutional rigidities, so that present consumption is also dependent upon past consumption patterns. Economic factors are important for even synthetic fiber usage, which does not appear to be so dependent upon technological developments and promotional success as previously suggested. The specification of the models does not account directly for the activity of the intermediate producing units between the mill and the retailer or for other important factors which are not easily quantifiable, such as style trends toward lighter clothing, increased air conditioning and winter heating, changes in the age-sex distribution of the population, and the increase in suburban living.

Two of the most important economic factors explaining fiber consumption are the level of per capita disposable income and the fiber price, although disposable income is a weak determinant of apparel wool and it is difficult to isolate the effects of disposable income on rayon and acetate fiber consumption.

For the natural and rayon-acetate fibers, the price of synthetic fiber is also an important determinant and indicates gross substitutability between the synthetic fibers and the natural fibers and between the synthetic fibers and the rayon-acetate fibers. A disappointing aspect of the analysis is that more extensive, significant fiber interrelationships cannot be isolated.

The coefficient estimates are reasonable, significant, and fit into consistent patterns. The general pattern of the estimates indicates that there are behavior differences between the consumption of man-made and natural fibers and between that of the different classes of wool and man-made fiber. Between the natural and man-made fibers, the income and own price elasticities are much greater for man-made fiber consumption, but the effects of changes in these variables take much longer to exert their full impact. The elasticities are larger to some extent both because the variables proxy technological quality improvements and the success of promotional campaigns and because man-made fibers have introduced style and luxury into some previously staple items. The more gradual response of man-made fiber consumption to changes in price and income is attributed to the reluctance of consumers to identify with new products and the additional knowledge, technique, and material necessary to process the newer fiber. The estimates further indicate that it is useful to distinguish between classes of wool, rayon-acetate, and synthetic fiber. For example, carpet wool reacts much more strongly to changes in per capita disposable income than apparel wool, but the reaction is much slower. The slower reaction of carpet wool is consistent with the durable nature of rugs and thus consumer reluctance to depreciate artificially their present carpeting. Both cellulosic and non-cellulosic staple and filament yarn differ with respect to their reaction to the other fibers. Finally, the reasonableness, consistency, and significance of the different estimates are very strong indications of a successful specification.

The dynamic models provide reasonable forecasts of consumption. Short-run, one year projections indicate a decline in natural and rayon-acetate per capita fiber consumption in 1967, a decline which has been supported in preliminary data. It is impressive that the models predict the direction of change, especially for cotton, apparel wool, and rayon-acetate, since their consumption rose continuously during the middle sixties. The one year projections indicate an increase in synthetic fiber consumption during 1966 and 1967, which is also consistent with preliminary data. A second set of forecasts projects consumption for the five years beyond the period of estimation. They indicate that per capita cotton consumption will dip in 1967 and then rise continuously through 1971 and that both apparel and carpet wool per capita consumption will continue to fall through 1971, with the latter falling more rapidly. The projections further indicate that cellulosic staple per capita consumption will rise gradually and cellulosic filament yarn per capita consumption will fall gradually through 1971 and that both synthetic staple and filament yarn per capita consumption will continue to rise, with staple consumption passing filament yarn about 1970. Also, by 1970 the market share of cotton will still be the largest, 48%, with synthetic fiber second with 33%, followed by cellulosic fiber and wool with shares of 15% and 3%. These long-run forecasts are based upon the assumption that the independent variables, the prices and income, will continue their trends of the last ten years.

The model also incorporates the disruptive effects of the large scale introduction of the synthetic fibers in the middle fifties. Even though the price of synthetic fiber is included (in its reciprocal form) in the natural and cellulosic fiber equations, the introduction may have caused a more fundamental structural change in the natural and cellulosic equations, altering all or some of the coefficients. However, only in the carpet wool equation is there significant evidence of such structural change. It is not surprising that the model does

not easily incorporate the quick and massive assault of man-made staple carpet fiber upon wool fiber. The structural change has been accounted for in the final form of the carpet wool model by replacing the synthetic fiber price by the level of synthetic staple mill consumption, which accounts implicitly for inroads of synthetic staple upon carpet wool.

The models simulate well over their periods of observation, but they do uncover large bias and possible autocorrelation in a few cases. Models which simulate well also have high coefficients of determination and reasonable Durbin-Watson statistics; thus, the simulation experience reinforces conclusions as to the goodness of fit based on the more traditional measures. It is also interesting that the dynamic model apparently has been able to sidestep the autocorrelation evidenced in static fiber models and that in those cases where the Durbin-Watson statistic is outside the acceptable range, the simulation results indicate a relatively large discrepancy in the variance of the actual and the simulated series.

Several aspects of the specification of the models are of interest. First, the adjustment mechanism can be shown to be that which minimizes the costs over time of being in disequilibrium, thus providing a theoretical underpinning for the model. Second, upon examination of the stochastic properties of the dynamic models, the Bergstrom model produces serially correlated disturbances under normal assumptions, while the Nerlove model does not. In the specification we also present the most likely sources of observation error for the data and then adopt a strategy to minimize the possibility of observation error by avoiding series, or specific observations, which appear especially vulnerable.

The second major division of the analysis investigates claims of the alleged textile cycle. Spectral analysis of time series is used to test hypotheses that have been advanced to describe the cycle. The final product of the analysis is the first rigorous description of the properties of the textile

cycle. The study concentrates on monthly mill consumption data, which are the best single measure of mill activity, but does introduce other related series. The mill consumption series themselves display the typical spectral shape, with excessive power in the lower frequencies. The data used in the analysis are transformed by first computing their logarithms and then taking first differences. The resultant series approximate the rate of growth of textile activity. The transformation permits statistically more meaningful estimates and is dictated analytically to isolate short-term movements in an environment of irregular growth.

There is indication of a short-run cycle of about twenty-four to thirty months in the rate of growth of fiber consumption in both the prewar (1923-1941) and the postwar (1947-1965) periods. This oscillation is shared by the cotton, wool, and cellulosic fiber sections (the synthetic fiber sector has not been investigated). The cycle for wool and cotton is less pronounced and longer in the postwar, while that for cellulosic fiber is as prominent and as short in the postwar. We attribute the dampening to more sophisticated inventory control and mill management, to the integration movement in textiles, which has resulted in the decreased importance of grey cloth markets and an increased emphasis upon diversified products, and to the secular decline in overcapacity.

Second, the fluctuations in all sectors of the industry are highly correlated with subcyclical oscillations in the Index of Total Industrial Production, in per capita disposable income, and in the Index of Apparel Production. Also, during both the prewar and the postwar the textile cycles have a greater amplitude than those in the Index of Total Production. The apparel production data are available for only the postwar, and again, the amplitude of the fluctuation in textile activity is greater. The high correlation between fluctuations of the rate of growth of mill activity throughout the industry and those in both total industrial and apparel production is

anticipated by the regression analysis, which shows that the demand for textile products is a major determinant of fiber consumption. The regression and spectral results together are not inconsistent with the hypothesis that the short-run fluctuations in the major sectors of the industry are derived from movements in the demand for textile products. The further observation of increased amplitude is not inconsistent with the proposition that while the fluctuations may derive from movements in aggregate demand, a magnified response is produced by activity within the internal structure of the textile industry. We are not able to measure the extent of the magnification between the retailer and the cutter, but there is evidence of amplification between the cutter and the textile mill.

8.2. Suggestions for Future Research

There are a number of extensions of the analysis. The first is a more detailed study of the growth of synthetic fibers, concentrating upon the relative rates of growth in the different product areas and determining if the growth rates are significantly different from each other. In Chapter 5 we propose a trend fitting procedure which, based on preliminary results, presents interesting insights into the pattern of growth. Second, the analysis can be expanded to explain and to forecast mill consumption in several other countries. Of particular interest are inter- and intra-regional differences in income and price elasticities and the extent to which consumption data can be pooled over different countries and different fibers within a region. We are particularly interested in the income elasticities which indicate relative growth potential. Preliminary studies indicate that there may be

important behavioral differences between countries¹. Because of the success with disaggregating between classes of fiber, we suggest continued disaggregation where possible. A third extension of the study is a detailed analysis of the similarities and differences between the short-term fluctuations in other, nondurable industries. Finally, the behavior of the units operating between the retailer and the mill can be introduced explicitly into the explanation of mill fiber consumption. It appears that such work is necessary to explain the magnification in the textile cycle. The work would involve a detailed description of the market for grey cloth, which in itself would be an interesting and valuable contribution to the literature on market structure. However, extensive empirical work here may encounter difficulties of insufficient data.

¹ Interorganization Research Program on Prospective Trends in Consumption of Textile Fibers, Prospective Trends in Consumption of Textile Fibers, Part I, II, III, IV (Secretariat of the International Cotton Advisory Committee, Washington, D.C., March 1962); B. P. Philpott, "Factors Affecting Demand for Wool Textiles in New Zealand," Publication No. 11, Agricultural Economics Research Unit, Lincoln College, New Zealand, March, 1965; and William H. Witherell, "Dynamics of the International Wool Market: An Econometric Analysis," Research Memorandum No. 91, Econometric Research Program, Princeton, New Jersey, September, 1967.

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ABSTRACT

The study focuses on two major problems. The first is to explain empirically the determinants of United States textile mill fiber usage (consumption) and to predict fiber usage. The second is to describe rigorously the nature of the alleged textile cycle in the rate of growth of mill activity.

Single equation, dynamic, autoregressive models are specified and estimated, using prewar and postwar annual time series data over seven separate fiber categories (cotton, apparel wool, carpet wool, rayon-acetate staple and filament yarn, and synthetic staple and filament yarn). The explanatory variables within the dynamic framework include per capita real disposable income, exports and imports of fiber and fiber products, the price of the fiber being studied, and the prices of other fibers. The models do not account for such factors as style trends, increased air-conditioning and winter heating, and regional population shifts, nor do they account directly for the activity of intermediate textile product manufacturers between the mill and the public.

To describe the "textile cycle," spectral analysis is used to test hypotheses which concern the existence of a cycle in both the prewar and the postwar, its length, its similarity over different fiber categories, and its similarity with short cycles in other industries. The data used in the analysis are monthly mill consumption series which have been transformed to approximate their rate of growth. The cotton, wool, and rayon-acetate sectors of the industry are studied separately during both the prewar (1923-1941) and the postwar (1947-1965).

When studied in a dynamic context, economic factors appear to be important determinants of textile fiber consumption. Per capita disposable income and the own price are the most consistently significant factors, while import-export flows and other prices appear to be important for only certain fibers. The impact of these factors differs among fibers. For example, the income and own price elasticities are much greater for man-made fibers than for the natural fibers, although changes in these variables take much longer to exert their full impact. The apparent dissimilarity in structure for the different fibers reinforces the decision not to use aggregate data.

It is speculated that the rapid introduction of synthetic fibers was so disruptive that it may have caused a fundamental shift in the consumption functions of the natural and cellulosic fibers. However, significant change occurred only in the carpet wool equation and then not until the middle sixties.

Forecasts for the five years beyond 1966 indicate that the market shares of cotton, wool, and rayon-acetate will decline, with only that of synthetic fiber rising. By 1970, the projected market share of cotton will still be the largest, with 48%, with synthetic fiber second with 33%, followed by rayon-acetate fiber and wool with shares of 15% and 3%.

Claims of an alleged textile cycle in the rate of growth of fiber consumption appear to have had some foundation. There is indication of a short-run, twenty-four to thirty month cycle in each of the major sectors of the industry during the prewar (1923-1941). These cycles, however, are less pronounced and longer in the postwar. The results are also consistent with the hypothesis that the fluctuations in mill activity are derived from movements in the demand for final textile products which are then magnified over the internal structure of the industry between the public and the mill.