DYNAMICS OF THE INTERNATIONAL WOOL MARKET: AN ECONOMETRIC ANALYSIS

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ABSTRACT

This study is an empirical analysis of the international market for raw wool. The object of this study is to build and estimate an annual simultaneous equation model of the world wool market for the years 1949 to 1964. The chief purpose of this model is to determine the most important dynamic aspects of this market and, in particular, the causes of the high variability of world wool prices.

The supply side of the model is constructed by specifying and estimating equations explaining the seasonal production of raw wool in six major wool-producing countries and a "Rest-of-the-World" sector as distributed-lag functions of wool prices, prices of alternate crops (wheat and beef), prices of the joint product, lamb, weather, technological progress and government support or reserve prices for wool. In general, wool production is found to respond weakly and only after a long lag to these factors. Five equations explaining end-of-the-season stocks of raw wool in five major producing countries as functions of current and expected future wool prices and, for Argentina and Uruguay, of government trade policies, complete the supply side of the model.

The demand side of the model is constructed by specifying and estimating equations explaining the annual net consumption of wool (mill consumption of raw wool plus net imports of semi-finished and finished wool products) in eight major consuming countries and a "Rest-of-the-World" sector as distributed-lag functions of wool prices, income, net consumption of synthetic fibers and, for some countries, "dummy" variables which take account of the disruptive effects of the Korean and Algerian Wars. In contrast to the fairly uniform results obtained for the wool production equations, the effects on wool consumption of a change in one of the explanatory variables are found to vary widely for the countries studied. In general, however, wool

consumption is found to be inelastic with respect to wool prices, particularly in the short run. The demand side of the model is completed by three equations explaining consumer stocks of raw wool in three major consuming countries as functions of present and expected future mill consumption of wool, these equations being of the "accelerator with buffer stocks" form. An attempt to incorporate the effects of speculation on wool prices in these equations is unsuccessful for all countries except Japan.

The final model of twenty-four structural equations and four identities is decomposed into two blocks, a recursive block, which is estimated by ordinary least squares, and a simultaneous block, which is estimated by two-stage least squares with principal components. The reduced form of the model is estimated from the structural estimates, and the long-run dynamic interrelationships of the market are studied by the estimation and analysis of impact, delay and cumulative dynamic multipliers for eight years after the initial change in an explanatory variable and by the estimation of the roots of the characteristic response function of the model. This analysis shows the market to be highly stable and characterized by long-run fluctuations, as both supply and demand sectors adjust weakly and very slowly to changing economic factors.

The study then proceeds to examine the shorter-run (monthly) movements in wool prices for different qualities of wool and for wool sold in different selling centers. Spectral and cross-spectral analyses of monthly wool prices show that, while these series move closely together in the long run, that is, one year or longer, the transmission of short-run stimuli between the different selling centers is by no means instantaneous or complete. A highly tentative spectral and cross-spectral analysis of seasonal wool production and prices tends to support the qualitative results of the analysis of the dynamic properties of the wool market model.

LIST OF TABLES

LIST OF FIGURES

Page

Page

TABLE OF CONTENTS

Page

CHAPTER 1

INTRODUCTORY REMARKS

1. Introduction

This study presents an annual model of the postwar world wool market. This model was developed in order to analyze the dynamic inter-relationships between wool production, consumption, inventory accumulation, and prices and thereby seek to explain the violent fluctuations in wool prices that have occurred since World War II.

There are a number of aspects of the world wool market that make it an interesting subject for analysis. Although government influence or participation in wool production and marketing occurs to varying degrees in some of the wool producing countries, the international price of raw wool is determined essentially at open auctions in Australia, New Zealand, and South Africa. Wool prices in the other three of the six largest producing countries (Argentina, United States and Uruguay), where the prevailing system is sale by private treaty to market agents, tend to follow the prices determined in the auctions. Since wool is predominately a Southern Hemisphere product for which the largest consumers are located in the Northern Hemisphere, over half of the world production enters international trade. The importance of wool among the exports of the big Southern Hemisphere producers has tended to increase in recent years; for example, Australia derived nearly half her total merchandise export earnings from this commodity in the 1950's. The great importance of raw wool to the major consumers is due to the fact that the cost of raw materials constitutes an unusually high proportion of the gross product of these industries. Thus both producers and consumers are extremely interested in the high variability in world wool prices.

There are surprisingly few previous important studies of this major commodity market. Blau's study of world wool prices in the interwar period is comprehensive in scope and contains many interesting insights but is somewhat dated in respect to both the techniques and the data used.[1] Philpott used more recent data in his study but limits himself to essentially two one-equation models, one explaining annual world wool prices and one explaining a five-year moving average of world wool prices.[2] Other studies cited in the bibliography are either purely descriptive or concentrate on particular subsectors or aspects of the market.

The purpose of this study is to specify and estimate the most important structural relationships in the world wool market. Particular emphasis is given to the distributed-lag nature of many of these relationships; and, in this respect, this study owes much to the work of Nerlove on agricultural markets.[3] The resulting structural model is then used to analyze the dynamic aspects of the market, following the approach of Goldberger in his study of the dynamic inter-relationships of the United States economy.[4] Although the world model is necessarily highly aggregated, consisting of only

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[1] Gerda Blau, "Wool in the World Economy," Journal of the Royal Statistical Society, CIX, Part III (1946), pp. 179-235. A similar study is Albert M. Hermie, Prices of Apparel Wool, Technical Bulletin No. 1041, United States Department of Agriculture (Washington, D.C.: U.S. Government Printing Office, 1951).

[2] B. P. Philpott, Fluctuations in Wool Prices 1870-1963, Agricultural Economics Research Unit Publication No. 13, Lincoln College, University of Canterbury, (New Zealand, 1965).

[3] See, for example, Marc Nerlove, The Dynamics of Supply: Estimation of Farmers' Response to Price (Baltimore, Maryland: Johns Hopkins Press, 1958).

[4] Arthur S. Goldberger, Impact Multipliers and Dynamic Properties of the Klein-Goldberger Model (Amsterdam: North-Holland Press, 1959).

twenty-eight equations, and the specifications of the relationships are necessarily quite simple due to data limitations, the model does provide a useful means of studying the causes of the high variability of world wool prices and the way exogenous factors, such as droughts in producing countries, affect the different sectors of the market over time.

2. Organization of the Study

The relevant institutional, technological, and historical aspects of the world wool market are described in Chapter 2. The annual model of the postwar world wool market is developed and analyzed in Chapters 3,4,5,6 and 7. Chapter 3 gives some general considerations in the development of this model. The supply side of the model consisting of equations explaining seasonal wool production in the major producing countries and a "Rest-of-the-World" sector is developed in Chapter 4. Equations explaining the accumulation of wool stocks in producer and consumer countries are specified and estimated in Chapter 5, which also includes an attempt to isolate a separate wool price equation. In Chapter 6, the consumption side of the model is developed, consisting of equations explaining wool consumption in the major consuming countries and in another "Rest-of-the-World" sector. The complete model is brought together in Chapter 7 in which the reduced form, the dynamic multipliers, and the stability properties of the model are calculated and analyzed and forecasts, both within and outside the sample period, are generated. In Chapter 8, the relationships between monthly prices for different quality wools and for wools sold at different selling centers are studied by the techniques of spectral and cross-spectral analysis. These methods also are used to study monthly United States mill consumption of wool and seasonal Australian wool production. Some concluding remarks and some indications of directions for possible future research are given in Chapter 9.

CHAPTER 2

THE INSTITUTIONAL, TECHNOLOGICAL, AND HISTORICAL BACKGROUND OF THE WORLD WOOL MARKET

1. Introduction

Many years before the beginning of recorded history, wool was being shorn from sheep, spun into yarn, and woven into cloth in most of the populated areas of the world. Today, in the 1960's, wool is still a major commodity that is being produced in almost every nation of the world. It is the most important export of Australia, New Zealand, and Uruguay. Wool has maintained its position of importance because it is one of the most suitable raw materials (natural or man-made) for the manufacture of textiles and because its production does not require an expensive technology. Beginning in Chapter 3, we will analyze both statistically and theoretically the international market for raw wool. The present chapter is devoted to providing the institutional, technological, and historical background for this study.

In section 2 of this chapter, we will consider the major characteristics of the commodity, wool, how it is grown, and how it is used. In section 3 we will consider the major characteristics of the world supply and demand configuration and how this configuration has evolved over the years. The structure of the major markets for raw wool will be discussed in section 4, along with the relatively recent development of the wool future markets. In section 5 we will consider the principal national and international trade policies and regulations that have affected international trade in wool and wool products. Finally, in section 6 we will consider the industrial fiber market in which wool competes and particularly the recent challenge of the synthetic fibers to wool's market share.

2. Sources, Uses, and Characteristics of Wool

A. Wool Growing

While sheep are raised in most nations of the world, wool generally can be produced most cheaply on large farms in the agriculturally less developed regions, especially in those regions where the climate is warm and dry. Wool production is a labor and land extensive process, and in these regions the opportunity costs of the land are relatively low. The production of raw wool a great distance from the majority of final consumers is economically feasible because wool has a relatively high value per pound and can be stored with little deterioration.

Sheep require little care except protection from disease and predators, some assistance at lambing time, and some food in time of extreme drought. However, the processes of lambing and shearing do require a considerable expenditure on trained labor during certain periods of the year. The sheep are usually shorn first within one year after they are born and yearly thereafter. Because of the relatively fixed length of the production process and the importance of overhead costs[1], the ability of wool producers to respond quickly to market expectations or actual market changes is quite limited, especially their ability to increase production. Short-run changes in the amount of wool produced may result from unfavorable weather conditions or the prevalence of disease. Wool producers have more freedom in reducing production. Mutton is jointly produced with

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[1]Gerda Blau finds that 65 per cent of total producer costs are either "fixed" (independent of the volume of production) or "semi-variable" (only partially dependent on the volume of production) in "Wool in the World Economy," Journal of the Royal Statistical Society, Vol. CIX, Part III (1946), pp. 191-192.

wool; and most producers, especially those of cross-bred wools, base decisions on the number of adult sheep and lambs to slaughter on the present and expected future relative prices of wool, lamb, and mutton.

In the longer run, wool producers make their production decisions by considering the relative expected returns of alternative uses of their resources, these uses being principally the raising of cattle or the growing of cereal grains. However, in some of the semi-arid and arid regions, alternative uses of the producer's land may not exist; and in such situations the producer may have little economic choice, even in the long run, but to continue production when the market conditions are adverse. It should also be noted that in recent years through the development and implimentation of more advanced agricultural methods, specifically, the improvement of pastures by fertilization, seeding, and irrigation, the breeding of more productive sheep, and the control of diseases and competitors for the food supply, producers have been able to increase significantly the yield per sheep and per acre of raw wool. In the later chapters we consider the short-run and long-run supply functions for raw wool, that is, the responsiveness of supply to such factors as wool prices, mutton prices, prices of alternative products, weather, and technological change.

B. Wool Grading

The commodity, raw wool, is heterogenous, varying widely in such characteristics as fineness of fiber, length of fiber, uniformity, elasticity, luster, strength, and suppleness and hence is very difficult to classify and grade for the benefit of trade. For example, under the British Government Purchase Scheme there are listed 1500 types of Australian wool alone. Moreover, the varying characteristics are not wholly correlated with the different breeds of sheep, for wide variations occur within the breeds. Yet despite this heterogeneity, it is possible to classify wool into several broad categories which reflect the commercial uses to which the different qualities of wool are best suited.

Raw wool is graded for trade mainly on the basis of two characteristics, fiber diameter and fiber length. There are two principal alternative systems that are used, the blood or American system, which originally referred to the breed of the sheep which produced the wool, and the Bradford count or numerical system, which originally referred to the maximum spinning potential of the wool. While both systems have lost their original significance, they are used extensively in the wool industry as an index of the general fineness of the wool. In this study we will use the count system exclusively, and hence Table 2.1 is given to show the correspondence between the two systems. In this system, the higher the number or count, the finer and usually the shorter the wool.

Table 2.1 Wool Grades - Blood versus Count

Fine	64s, 70s and 80s
Half Blood	60s and 62s
Three eighths Blood	56s and 58s
Quarter Blood	50s and 54s
Low Quarter Blood	46s and 48s
Common	44s
Braid	36s and 40s

Source: Elroy M. Pohle, "The Marketing of Wool," in *Wool Handbook*, ed. Werner Von Bergen, (Vols. I; 3rd ed.; New York: Interscience Publishers; 1965), p. 549, Table 1.

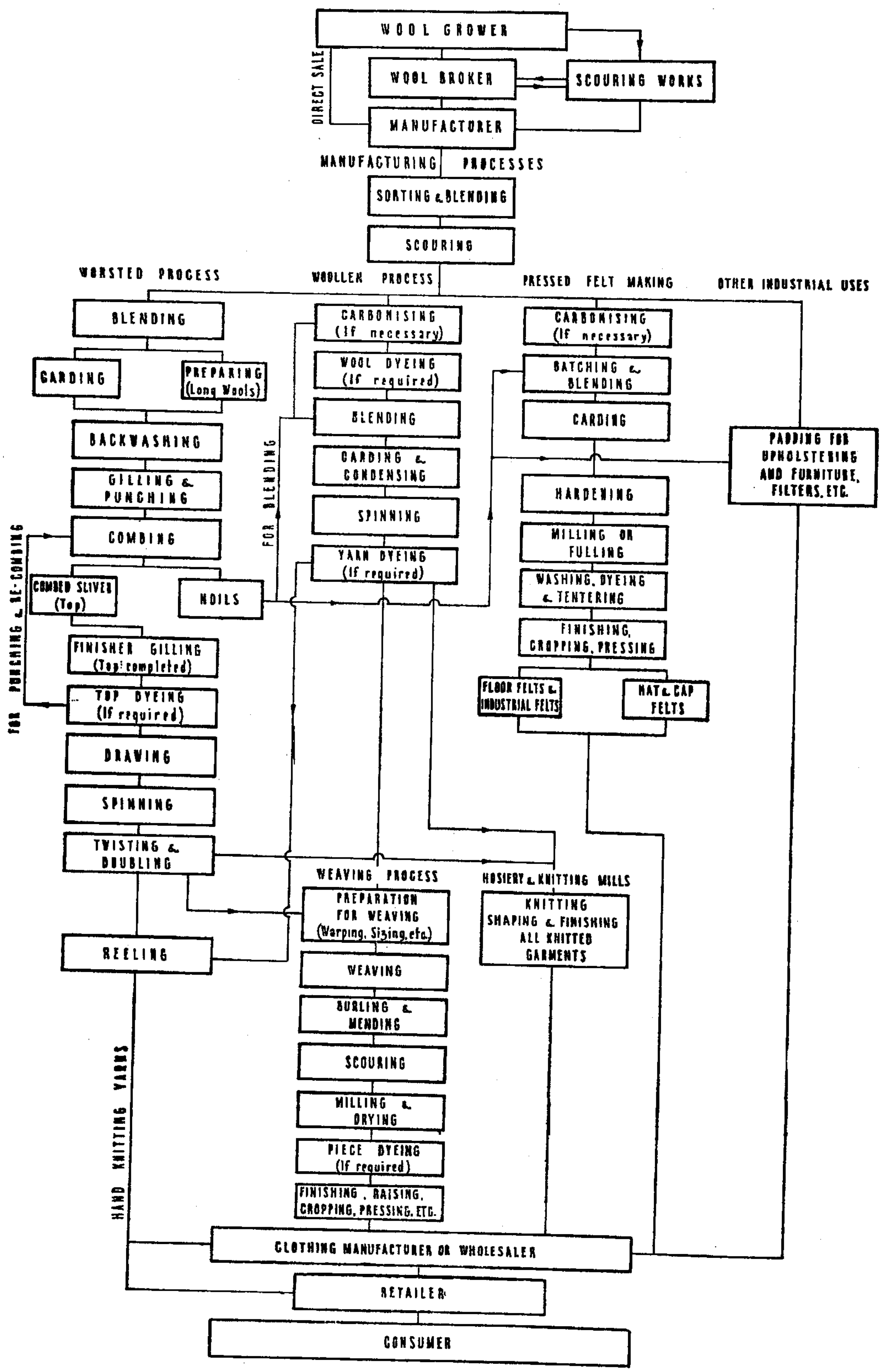
The consumers of raw wool would prefer a more systematic classification of the different grades of wool than now exists, for they desire a fairly standard raw material which will permit production of yarn with few adjustments for different batches of raw material. The producer of raw wool prefers to emphasize the individuality of his annual wool crop or "clip" in order to differentiate his product and achieve a higher price than perhaps would be achieved if a more systematized classification scheme were employed. Also, classing of wool is an expensive procedure However, it appears that one of the causes of the differential of the prices of Australian wools over those of comparable United States wools is the greater standardization of the product that the Australians achieve through much more careful classing of the wool. Finally, in respect to the fact that wool is jointly produced with lamb and mutton, it is important to note here that the finer wools, the 64s, 70s and 80s are produced mainly by the Merino sheep, which are poor producers of lamb and mutton, while the coarser, longer wools are produced by the crossbred sheep, which are the best sheep for lamb and mutton.

C. Uses of Wool

The first breakdown of wool into classes determined by end use is into the fairly disjoint classes of apparel and carpet wool. Unfortunately, these two classes of wool are aggregated together in most wool market data. Carpet wools, as the name suggests, are used mainly in the production of floor coverings, although sometimes they are used for special effects in certain kinds of apparel fabrics such as heavy tweeds. Carpet wools, which comprise about one fifth of the wool produced in the world annually, are classified as grades up to the 44s, using the count system, and are generally coarse, long, wiry, strong, kinky and frequently have a color defect. They come from native, unimproved breeds of sheep and are generally unsuitable for the manufacture of apparel. Apparel wools are used in the manufacture of clothing, draperies, blankets, upholstery, and felts.

Figure 2.1, describes in flow chart form the many processes that raw apparel wool must pass thru before it reaches the final consumer. The raw wool that is removed from the sheep contains "grease" (which is secreted by the sheep onto the wool), dirt, and a large amount of water (for the wool fiber is hygroscopic). The process of scouring the wool removes most of these impurities and leaves the wool in the "clean" state. Most wools are purchased on the "clean basis," that is, on the expected yield of clean wool from the greasy wool. Although this factor does introduce a further

Figure 2.1. Flow Chart Illustrating the Main Manufacturing Processes of the Wool Industry.



Source: Commonwealth of Australia, Bureau of Agricultural Economics, Statistical Handbook of the Sheep and Wool Industry, (3d ed; Canberra, Australia, 1961), p. ix.

element of uncertainty into the sale of raw wool, this element is apparently not very significant; for both buyers and sellers have perfected to a fine degree the estimation of the yield of greasy wool. The clean wool is then used in either the worsted process or the woolen process or is pressed into felt for hats or for industrial uses.

The longer wools, wools of a fairly uniform length of two inches or more, are used in the worsted process in which the wool fibers are carded (that is, drawn through large rollers covered with fine metal teeth), combed, and drawn out into a thin strand of parallel fibers which are twisted tightly together to form a strong, thin yarn of fairly even thickness. This worsted yarn is used mainly for making temperate and summer climate clothing. Wools of a shorter length are used in the woolen process in which the wool fibers are carded and then drawn into a long, softly twisted strand which is spun into a bulky, not so strong yarn of less even thickness than the worsted yarn. This woolen yarn is used mainly for warmer bulkier wool apparel such as tweeds, flannel, and knitted goods. The very short wools are used for felt products. Because of the relative quantitative insignificance of the use of wool for felt products (e.g. only about 2 per cent of the wool consumed in the United States goes into felt products), we will concentrate on the demand for wool for the woolen and worsted systems in this study.

The demand for raw wool is clearly a derived demand, derived from the composite consumer demand for the many apparel, household, and other wool products. The demand for wool products varies over time with consumer incomes, tastes, fashions, weather, the prices of wool products relative to the prices of substitute and other products, the percentage of centrally heated homes, and consumer stocks of apparel goods. Because producers of semi-finished and finished wool products generally do not find it feasible to purchase raw wool and sell immediately tops (combed and scoured wool), yarns, textiles, or finished products, they will commonly have to purchase the raw wool at market prices long before their products are sold or contract for the finished product before the raw wool is bought. Hermie estimates that from 6 to 12 months elapse, on the average, in the wool apparel industry between the time raw wool enters the system and the time the end products are sold at retail.[2] The significance of this factor is increased by the fact that raw materials constitute an unusually high proportion of the gross product of all stages of the production of woolen textile goods up through the fabric stage (but not so high a proportion of the gross product of the finished apparel stage) and by the fact that the prices of raw wool are relatively highly variable. We will consider later the importance of this long period of production for the wool market. The questions of producer substitution of other fibers for wool in the wool textile industry and of consumer substitution of non-wool products or products containing less wool for wool products will be deferred to section 6 of this chapter and to subsequent chapters. Let us now consider the geographic distribution of supply, demand and the resulting international trade flows of the commodity, wool.

3. International Trade in Wool

While some wool is produced in nearly every part of the world, Table 2.2 shows that the Southern Hemisphere countries of Australia, New Zealand, Argentina, South Africa, and Uruguay produced in the 1964-65 season some 58 per cent of the world's wool production; and Australia alone produced about 31 per cent. These five countries are even more important in the apparel wool market, for they account for about 72 per cent of the total apparel wool production. The importance of these Southern Hemisphere countries on the supply side of the wool market did not develop until the latter half of the

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[2]Albert M. Hermie, Prices of Apparel Wool, Technical Bulletin No. 1041, U.S. Department of Agriculture (Washington, D.C.: U.S. Government Printing Office, 1951), p. 18.

Table 2.2. Estimated World Production of Raw Wool.

million lb. – greasy basis.

	Average 1946-47/ 1950-51	Average 1951-52/ 1955-56	1960-61	1961-62	1962-63	1963-64	1964-65 *a*
Commonwealth							
Australia	1,060	1,261	1,625	1,698	1,673	1,785	1,794
New Zealand	376	434	588	587	620	617	623
United Kingdom	84	99	121	131	131	127	128
India	} 112	{ 74	78	78	78	78	78
Pakistan		41	43	43	43	43	44
Canada	12	8	8	8	7	7	7
Basutoland	9	8	8	9	9	9	9
Other Commonwealth	7	8	9	9	10	9	9
Total Commonwealth	*1,661*	*1,933*	*2,480*	*2,563*	*2,571*	*2,675*	*2,692*
Foreign							
Argentina	448	393	431	413	408	395	419
South Africa *d*	210	268	299	319	300	303	296
United States	309	296	323	320	300	287	264
Uruguay	163	199	181	185	190	192	187
Turkey	71	79	104	102	94	95	95
Spain	89	85	84	88	89	86	79
Brazil	43	52	51	54	56	58	58
France	39	52	57	56	56	54	53
Chile	43	43	49	49	49	49	49
Iran	29	38	40	40	41	41	41
Morocco	24	33	34	35	35	35	40
Italy	33	37	32	32	29	28	27
Yugoslavia	32	35	30	30	29	29	27
Iraq	27	33	28	28	29	28	28
Greece	17	21	25	20	21	21	21
Irish Republic	13	16	24	24	27	26	26
Portugal	18	24	25	25	26	23	26
Peru	18	21	22	24	26	33	25
Other Western Europe	33	28	30	31	31	34	34
Other Africa *b*	34	52	44	42	46	44	44
Other Asia (excluding China)	37	48	48	43	46	48	48
Other America	30	32	28	28	28	28	32
Non-communist total	3,422	3,818	4,468	4,551	4,527	4,612	4,611
Sino-Soviet group *c*	473	722	1,120	1,144	1,148	1,152	1,100
Of which: Soviet Union	*308*	*484*	*777*	*798*	*806*	*809*	*752*
Eastern Europe	*83*	*118*	*162*	*171*	*172*	*173*	*178*
Estimated world total	3,895	4,540	5,588	5,695	5,675	5,764	5,711
Of which:							
Merino	1,439	1,724	2,239	2,301	2,277	2,353	2,328
Crossbred	1,477	1,680	2,115	2,159	2,177	2,195	2,166
Total apparel	2,917	3,404	4,354	4,460	4,454	4,548	4,494
Other	978	1,136	1,234	1,235	1,221	1,216	1,217
Clean equivalent							
Merino	*752*	*925*	*1,227*	*1,255*	*1,245*	*1,303*	*1,288*
Crossbred	*945*	*1,082*	*1,381*	*1,398*	*1,407*	*1,425*	*1,407*
Total apparel	*1,697*	*2,007*	*2,608*	*2,653*	*2,652*	*2,728*	*2,695*
Other	*489*	*568*	*617*	*617*	*611*	*608*	*609*
Total	*2,186*	*2,575*	*3,225*	*3,270*	*3,263*	*3,336*	*3,304*

a Provisional.

b Revised to include South West Africa.

c Soviet Union, Albania, Bulgaria, Czechoslovakia, Eastern Germany, Hungary, Poland, Roumania, China and Dependencies, Outer Mongolia and Tibet.

d Revised to exclude Basutoland and South West Africa.

Source: Commonwealth Economic Committee, Industrial Fibres, No. 16 (1966), p. 35, Table 17.

nineteenth century. Up to that time, the major wool producing countries were England, Spain, and Germany. This great change in the distribution and size of the world's wool supply was a result of the arrival, toward the end of the eighteenth century, of the first Merino sheep in the Southern Hemisphere countries.

These thinly populated lands were particularly well suited for the labor and land extensive methods that wool production requires. The chief producers of carpet wool are the Soviet Union, Argentina, the Balkan Countries, China, India, Iran, Pakistan, and Turkey. In this study we will be concentrating on the market for apparel wool, and it is thus interesting to note that not only are the demands for apparel and carpet wool fairly independent, but also the production of the two types of wool is carried on, for the most part, in separate parts of the world.

The last 25 years has seen about a 30 percent increase in total world production of wool, with production being at record levels in recent years in Australia, New Zealand, Uruguay, and the Soviet Union. The United States production, however, declined sharply between 1942 and 1949 and has been reasonably stable since then. This decline in the United States was due largely to the fact that returns from other agricultural enterprises were relatively greater than the returns from the raising of sheep. There has been a significant shift from fine wool sheep to lamb and mutton breeds in Argentina, Uruguay, and New Zealand due to the development of cold-storage overseas transportation. Production of Merino wool has varied more from year to year than production of the crossbred wools. This difference is due to the facts that Merino sheep are raised in areas more susceptible to droughts and that production of crossbred wools is linked to mutton and lamb prices, which are more stable than wool prices.

Looking at the pattern of world consumption of raw wool as given in Table 2.3,we see that the major consumers, the United Kingdom, the United States, Japan, France, Germany, and Italy, which together consume about 55 percent of the total wool consumed,

Table 2.3. Estimated World Consumption of Virgin Wool.

million lb. – clean basis

	Average 1946-50	Average 1951-55	1960	1961	1962	1963	1964
United Kingdom	454	440	481	472	448	458	418
United States	595	412	378	379	394	379	346
France *c*	248	233	301	301	291	296	263
Italy	118	117	198	187	205	196	185
West Germany	63	145	151	150	147	153	142
Belgium	75	63	86	82	100	95	93
Netherlands	38	25	22	21	22	23	22
Total Common Market	*542*	*583*	*758*	*741*	*765*	*763*	*705*
Japan *b*	17	98	281	325	297	302	310
Australia	66	51	74	65	73	82	77
Argentina *a*	(61)	(62)	(43)	(54)	(35)	(30)	(53)
Turkey	(40)	(44)	(57)	(57)	(57)	(54)	(51)
Uruguay *a*	(9)	(33)	(37)	(44)	(41)	(46)	(49)
Canada	38	25	20	19	19	18	17
Sweden	22	13	11	11	10	11	11
Other countries	287	295	365	380	395	408	407
Non-communist total	2,131	2,056	2,504	2,547	2,534	2,551	2,444
Soviet Union, China and Eastern Europe	(302)	(436)	(800)	(784)	(783)	(771)	(789)
Estimated world total	2,433	2,492	3,304	3,331	3,317	3,322	3,233
Of which Commonwealth	*589*	*548*	*617*	*600*	*595*	*623*	*577*

a Season ending September of year shown.
b From 1959 includes estimated consumption by commission combers. All figures on an estimated clean basis using a clean yield factor of 93 per cent. for scoured wool.
c Of which consumed in the wool industry (million lb.): *1960* 283, *1961* 283, *1962* 273, *1963* 278, *1964* 248

Source: Commonwealth Economic Committee, Industrial Fibres, No. 16 (1966), p. 47, Table 25.

are nations located in the Northern Hemisphere. Thus it is clear why 50 percent of the world's production of raw wool enters into internation trade. Such trade is facilitated by the high value per pound of raw wool and the fairly low rate of deteriation of stored wool. The consumption of wool is widely distributed over the globe. There are wool textile industries of various sizes existing in more than 50 countries. No consuming nation dominates the demand side of the market as much as Australia dominates the supply side. The most important consumer, the United Kingdom, imports only about 10 percent of the total world production. It should be noted from Table 2.3 that Japan's consumption of wool has grown more than threefold from the average level of 98 million pounds in the years

1951-55. Moreover, Japan buys almost all its wool from Australia. Thus in a few short years Japan has risen to a very important position in the world wool market.

Tables 2.4, 2.5, and 2.6 show wool exports, retained wool imports and the distribution of exports of raw wool from the chief exporting countries. The five major exporting countries, Australia, New Zealand, South Africa, Argentina and Uruguay accounted for 81 percent of the world exports of raw wool in 1964. Australia is a major source of wool for most of the major importing countries, with Japan being the largest consumer of Australian wool, followed by the United Kingdom and the European Common Market countries. The most important customer for New Zealand wool is the United Kingdom, followed by the United States and France. The United States and the United Kingdom are the largest buyers of Argentina's wool exports, while the United Kingdom is the largest customer for Uruguay's wool. In the past France has been the largest purchaser of South African wool; but in 1963-64 and 1964-65 the United Kingdom was marginally a larger customer.

The United States, the Soviet Union and, to a much lesser extent, the United Kingdom are the only major consumers of raw wool that produce a significant proportion of the wool they consume. The United States, which produces about thirty percent of the wool it consumes, almost all of this being apparel wool, tends to import the coarser carpet wools of Argentina and New Zealand along with some apparel wool. The Soviet Union, which produces three or four times as much wool as it imports, tends to import apparel wool mainly from Australia, while it imports carpet wool mainly from the Asian countries of Mongolia, China, India and Afghanistan.

While the importance of wool among the exports of the major Southern Hemisphere producers tended to increase since the 1930's, a period in which wool prices were depressed relative to other commodity prices, Table 2.7 shows that this trend has apparently

Table 2.4. Exports of Raw Wool from the Principal Exporting Countries.

million lb. – actual weight

	Average 1946-50 *a*	Average 1951-55 *a*	1960	1961	1962	1963	1964
Commonwealth							
*Australia	1,075·3	1,040·5	1,339·0	1,418·8	1,425·4	1,430·4	1,394·5
*New Zealand	396·6	390·3	522·0	554·8	545·2	564·2	552·6
†India	} 52·2	27·8	30·4	31·5	24·1	16·7	28·3
†Pakistan		25·0	31·2	32·3	30·7	30·8	21·6
United Kingdom	17·7	24·9	41·3	46·6	49·0	58·7	43·6
Canada	3·4	2·6	3·4	4·2	3·3	3·7	2·4
Falkland Islands	4·6	4·4	4·6	4·8	4·7	5·1	4·8
Kenya	0·9	1·4	2·1	2·6	3·1	3·4	2·9
†Cyprus	0·9	1·0	0·8	0·8	1·3	1·0	1·2
Total Commonwealth	*1,552*	*1,518*	*1,975*	*2,096*	*2,087*	*2,114*	*2,052*
Foreign							
Major exporters:							
*Argentina	350·7	229·8	306·5	306·5	345·1	289·4	203·5
*South Africa *c*	263·9	233·7	242·0	277·6	275·3	248·6	243·9
*Uruguay	141·3	115·4	77·1	159·4	101·2	91·1	48·7
Others:							
†Afghanistan *d*	..	13·9	11·9	11·8	14·0	12·6	10·1
Belgium *g*	26·3	29·4	42·4	47·9	49·9	49·9	36·4
Chile	15·5	12·5	13·2	21·1	13·1	17·4	12·2
France *i*	27·5	35·7	76·5	76·5	77·3	86·3	70·0
West Germany	1·0	3·9	9·4	9·0	10·4	11·5	9·4
†Iran *d*	6·1	17·0	13·8	10·4	8·6	8·6	(6·8)
†Iraq	11·0	11·3	9·9	9·4	8·6	12·7	13·2
Irish Republic	10·1	12·3	20·1	22·4	23·7	24·1	16·2
Italy	2·5	3·4	5·3	5·7	7·0	8·9	7·9
Netherlands	2·1	2·5	8·7	9·2	10·0	12·4	9·7
Soviet Union *e*	..	..	39·3	61·7	53·1	59·5	54·0
†Syria	9·7*f*	12·0	11·3	8·8	7·7	12·0	17·6
†Turkey	3·6	2·8	12·2	12·7	7·5	9·3	10·6
Other foreign	..	..	76	56	68	92	137
Total foreign	926*h*	781*h*	976	1,106	1,081	1,046	907
Total, world	..	..	2,951	3,202	3,168	3,160	2,959
of which:							
Non-communist world *b*	2,478	2,299	2,874	3,120	3,083	3,058	2,848
*The five chief exporters	2,228	2,010	2,487	2,717	2,692	2,624	2,443
†Countries exporting mainly carpet wools	..	115*c*	122	118	103	104	109

a Or years available.
b Including Yugoslavia.
c Including exports of Basutoland and South-West African wool.
d Year commencing 21st March.
e Clean basis.
f Lebanon included.
g Largely imported wools, re-exported after scouring.
h Excluding the Soviet Union, Eastern Europe and China.
i Largely pulled wool from imported skins.

Source: Commonwealth Economic Committee, Industrial Fibres, No. 16 (1966), p. 37, Table 18.

Table 2.5. Retained Supplies of Imported Raw Wool in the Principal Importing Countries. (Excluding Wool on the Skin)

million lb.

	Average 1946-50	Average 1951-55	1960	1961	1962	1963	1964
			(i) Actual weight				
United Kingdom *a*	514	605	583·9	575·1	576·1	590·2	538·4
Japan	28	161	417·2	559·9	471·9	526·3	497·5
France *d*	389	316	363·1	382·8	380·0	352·6	297·9
United States *e*	721	442	309·4	336·0	363·5	367·9	283·1
Italy *b*	176	157	270·7	255·1	303·3	294·9	266·7
West Germany *b*	97	167	200·1	211·0	212·4	223·1	216·7
Belgium *b*	175	116	147·1	179·8	192·3	157·8	196·4
Netherlands *b*	39	23	21·9	22·2	18·6	20·6	22·5
Canada	40	24	17·4	19·1	18·2	16·6	19·8
Switzerland *b*	25	14	13·0	13·1	14·8	14·7	12·2
Austria *b*	10	11	13·3	15·0	14·9	16·0	13·8
Sweden *b*	28	13	9·9	8·8	9·4	7·3	9·6
Total of above countries	2,242	2,049	2,367	2,578	2,575	2,588	2,375
Of which: Common Market	*876*	*779*	*1,003*	*1,051*	*1,107*	*1,049*	*1,000*
Soviet Union *c*	32 *f*	(54) *f*	134·5	120·6	106·0	92·6	100·7
East Germany *c*	— *f*	19	42·7	50·8	46·7	51·4	49·2
Czechoslovakia *c*	14 *f*	29	55·1	48·5	44·1	44·0	46·3
Poland *c*	42 *f*	28	41·3	38·8	40·7	32·8	34·6
Other E. Europe *c*	5 *f*	9	19·3	15·2	8·6	13·2	14·4
Total Soviet bloc *c*	93 *f*	139	292·9	273·9	246·1	234·0	245·2
China *c f*	(3)	(2)	51·1	24·9	31·7	36·1	42·2
Total	2,338	2,190	2,711	2,877	2,853	2,858	2,662
	g		(ii) Estimated clean content				
United Kingdom a	*366*	*394*	*389*	*379*	*385*	*395*	*367*
Japan	*27*	*95*	*251*	*342*	*284*	*320*	*299*
France d	*223*	*196*	*232*	*245*	*243*	*226*	*192*
United States e	*406*	*295*	*228*	*248*	*270*	*277*	*212*
Italy b	*86*	*99*	*176*	*166*	*196*	*191*	*172*
West Germany b	*85*	*111*	*135*	*143*	*145*	*152*	*146*
Belgium b	*68*	*61*	*84*	*104*	*112*	*89*	*116*
Netherlands b	*30*	*19*	*16*	*16*	*14*	*15*	*17*
Canada	*30*	*20*	*14*	*15*	*15*	*13*	*16*
Switzerland b	*14*	*9*	*10*	*10*	*11*	*11*	*9*
Austria b	*9*	*8*	*10*	*11*	*11*	*12*	*10*
Sweden b	*19*	*10*	*9*	*8*	*8*	*7*	*8*
Sino-Soviet bloc	*71*	*129*	*300*	*264*	*241*	*233*	*247*
Total of above	*1,434*	*1,446*	*1,854*	*1,951*	*1,935*	*1,941*	*1,811*
Of which: Common Market	*492*	*486*	*643*	*674*	*710*	*673*	*643*

Note.—'Retained supplies' of imported raw wool may be defined as imports minus re-exports and minus wool re-exported after treatment. However, figures of 'imports minus exports' have been used in cases where it is believed that most exported wool is of foreign origin.

a Imports minus re-exports and minus wool re-exported after treatment.
b Imports, minus exports.
c Of the Communist countries all but East Germany, Poland and China are on a basis described as clean, scoured or washed.
d Imports less exports of imported wool treated in France.
e Imports for consumption.
f Estimated from the exports of supplying countries.
g Average 1948-50.

Source: Commonwealth Economic Committee, Industrial Fibres, No. 16 (1966), p. 42, Table 22.

Table 2.6. Distribution of Exports of Raw Wool from the Chief Exporting Countries.

million lb. – actual weight

Exporters→ / Importers	Australia			New Zealand			South Africa			Argentina			Uruguay		
	1962 -63	1963 -64	1964 -65	1962 -63	1963 -64	1964 -65	1962 -63	1963 -64	1964 -65	1962 -63	1963 -64	1964 -65	1962 -63	1963 -64	1964 -65
U. Kingdom ..	222	247	206	141	156	126	37	44	46	51	33	40	32	21	36
Canada ..	5	4	7	4	4	7	1	1	1	—	—	—	1	—	—
Belgium ..	100	103	109	39	41	51	14	12	10	22	11	14	3	1	2
France	136	142	126	100	86	73	51	43	40	35	25	18	4	2	1
W. Germany ..	82	95	96	37	37	40	36	39	38	28	17	13	9	6	5
Italy	128	136	102	38	38	29	35	43	27	26	15	27	4	1	2
Netherlands ..	2	2	8	19	18	12	2	2	1	5	5	10	2	1	1
Japan	392	439	429	34	32	32	25	28	33	24	17	17	7	1	—
United States	72	50	95	100	85	85	39	32	38	83	46	69	19	2	36
China	31	35	19	4	7	6	—	—	—	—	—	—	—	—	—
Czechoslovakia	16	24	20	1	4	2	1	1	—	2	2	4	4	1	3
Poland	22	23	23	5	5	5	1	—	—	13	8	13	1	—	—
Soviet Union ..	50	46	51	—	—	6	—	—	—	1	3	16	5	1	3
Other countries	124	125	134	41	51	49	11	10	10	34	25	22	11	9	16
Total ..	1,382	1,471	1,425	563	564	523	253	255	244	324	207	263	102	46	105
Of which:															
Commonwealth	242	271	235	156	167	137	38	45	47	51	33	40	33	21	37
Common Market	448	478	440	234	221	205	137	139	116	116	72	82	21	11	11
Sino-Soviet bloc	123	134	120	10	21	21	3	1	—	17	15	33	11	2	9

Source: Commonwealth Economic Committee, Industrial Fibres, No. 16 (1966), p. 39, Table 20.

Table 2.7. Relative Value of Exports of Raw Wool to Total Exports.

Country and Units of value	Value of raw wool *a*					Per cent. of wool to total				
	1960	1961	1962	1963	1964	1960	1961	1962	1963	1964
Australia (£A mn.) *b* ..	325	360	366	463	390	36	35	35	34	31
New Zealand (£ mn.) ..	102	100	96	113	133	34	36	34	35	35
Argentina (U.S. $ mn.)	147	139	140	149	115	13	14	12	12	8
S. Africa (Rands mn.)	88	102	100	106	113*c*	11	12	12	12	12*c*
Uruguay (U.S. $ mn.)	45	86	58	58	35	35	49	38	35	20

a Excluding wool on skins.
b Years commencing 1st July of year shown.
c Provisional.

Source: Commonwealth Economic Committee, Industrial Fibres, No. 16 (1966), p. 40, Table 21.

reversed itself in recent years. In Australia, wool accounted for only 31 percent of Australia's export earnings in 1964, which was the percentage share in 1938-39. This decline in importance is apparently related to the fairly stable long-run demand for wool products, which is growing at a lower rate than the incomes of the importing countries, to the inroads into the wool market that synthetics have made in the last six years and to the industrial development and diversification of exports that has taken place in most of these exporting countries.

Stocks of raw wool of varying quantities are held by wool producers, brokers, governments, and consumers of raw wool, while top makers, spinners, weavers, knitters, apparel manufacturers, cloth and apparel jobbers, and retailers all carry some stocks of semi-finished and finished wool goods. These stocks seem to be quite significant in the determination of wool prices, and hence we will consider them in greater detail in Chapter 5. But now let us look at the recent history of these wool stocks as shown in Table 2.8 and 2.9.

Table 2.8. Estimated World Supply Stocks of Raw Wool.

million lb. – clean basis

At beginning of season *a*	1959-60	1960-61	1961-62	1962-63	1963-64	1964-65	1965-66
United Kingdom Government strategic reserve	62	48	32	14	—	—	—
British Wool Marketing Board	7	5	7	6	6	7	6
Australia	19	30	35	33	28	37	48
New Zealand (carry-over)	10	17	16	15	14	17*c*	25*cd*
New Zealand Wool Commission ..	11	—	*b*	—	—	—	—
South Africa (carry-over)	1	1	1	1	1	2	3*d*
South African Wool Commission ..	4	—	*b*	—	—	—	1
Argentina	31	52	25	22	14	42	47
Uruguay	9	28	11	14	13	40	24
Total	154	181	128	105	76	145	154
Net change in supply stocks during season	+27	−53	−23	−29	+69	+9	..

a At 1st July for all except Argentina and Uruguay, which are 1st October.
b Less than 0·5 million lb. each, but together 0·9 million lb.
c Revised basis.
d Excluding wools sold awaiting shipment.

Source: Commonwealth Economic Committee, Industrial Fibres, No. 16 (1966), p. 49, Table 27.

Table 2.9. Reported Commercial Stocks of Raw Wool in Specified Countries at 30 June (Clean Basis).

Reporting Countries	Stocks at 30 June 1961	1962	1963	1964	1965
	m.lb.	m.lb.	m.lb.	m.lb.	m.lb.
United Kingdom(a)	187	162	152	168	178
EEC Countries:					
France(b)	111	111	115	103	78
Italy(c)	35	53	41	33	31
West Germany(c)	32	30	29	26	29
Belgium(c)	27	35	28	27	20
Netherlands(c)	6	6	4	4	4
Total EEC	(211)	(235)	(217)	(193)	(162)
Japan(d)	43	41	38	30	33
U.S.A.(e)	..	..	143	143	166

(a) Excluding Government strategic reserve and British Wool Marketing Board stocks. (b) Almost exclusively owned by merchants. New series; quarterly data not available for previous periods.
(c) All held by manufacturers. West German figures for 1963, 1964 and 1965 include stocks held outside the wool industry.
(d) Almost all held by manufacturers. (e) Includes the remaining portion of the domestic clip.

Sources: Commonwealth of Australia, Bureau of Agricultural Economics, The Wool Outlook, No. 19 (Canberra, Australia, 1965), p. 10, Table 7, and Commonwealth Economic Committee, Wool Intelligence, Vol. XIX (September, 1966), p. 547, Table VII (a).

Table 2.8 gives the movement of the world "supply stocks," that is, the stocks of wool held in the chief producing countries and by government agencies from 1958-59 to 1965-66. It is these stocks which are potential additions to supply. However, they are not all available for supply because some minimum amount of wool is always in the "pipeline." It is interesting to note the increase in wool stocks held in South America in 1964-65. This increase is due to the Argentinian and Uruguayan wool producers holding off selling in the hope of obtaining better prices than those that were being offered by exporters. These producers asked for prices that were out of line with the world market because the internal price levels in their countries were very high and because they had received unfavorable exchange control and tax treatment from their governments. These governments have been trying recently with some success to encourage wool exports by more favorable treatment of these exports than has been the practice in the past. It is noted in the next section and in Chapter 5 that the complicated mass of frequently changing government regulations, such as multiple exchange rates and varying export taxes, relating to the export of wool from these countries causes their exports of raw wool and hence their stocks of wool to fluctuate from year to year.

Table 2.9 gives the reported commercial stocks of raw wool, that is, wool that is held mainly by manufacturers of semi-finished and finished woolen goods. The eight countries in Table 2.9 report stocks on a quarterly basis and these estimates seem to be a good indicator of what is happening to total world commercial stocks for which no adequate series exists. As is shown in Chapter 5, the level of these stocks is determined by present and expected future mill consumption of wool and, to a limited degree, by present and expected future wool prices. However, in the annual model used in this study, it is possible to isolate the effect of price speculation on commercial wool stocks only for the Japanese wool textile industry.

4. Major Wool Markets

Practically all British Dominion wools are sold at public auction; while practically all of the clips of Argentina, Uruguay, and the United States are disposed of by private sale. Until about World War I most of the world's wool clip was moved to the major consumption centers of London and Boston where the most important markets were. However, as wool production grew larger, more and more wool was sold at the country of origin; and today the single most important market for raw wool is Sydney, Australia. In this section we will consider the arrangements for the marketing of wool that exist in the major wool markets of the world.

A. Marketing of Wool in Australia

Early Australian wool growers sold most of their wool in the London market. In 1818 the first bales of wool from Australia were sold by auction in London in Garraway's Coffee House. London remained the chief market for Australian wool until about the beginning of World War I. However, because of improved transportation and communication, changes in the structure of wool textile industries permitting them to buy wool directly in the markets of the producer countries, the growth of the American, European, and Asian (especially Japanese) woolen and worsted industries, and the increased availability of credit to wool growers, the proportion of Australian wool sold in London declined steadily since 1875; and today more than 95 percent of the wool produced in Australia is sold at Australian auctions.[3]

The sales mechanism of these auctions and even the names of many of the major agents in the market are essentially the same as those of the London wool market of 1945. As Barnard suggests, perhaps this stability of the market institution is an indication of the conservativeness of this market and of its general unwillingness to seek or to respond quickly to new ideas.[4] On the other hand, it may be an indication of the appropriateness of these institutions for this market. The major structural change that has characterized the Australian wool market is the increase in number

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[3] G. F. Rainnie, "Raw Materials and Markets," in The Woolen and Worsted Industry: An Economic Analysis, ed. G.F. Rainnie, (Oxford, England: Clarendon Press, 1965), pp. 9-10.

[4] Alan Barnard, "A Century and a Half of Wool Marketing," in The Simple Fleece, ed. Alan Barnard, (Parkville, Victoria, Australia: Melbourne University Press, 1962), p. 476.

of selling centers from five to thirteen. While Sydney is now the world's most important single wool selling center, there are other major Australian auction markets in Melbourne, Geelong and Adelaide. This decentralization was caused by new selling brokers seeking to establish markets closer to the source of supply, by improvements in transportation and communications and by the increased size of the Australian wool clip.

In July of each year, the National Council of Wool Selling Brokers of Australia, the Australian Woolgrowers' and Graziers' Council and the Bureau of Agricultural Economics meet together to estimate the wool clip and fix auction programs for the year. This group determines dates of sales and amounts to be offered so that, during most of the days of the week from September to June, there will be a fairly continuous market for wool in at least two of the different selling centers.

The raw wool is classed in the shearing shed into a number of homogeneous grades, taking account of the product characteristics desired by the prospective buyers, and is then pressed into bales of about 300 pounds. The wool grower usually consigns his wool to a selling broker located in one of the selling centers. The selling brokers do a strict brokerage business and do not buy on their own account. They supply warehouse space for storing and displaying the wool. The wool is catalogued and sold by the broker in the order in which it arrives at the broker's warehouse. The selling brokers offer two catalogues daily listing the amounts and characteristics of the wool to be offered for sale at the auction.

The major wool buyers are a fairly small number of highly experienced specialists who have buying orders from all over the world for textile mills, wool merchants, and for re-handlers (who buy badly classed wool, reclass, and resell it). As an indication of the degree of concentration on the buyers' side of the market, Barnard notes that "...in 1957-58, the twelve largest buyers accounted for 46 percent of all auction purchases in New South Wales and Queensland..."[5] Probably this concentration is related to the increased amalgamation and integration of wool processors and manufacturers in the major wool consuming countries.

Let us consider now how the buyers actually operate. A prospective raw wool consumer, say a textile mill in the United States, will go to one of the various United States representatives of the Australian wool buyers and place an order to buy a certain amount of wool of a specific grade within a certain price range. The buyer with these orders in his book will examine and value those lots of wool that are being offered for sale in which he is most interested. He is allowed to make only visual observations of the wool and must, by these observations, judge the quality and the clean yield of the raw wool. These judgements require considerable skill, for there are great variations in the yields of different lots. The wool producer, represented by the selling broker, and the wool consumer, represented by the buyer, are brought together in the auction room; and prices are determined by competition between the bidders. The prices at which the wool is sold include the charges for purchasing the wool and shipping it to the consumer. The buyer usually must pay the insurance costs.

In recent years the Australian open auction market system has undergone significant strains which have stimulated some demands for change or modernization of the system. These strains were caused mainly by the great increase in the size of the total Australian wool clip, along with a decrease in the average size of the individual clips, an increased concentration of buyers, and fairly unstable wool prices with periods during which these prices fell to abnormally low levels. The increase in the number of small individual clips, that is, clips of less than fifty bales, has made it very difficult for the buyers to examine the clips before sale and

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[5] *Ibid*, pp. 487-88.

has therefore led to some "bulk classing" of smaller clips into larger clips. Many small growers are against bulk classing, for they feel they can obtain more from an individualized or differentiated product. Other suggestions that have been made for easing the strain of the increased volume of sales are lengthening the selling season and/or increasing the number of centers that hold auctions concurrently.

There has been increased concern about the degree of collusion that exists in the market, especially about the amount and quantitative effects of buyers' "pies." A pie is essentially an agreement between two or more buyers not to bid against each other on wool desired by all members of the pie. Considerable disagreement exists as to whether or not pies are more prevalent now as compared to the pre-World War II period and as to the effect of pies on the market.[6] An adequate analysis of the effects of such collusive behavior would require more data than that now existing.

The final major element of concern is the instability of wool prices and the supposed degree to which this instability is a result of the auction system with its free interplay of the forces of supply, demand, and speculation. This instability increases the uncertainty growers face when making investment, production, and marketing decisions and also increases their costs due to a "ratchet effect" on wages and home-produced imports, which causes costs to rise in times of rising prices but remain fairly constant in times of falling prices. Wool users experience considerable losses or gains from changes in the value of their inventory that result from this price instability of wool. However, to some producers, for example, many producers in the United Kingdom, this uncertainty is considered a positive factor; for it gives them an opportunity to

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[6] See, for example, F. H. Gruen, "The Case for the Present Marketing System" in The Simple Fleece, op. cit., pp. 492-496.

play the market.[7] Finally, the Australian Government has been concerned about the effect of the instability of wool prices on farm income which leads to significant unstabilizing variations in the income of the Australian economy requiring neutralization by monetary and fiscal policy.

In part H of this section we consider to what extent wool futures markets can be used to off-set the uncertainty caused by price instability. Australian brokers and growers seem to feel that futures markets are prejudicial to their interests, that, in the long run, such markets will depress the spot prices.[8] However, in recent years, the percentage of wool buyers who make purchases for their own account has increased considerably, mainly because of an increased demand by wool consumers for wool for future delivery at a fixed price.

The major change in the Australian market system that has been strongly promoted by many manufacturers, approved by the Government, and which was voted down by the wool growers in December, 1965, is a reserve-price scheme, similar to that in New Zealand, under which reserve prices would be fixed and maintained for raw wool by a wool commission. Such a scheme would require, if it is to be effective in the large Australian market, a large amount of capital, some of which would probably come from the Government, and an ability to predict, fairly consistently, future supplies and demands in a market which is not independent of the reserve-price scheme commission's actions. It appears that a major cause of the negative vote by the growers was a distaste for the increased government participation

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[7] G. F. Rainnie, "Raw Materials and Markets," _op. cit._, p. 15. However, in the annual model used in this study, no evidence of such price speculation by United Kingdom textile mills was found, though speculation may be important with respect to shorter-run price movements.

[8] Alan Barnard, "A Century and a Half of Wool Marketing," _op. cit._, p. 480.

in the market that the reserve-price scheme implied.

B. Marketing of Wool in New Zealand

Over 90 percent of the New Zealand wool clip is sold at open auctions which are held throughout most of the year. Since these auctions are arranged similarly to the Australian auctions, we need not repeat our description of this mechanism here. The major exception to this similarity is the New Zealand Wool Commission, which came into operation in January, 1952, through an agreement between the New Zealand Wool Board and the New Zealand Government for the New Zealand Floor Price Plan. The Plan is a reserve-price scheme, similar to that proposed for Australia, under which a reserve or floor price is set each year for New Zealand wool sold at auction in either New Zealand or London. This price is supported by the Commission either by its buying wool in the market or by its reimbursing the seller of any lot of wool which sells for less than the reserve price by the difference between the selling price and the reserve price. The Commission has augmented its initial capital fund of £N.Z. 26.5 million by profits on the resale of wool and by interest earned on investments and hence has not faced the capital drain that many thought such a plan risked in times of price decline such as that of between May, 1957, and December, 1958. Gruen points out that the Commission's success in preventing a capital loss is due partially to the fact that the Commission has not attempted complete stabilization but, instead, only partial stabilization.[9] For example, the Commission purchased less than 5 percent of the New Zealand wool clip during the period of declining prices mentioned above. It must be mentioned, however, that the enabling legislation of the New Zealand Wool Commission directed the Commission to follow a conservative approach aimed at avoiding sudden short-run falls in

[9] F. H. Gruen, op. cit., pp. 504-505.

the market price rather than the more radical approach of determining what the "economic" price should be and vigorously attempting to stabilize actual prices around this price. The Commission has succeeded in carrying out its limited but important objectives thus far.

C. Marketing of Wool in South Africa

All South African greasy wool must, by law, be sold at public auctions the organization of which is similar to that of the Australian auctions. These auctions are held throughout most of the year. However, selling brokers do have the option of withholding their wool if the market price is below their limit and then negotiating privately for a better price. A fair quantity of greasy wool is sold by private treaty in this way.

Like New Zealand, South Africa has a reserve-price plan which is operated by the South African Wool Commission. This Commission is composed of growers, brokers and Government representatives. The South African reserve-price scheme has succeeded in successfully disposing of all wool which it has had to buy in support of the reserve price. The plan came into operation in March, 1958, and has maintained essentially the same reserve price ever since. This reserve price has been well below realized prices for most of the period. However, the South African Commission has had to purchase a larger portion of its country's offerings (e.g., 10 percent of South Africa's offerings of wool in the 1960-61 season) than has the New Zealand Commission. One important cause of these larger purchases is that the operations of the New Zealand Wool Commission probably have a greater effect on the world prices due to the greater quantitative importance of the New Zealand wool clip in the world wool clip, especially in the classes of wool New Zealand produces. Thus, the South African scheme has had greater burdens placed upon its not very adequate funds and has had greater difficulty in disposing of the wool it has had to purchase.

On the whole, these schemes have been successful in carrying out their limited objectives. They have not, however, substantially reduced the variability of wool prices. The New Zealand and South African wool prices seem to follow very closely the Australian prices and have the same degree of variability. Probably the greatest effect of these "price-stabilization" plans has been the very important one of strengthening the confidence of wool growers by setting a lower limit to the range of their price expectations. Wool growers in these countries are now confident that the Wool Commissions will limit the extent to which the price of their product can decline.

D. Marketing of Wool in the United Kingdom

The London wool market, which was once the foremost central auction market for wool, is still a major alternative market for Australian, New Zealand and South African wool and an important "spot" wool market for the United Kingdom and Europe. The London auction system is the model on which the Australian, New Zealand and South African auction systems are based, and hence there is no need to repeat the description of such a system here. However, the market faced by the British wool producers is somewhat different, for in October, 1950, the British Wool Marketing Scheme came into operation. This scheme is sponsored by British wool producers, who must sell their wool at guaranteed prices to the British Wool Marketing Board, the administrator of the scheme. These guaranteed prices are set by the Government annually after consultation with the producers. The wool is then sold at public auctions in London and other auction centers in the United Kingdom. If the auction price is greater than the guaranteed price, the difference goes into a fund which helps finance the scheme in times when auction prices fall below the guaranteed price.

E. Marketing of Wool in Argentina

All wool is sold in Argentina by private sale either directly to large exporting firms (about one-half of the clip is sold this way) or to dealers (about one third is sold this way) or is sold on consignment through commission houses in the central markets of Buenos Aires, Bahia, Blanca and Rosario. For the most part, there is no classing of the wool before sale. No wool is sold at public auctions in Argentina. Sales by private treaty are probably less favorable to the wool grower than open auction sales, for the grower has more limited knowledge of general market conditions than do the marketing agents with whom they deal. Blau suggests that the explanation of why sale by private treaty is the prevalent method in South America is mainly historical. For these countries, the importance of their mother country, Spain, as a purchaser of their wool dwindled relative to that of other countries whose firms established large scale buying agencies in these South American countries.[10]

There is a complicated mass of Government regulations which have affected the Argentinian wool market significantly in past years. These Government measures have taken the form of varying and multiple exchange rates and special export and sales taxes, which have been used at some times for encouraging the export of wool and at other times for revenue purposes. The many frequent changes in Government regulations have caused significant erratic fluctuations in Argentina's yearly exports and end-of-the-season stocks, which have had an effect on the international wool market.

F. Marketing of Wool in Uruguay

The bulk of the raw wool produced in Uruguay is sold by private treaty to dealers in Montevideo. However, there is considerable interest in the open auction method of selling wool; and since 1956, there has been a limited voluntary system of auction sales which is supported by the government. Like Argentina, Uruguay has had frequently changing government trade regulations, such as multiple

[10] Gerda Blau, op. cit., pp. 217.

exchange rates, premium payments for wool exports and sales and export taxes, which have had a considerable effect on yearly exports and retained stocks.

G. Marketing of Wool in the United States

Nearly all wool produced in the United States is sold by the following three types of private treaty: a) direct buying in the producing areas by dealers or agents for dealers or mills (the largest proportion of sales is accounted for by this method), b) cooperative marketing in central selling centers through cooperative marketing organizations to which the member producers consign their clips and c) sealed-bid sales. There has been an increase in recent years in wool processors or manufacturers who buy directly from the wool growers. The major United States central market for wool is Boston, but in recent years the centers of Charleston, South Carolina and Philadelphia have increased in importance with the movement of textile manufacturers to the South.

The price of United States raw wool has been supported in some way since 1938. From 1952 to 1955 the Commodity Credit Corporation was willing to buy all wool that could not be sold at the support price. It also made non-recourse loans to wool growers, the security for which was wool lodged with the Commodity Credit Corporation. The wool growers had the option of surrendering their wool in full discharge of their debt if they could not sell the wool in the market for more than the loan. In August, 1954, the National Wool Act of 1954 was passed by Congress. Through this Act, the Government recognized wool as an essential and strategic commodity. The aim of this Act is to encourage an increase in the production of raw wool of about one third by supporting the price of wool principally by means of incentive payments to wool growers to give them a price up to 110 percent of parity with the limitation that all payments under the Act must not exceed 70 percent of the gross receipts from duties collected on imports of wool and wool manufacturers on and after January 1, 1953.

H. Wool Futures Markets

The wool futures markets which have been established at Antwerp, Robaix-Tourcoing, New York, London, Nagoya, Osaka, Tokyo and Sidney provide a means whereby producers, traders and manufacturers can protect themselves against risks of price fluctuations. The markets in Antwerp and Roubaix-Tourcoing started in 1888, the New York market in 1931, the London market in 1953, and the Sidney market in 1960. Although not as important as the futures markets for some other commodities such as wheat and cotton, the wool futures markets are an integral part of the market mechanism for wool and wool tops (that is, scoured and combed wool). In this section we will only briefly describe these markets. An adequate study would constitute a full research project in itself; and, in fact, an excellent study of the New York Wool Futures Market has been done by Howell.[11] He analyzes the New York Market's past performance with particular emphasis on the protection this market provides wool producers, traders and manufacturers against changes in the prices of raw wool, wool tops and selected wool yarns and fabrics.

One difficult problem in setting up efficient futures markets in wool is finding a commodity which is standardized with respect to quantity and quality on which to base the contracts. It is because of this problem that futures markets have dealt mainly, in most cases exclusively, in contracts based on wool tops, which are a more standard product than greasy wool. The New York Market and the Sidney Market are the only futures markets with significant trade in greasy wool contracts.

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[11] L. D. Howell, Analysis of Hedging and Other Operations in Wool and Wool Top Futures, Technical Bulletin No. 1260, U.S. Department of Agriculture, (Washington D.C.: U.S. Government Printing Office, 1962). See also, G. F. Rainnie (ed.), The Woolen and Worsted Industry, "Appendix A."

The need for a futures market for wool results from the high variability of wool prices, the considerable amount of stocks that must be held by producers of wool, traders, and manufacturers of semi-finished and finished wool products, and the practice of manufacturers entering into contracts in which they agree to deliver products in the future at fixed prices. The principal reason that manufacturers and large dealers hold such large stocks is that the production of raw wool is seasonal and most small growers and dealers prefer to pass price risks onto the larger dealers and manufacturers by selling their product almost immediately when it becomes available. Another reason for so many stocks being in the system at one time is the quite long period of production of six months to a year from raw wool to a finished product. The holders of these stocks often desire to hedge against the price risks involved in these stocks by entering the futures market. Most buyers of wool and wool top futures sell them before the contract expires. Deliveries on the wool futures market are a very small percentage of all trading; for example, in the United States, they rarely exceed 3 percent of the total yearly trading.[12]

The possibility of hedging is based on the assumption that changes in the spot price of wool will be associated with similar changes in future prices. To the extent that this relationship is both strong and stable, the futures market provides a means by which wool growers and wool textile manufacturers can pass on the risks of changing prices to professional speculators, who are better equipped to carry such risks because of their experience in forecasting and their ability to devote their full time to following the market.

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[12] W. Brewster Southworth, "Future Trading in Wool and Wool Top Contracts," in Wool Handbook, ed. Von Bergen, Vols. I, II; 3d ed. (New York: Interscience Publishers, 1965), p. 683.

Howell found that over the five year period of April, 1955, to March, 1960, the correlation coefficient between changes in spot prices of Territory Fine Staple Wool in Boston and corresponding changes in the prices of wool futures in New York for the near-active month was .88 and the correlation coefficient between changes in spot prices of 64s wool tops and corresponding changes in the prices of New York wool top futures for the near-active month was .90.[13] Over the same period, the proportion of changes in the spot prices that could have been offset by hedging with futures contracts average over 70 percent.[14] Rainne found that the relationship between spot and near future prices in the London Wool Futures Market has been quite variable.[15] This variability, which is also found in the New York Wool Futures Market, introduces another risk to the hedger besides the risk of changing spot prices, which he is seeking to avoid. This variability is due to differences in the quality of the wool and wool products for which the prices are quoted, to the relatively low volume of transactions in these markets, which permits trading in certain contracts to become restricted, and, in the case of the London market, to the "growing pains" of a relatively new market. As Rainne notes, the process of hedging in a wool futures market should not be considered insurance against price risks with a known "cost" or "risk premium;" for the "cost," which varies with the relationship between spot and future prices, is not known and, in fact, may well be a discount.[16]

One advantage of all the wool futures markets is that the existence of quotations of prices of wool for present and future

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[13] Howell, _op. cit._, pp. 17-18.

[14] _Ibid._, pp. 36-49.

[15] G. F. Rainnie (ed.), _The Woolen and Worsted Industry: An Economic Analysis_, _op. cit._, "Appendix A," p. 185.

[16] _Ibid._, p. 187.

delivery promotes improved control of inventories by making more explicit the costs of holding wool in times of shortage of supply and the gains of holding wool in times of surplus supply.[17] More generally, these quotations improve the economic efficiency of the market by increasing the information held by participants in the market on the current and collectively expected future market conditions. Part of the reduction in the variability of wool prices that has occurred in the last ten years may be due to the development of the new futures markets in London, Japan and Sydney and to the growth of the older markets.

5. The Effects of Economic and Tariff Policies on World Wool Trade

In analyzing the world market for wool, it is very important that we consider how this market has been and is now affected by the economic and tariff policies of the major countries and groups of countries. We will concentrate here on how these policies have evolved in the post World War II years, for it is this period in which we are most interested. It is important to note first that, unlike most other major commodities, there is no international control agreement for wool or wool products. Perhaps the major developments in economic and tariff policies since World War II that have had the strongest effects on the wool and wool product market have been the emergence of regional trade blocs and the liberalizationof trade barriers through the Organization for European Co-operation, which, by the mid 1950's, had led to the abolition of import licensing control in Europe, and through the General Agreement on Tariffs and Trade (G.A.T.T.) under which the Kennedy Round of discussions on trade liberalization are now taking place.

The European Economic Community (E.E.C.) was set up in 1957 with the aim of eliminating the customs barriers between its members

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[17] *Ibid.*, p. 178.

(Belgium, France, Western Germany, Italy, Luxembourg and the Netherlands) and its associates (Overseas Territories, Greece and Turkey) and setting up common external trade barriers to non-member countries. The E.E.C. countries use about one-fifth of the world's production of raw wool. These countries carry on an intensive trade in semi-finished and finished wool products with each other and together are a net exporter of wool products to the rest of the world. The European Free Trade Association (E.F.T.A) was established in 1960 with the aim of eliminating the customs barriers between its members (the United Kingdom, Austria, Denmark, Norway, Portugal, Sweden and Switzerland) and its associate (Finland) on all industrial products. However, unlike E.E.C., E.F.T.A. does not call for the setting up of a common external tariff. The creation of these regional trade blocs has greatly changed the flows of trade in wool and woolen products between member and non-member countries by increasing the trade between member countries and decreasing the trade between countries belonging to different trade blocs and, in many cases, has reduced trade between countries belonging to a trade bloc and countries outside of these blocs. Unfortunately, the scope of this research is not broad enough to permit us to go deeply into the difficult and interesting question of the net effect of these regional trade blocs on international trade in wool and wool products. Certainly a positive effect has been the rapid economic growth of most of the member nations in the 1950's and 1960's, but it is difficult to measure how much of this growth can be imputed to the formation of these trade blocs.

Probably the most important barriers to free trade in wool and woolen products in recent years and at present are the heavy duties which the United States has imposed on raw wool imports (except for carpet wool imports, for the United States produces almost no carpet wool) and on all manufactured wool imports. In 1956 the United States introduced a strong tariff quota system on imports of wool fabrics, which was rescinded in 1961 when the basic tariff rates were substantially increased. These tariffs are aimed especially at the low priced and low quality wool textiles from Italy and Japan. The United States wool textile industry is seeking even further restraints on foreign competition by asking for a quota-by-origin system similar to that incorporated into the G.A.T.T. International Cotton Textile Agreement.

Import licensing restrictions of varying degrees of severity remain in most of the other countries of the world with stronger restrictions on imports of wool products than on imports of raw wool. The strongest restrictions are usually found in the underdeveloped countries that are having balance of payments difficulties and/or are protecting "infant" textile industries. Latin American countries have errected such severe trade barriers in the form of import prohibitions, quotas, prohibitive duties and import licensing that imports of wool products into Latin America have dwindled to much smaller proportions then they once were.

Trade with Japan was severely restricted for a number of years after World War II, and many nations, invoking Article 35 of G.A.T.T., would not grant Japan most-favored-nation treatment to her goods because of fear of market disruption. Japan, in turn, maintained high barriers against many imported goods. Since 1962 many countries have ceased to invoke Article 35, Japan has lowered many of her restrictions, and an extremely vigorous and growing trade in wool and wool products now exists between Japan and the rest of the world. Japan has helped dispel some of the fears of market disruption by voluntarily limiting her textile exports.

The Sino-Soviet bloc countries, of course, have the most strongly regulated trade in wool and wool products, with all transactions conducted through state trading organizations. It has been the practice of these organizations to enter the raw wool market intermittently for limited periods of time and to carry on little trade at all in manufactured wool products, which are classed as "unessential imports." It has been the hope of wool producers for many years that the large potential markets of the Sino-Soviet bloc, especially that of China, will be opened to a much greater extent than at present to the noncommunist world.

6. The International Fiber Market

In this final section we consider the competitive position of wool in the industrial fiber market; and, in particular, we examine the challenge wool faces from the competition of synthetic fibers. If we look at Table 2.10, which gives the fiber consumption of the wool textile industries of the United Kingdom, the E.E.C., Japan and the United States, (which together accounted for 57 percent of the total wool consumed in 1963), we can see that the proportion of virgin wool to total fibers consumed by the wool textile industry fell from 55.6 percent in 1963 to 52.7 percent in 1964, while the proportion consumed of man-made fibers rose from 17.4 percent to 21.0 percent. Also the proportion consumed of other non-wool

Table 2.10. Proportions of Materials Consumed by the Wool Textile Industry: Aggregate for the United Kingdom, The EEC, Japan and the U.S.A.

Material	1963	1964	January-September	
			1963	1964
	%	%	%	%
Virgin wool	55.6	52.7	55.5	53.1
Non-virgin wool	18.1	17.0	18.3	17.3
Man-made fibres	17.4	21.0	17.2	20.3
Other non-wool fibres	8.9	9.3	9.0	9.3
Total materials consumed	100.0	100.0	100.0	100.0

Source: Commonwealth of Australia, Bureau of Agricultural Economics, The Wool Outlook, No. 19 (Canberra, Australia, 1965), p. 11, Table 9.

fibers, chiefly cotton, rose from 8.9 percent to 9.3 percent. During this period, the total consumption of fibers by the wool textile industries of these countries rose each year. One cause of this proportionate fall in wool consumption is surely the fact that wool supplies in this period were insufficient to meet the consumers' demand for finished wool products, and so some substitution of non-wool fibers for wool fibers was necessary if these increased demands were to be met. But there does seem to be a significant amount of consumer and producer substitution taking place that is based on other facts, such as the greater variability of wool prices and the more standard quality of synthetic fibers. It is statistics such as are given in Table 2.10 which have caused increased concern in recent years to the producers of raw wool.

While chiefly concerned about the challenge of the synthetics, wool producers have cause to be concerned also about competition from other fibers, particularly cotton and non-virgin wool. These two fibers have always been used by producers of woolen textiles to cheapen their products, especially in times of high wool prices. There are indications that, with the rising economic expectations of many areas of the world and the growth of textile industries in many of the newly developing countries and in Italy and Japan, one of the biggest markets for wool textiles will be in this area of the low quality and low cost textiles.

The principal competitors of raw wool, however, are the ever-increasing numbers of synthetics which began with Nylon in 1938 and became a truly important competitive force with the arrival of the polyesters such as Dacron, Kodel and Terylene and the acrylic fibers such as Acrilan and Orlon in the early 1950's. These synthetic fibers can be produced as either a continuous filament or a staple. The staple is produced by cutting the filament into pieces roughly the same length as the natural fibers such as wool. It is the staple form of the synthetic fibers which are most similar to and most competitive with raw wool. Fortunately for the wool growers, scientists have not yet perfected a synthetic fiber which has all of the qualities of raw wool; nor is it likely that they will do so in the near future. But they have been able to develop fibers which are light, very strong, long wearing, resistent to felting and which can be produced with a high degree of standardization of quality. The importance of this last characteristic is great, for textile producers have to spend a very considerable amount of time and money preparing wool for the textile process because of the unevenness of its quality.

The synthetics industries were hampered in the early years of their existence by insufficient capacity, especially in Europe, and had to charge a high price for their products to cover the considerable fixed costs of research, sophisticated plants and initial promotion schemes. However, as Table 2.11 shows, production and planned capacity is increasing at a very fast rate. Moreover, the synthetic industry has experienced significant economics of scale in expanding and has been able to bring down prices significantly so that they now are considerably below those of the wools with which they compete. However, Polasek has shown that, at least in the United States, the relative price levels of wool and synthetic fibers apparently have had little effect on changes in the market shares of these fibers.[18]

Another characteristic of wool prices, their relatively high variability, have had perhaps a greater effect on the competitive position of wool. As Figure 2.2 shows, synthetic prices change very infrequently. In fact, synthetic producers acknowledge the fact that they make a concerted effort to hold their prices constant, even when it would be more profitable <u>in the short run</u> to increase prices. Synethetic producers, moreover, have the advantage of

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[18] Metodery Polasek, "Synthetic Fibres and Australia's Economic Future," <u>Economic Record</u>, Vol. XLI (March, 1965), p. 35.

Table 2.11. Estimated Production and Planned Capacity of Non-Cellulosic Man-Made Fibres.

million lb.

	Average 1951-55	1960	1961	1962	1963	1964	Planned capacity 1966
United Kingdom	22	134	146	183	232	279	652
Canada	10	37	43	50	58	66	151
Australia	—	5	5	6	12	17	42
United States	258	677	751	973	1,156	1,407	2,464
Japan	17	261	338	403	527	754	1,099
West Germany	14	116	144	207	241	306	564
France	14	100	113	144	179	204	340
Italy	11	75	96	139	171	221	409
Netherlands	3	20	25	41	55	72	137
Belgium	3	6	7	10	13	17	24
Switzerland	2	15	19	24	33	38	63
Spain	—	6	8	13	23	26	57
Brazil	—	10	13	19	23	28	50
Mexico	—	2	4	7	9	12	36
Argentina	—	3	4	5	10	22	50
Other countries *a*	—	3	5	11	16	27	204
Total non-Communist countries	354	1,470	1,721	2,235	2,758	3,496	6,342
Soviet Union	7	33	52	75	94	126	276
East Germany	5	17	24	31	35	38	61
Poland	6	17	19	19	23	34	81
Czechoslovakia	1	7	9	14	16	18	29
Other Eastern Europe	—	3	4	5	9	9	25
China	—	1	1	1	1	1	2
Estimated world total	373	1,548	1,830	2,380	2,936	3,722	6,816
Of which: Commonwealth b	*32*	*176*	*194*	*240*	*304*	*365*	*869d*
Common Market	*45*	*317*	*385*	*542*	*659*	*820*	*1,501c*
European Free Trade Association	*2*	*15*	*20*	*25*	*35*	*42*	*78*
Sino-Soviet group	*19*	*77*	*109*	*145*	*179*	*225*	*474*

Sources: Textile Organon and National statistics.

a Colombia, Chile, Denmark, Egypt, India, Israel, Korea, Norway, Peru, Portugal, Sweden, Taiwan, Uruguay, Venezuela and Yugoslavia.

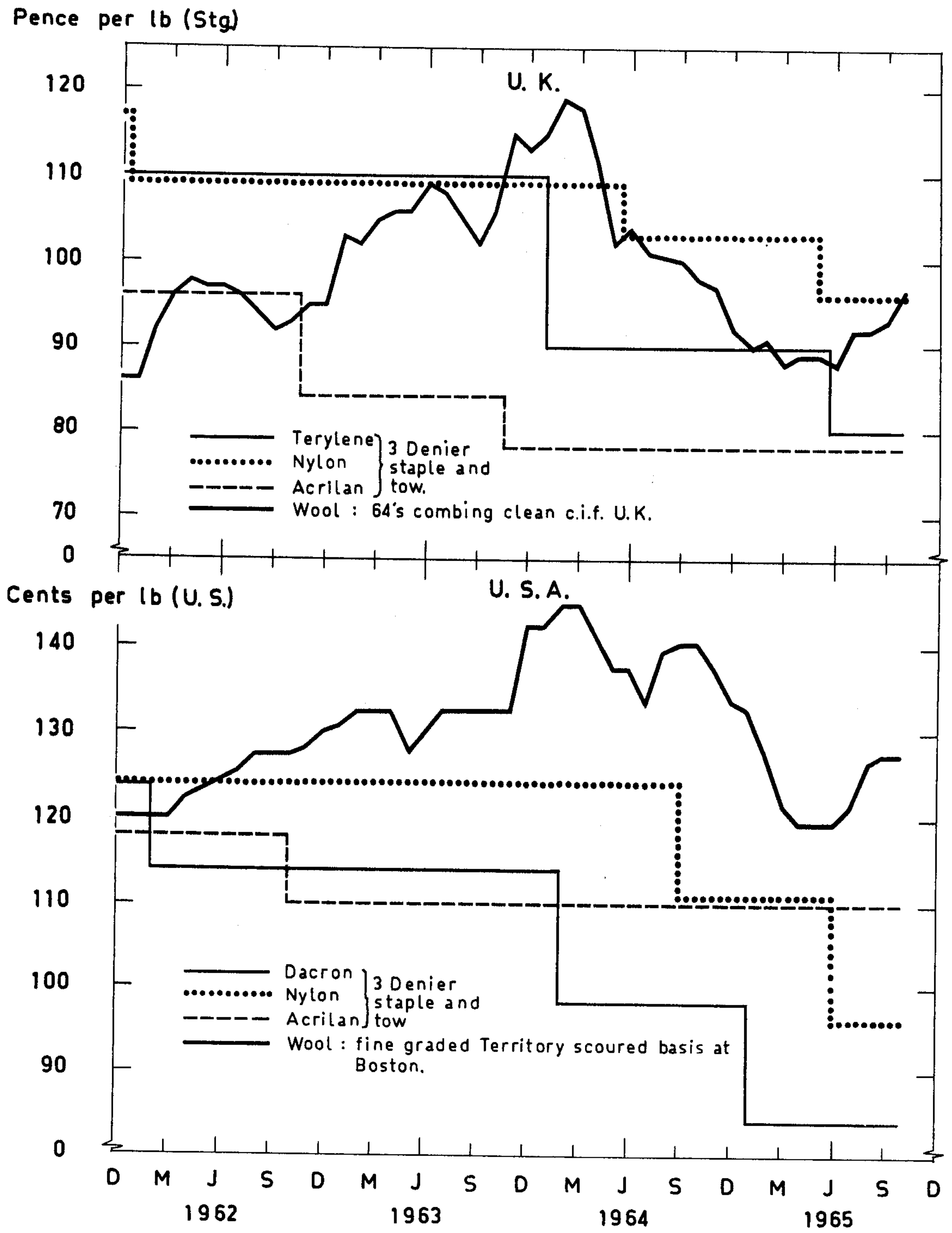
b Including India.

c Including 24 million lb. of yarn for Luxembourg.

d Including, Malta, New Zealand and Pakistan.

Source: Commonwealth Economic Committee, Industrial Fibres, No. 15, (1965), p. 109, Table 64.

Figure 2.2. Prices of Wool and Non-Cellulosic Man-Made Fibers.



Source: Commonwealth of Australia, Bureau of Agricultural Economics, The Wool Outlook, No. 19 (1965), Graph II.

being able to adjust supply much more readily to changes in demand and thus reduce pressures for price changes. Thus, by switching to synthetics, a textile manufacturer can reduce the risks due to price variability of losses on stocks and fixed contracts for future delivery of goods. Also, he is spared the bother and expense of following day-to-day price movements in the wool market and maintaining special buying agents in the major wool markets or dealing with professional wool dealers. Instead, he needs only to call up the producer of the synthetic fiber and place an order for a fiber with known specifications at a known and quite constant price.

Certainly one of the most important reasons why synthetics have become so important in the wool textile market is the shift in consumer demand toward lighter weight clothing and to clothing which is longer wearing, more easily cleaned and has certain other innovations such as permanent creases or pleats. Polasek has shown that there has been some marked differences in the impact of synthetics in various end uses of the wool fiber in the United States. For example, items such as men's sport shirts, women's and childrens' sweaters and women's blouses and shirts are quite vulnerable to synthetics substitution, while items such as men's regular weight suits, overcoats, and jackets, women's suits and women's skirts are considerably less vulnerable.[19] The shift toward lighter weight clothing was caused partially by the increased use and efficiency of central heating and the increased percentage of leisure time spent indoors. In response to this demand shift, some excellent light weight wool textiles have been developed. Yet only recently have the wool producers begun to carry out extensive research into new ways to improve the woolen fiber and to treat woolen textiles so that they have some of the desirable properties that the new synthetics have. Also, in the last few years the wool producers have

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[19] Polasek, op. cit., pp. 26-31.

begun a fairly extensive wool promotion program to counter, to some extent, the large amount of promotion done by the synthetic fiber producers. The degree of success of this wool promotion scheme has not yet been evaluated. Finally, wool producers have been studying ways in which raw wool can be made a more standardized product through more complete and scientific classing of the wool clip. Such innovations would probably help wool significantly in competition with synthetics in those areas of the market where a high premium is put on fibers with fairly constant characteristics.

The blending of wool with synthetic fibers, especially the polyesters, in order to achieve some of the best properties of both has been very successful. In the opinion of many, it is in such blends that a great part of the future market for wool lies. However, the wool producers, so far, apparently have decided that the use of such blends weakens the potential market for wool; and therefore, they have concentrated on promoting products made of 100 percent virgin wool and in developing a "quality image" for wool. In judging the wisdom of such a course of action, we should note that the acrylic fibers, which have displaced more wool than nylon and the polyester fibers together, are competing with wool mainly in the pure unblended form in such important end uses as knitwear, blankets and carpets.

Now that we have examined the basic institutional, historical, and technological background of this study, let us turn to the statistical and theoretical analysis of the international wool market.

CHAPTER 3

AN ANNUAL MODEL OF THE WORLD MARKET FOR RAW WOOL: INTRODUCTION AND DATA CONSIDERATIONS

1. Introduction to the Model

In this and the following four chapters we will consider the construction of an annual model of the world market for raw wool for the years 1949 to 1964. It is hoped that the formulation, estimation and use (e.g. generation of forecasts, study of stability properties, study of impact multipliers, etc.) of this model will help in the understanding of the long-run structural aspects of this market. This model will permit us to analyze not only the immediate impact of an exogenous shock in the country (ies) in which it originates but also the secondary impacts of this shock throughout the world market. The model will include functions describing the stock adjustment behavior of both wool producers and wool consumers. It will also include lagged exogenous and endogenous variables in many of the relationships. Hence, the model will be a dynamic one and will contain some recursive relationships. However, since it will not be fully recursive, simultaneous estimation techniques will be used.

By looking at annual data, we will, in effect, filter out the shorter-run movements in the market such as seasonal variations in production and consumption and short-run spectulative movements. In Chapter 8 these short-run aspects will be studied by applying spectral and cross-spectral analysis techniques to monthly wool market data. The use of an annual model, however, does permit us to examine the important relationships which are of an essentially long-run nature, for example, the supply function of raw wool, the competition between wool and synthetic fibers and the consumers' demand functions for textile products. Also, the production of raw wool is an annual process, for sheep are generally shorn only once a year. Thus, for all wool-producing countries, there exists only annual data on the production of raw wool. Finally, by looking at an annual model, we can consider consumption data for many countries for which there exist no monthly or quarterly data; and hence we can include the wool markets of these countries as endogeneous sectors of the world model. Of course, even in an annual model, there are a large number of countries that will have to be lumped together as a "Rest-of-the-World" sector.

The annual model will be descriptive of the main aggregative flows in the wool market. Because of insufficient data, the desire to encompass the whole market and the need to make the model manageable, the degree of aggregation in the model will be very high. The market will be analyzed at the levels of the production and final domestic consumption of wool. We will also include equations explaining the level of stocks of raw wool held by the major wool producing and wool consuming countries. However, due to a lack of data, we cannot analyze the determinants and effects of stocks, consumption and trade flows of semi-finished wool products and of retail, wholesale and consumer stocks of finished wool products.

In particular, the original form of the model will consist of (a) seven equations explaining the production of wool in the six major wool producing countries (Australia, New Zealand, South Africa, Argentina, Uruguay and the United States) and in a "Rest-of-the-World"sector, (b) five equations explaining the level of "producer stocks" of wool (that is, wool stocks carried over to the next season) in five wool producing countries (all of the above mentioned countries except the United States in which almost all wool is sold immediately after it is shorn), (c) nine equations explaining net domestic consumption of wool (mill consumption plus the raw wool content of net imports of semi-finished and finished wool products) in eight major wool consuming countries (United States, United Kingdom, Japan, France, Italy, West Germany, Belgium and Netherlands) and in a "Rest-of-the-World" sector, (d) three equations explaining the level of stocks of raw wool in three major wool consuming countries (United States, United Kingdom and Japan),

(e) one equation "explaining" wool prices by the changes in the level of "implied residual stocks of wool", a variable indicating the amount of imbalance between supply and demand in the market, and (f) four identities, three of which define mill consumption in three countries (United States, Japan and the United Kingdom) as net domestic consumption minus net imports, and one accounting identity which states that "implied residual stocks" is equal to world wool supply minus the sums of world wool consumption and changes in wool stocks in the United States, United Kingdom and Japan, where world wool supply is defined as world wool production minus changes in supply stocks and "noncommercial stocks" (such as stocks held in strategic stockpiles). This model, therefore, will consist of 25 functional equations and four identities. In the final form of the model, which is analyzed in Chapter 7, the equation explaining price by "implied residual stocks" is dropped because it proves to be unsatisfactory; and the producer stocks equation for New Zealand is normalized on the wool price variable, as is described in Chapter 5, section 5. In this 28 equation final model, the accounting identity defines New Zealand producer stocks; and implied residual stocks are assumed to be exogenous, since a large proportion of this variable is apparently an accumulated error in measuring the other variables.

Since wool prices are thought to be relevant to wool production only in a lagged form, there is no simultaneity problem in estimating the equations explaining wool production. Hence these equations are estimated separately by the methods of ordinary, and in some cases, an approximate form of generalized least squares. The rest of the model is estimated simultaneously by the method of two-stage least squares. In the rest of this chapter we discuss some general considerations of the data we will use in this analysis. In Chapter 4 we analyze the wool production sector of the model. In Chapter 5 we analyze the stock sectors and the price equation of the model. In Chapter 6 we analyze the consumption demand sector. Finally, in Chapter 7 we analyze the complete model in its final form, giving particular emphasis to the model's stability properties and making use of its reduced form equations to derive the dynamic multipliers of the exogenous variables.

2. The Data

The relationships of our model will be expressed, in so far as is possible, in terms of comparable real economic variables. Clearly many of the variables, such as wool production expressed in millions of pounds, are already in real terms. However, other variables, namely price and income data, are in terms of the current prices of the respective countries. These data will be converted to current U. S. dollars at the then current exchange rates and deflated by the whole-sale price indices of the respective countries. While admittedly not perfect (due to the lack of complete flexibility in exchange rates), this method should be an adequate transformation of the data into comparable form.

For the annual world price of wool we will use a weighted average of the seasonal averages of the Dominion wool price series for 64s and 46s (Bradford counts) wool, the weights being determined by the percentage of Merino and crossbred quality wool in the total world clip. Thus we are using the price of a composite quality wool. (Alternatively, we could use the price of a representative type of wool, for example, the Dominion price of the 56s wool.) The Dominion wool price series are average weekly series of prices for the different qualities of wool and are compiled by the New Zealand Wool Commission (Jordon Agency) on the basis of quotations from sales held during the week in the United Kingdom, Australia, New Zealand and South Africa. We show in Chapter 8 why we feel these prices are, as experts in the wool market suggest, a good index of movements in the whole spectrum of world wool prices. The use of a single price rather than separate prices for different qualities is dictated by the lack of a wool-quality breakdown of much of the data necessary for this annual world model. Figure 3.1 shows how closely together the seasonal Dominion wool prices for

70s, 64s, 56s and 46s quality wools have moved in the period covered by this study. The relationships between the different quality wools will be examined, however, in the less aggregated analysis of Chapter 8 in this study. These wool prices are quoted in terms of British pence (pounds), and hence we convert these prices to U. S. dollars at the current exchange rates. We then deflate this price series by an index of seasonal world trade commodity prices constructed as an average of the monthly Sauerbeck index of commodity prices over the months of July to June with 1958-59 = 100. Other studies [1] have found that the particular choice of an index of world trade prices appears to have supprisingly little effect on the coefficient estimates, and the Sauerbeck series seems relevant for the countries which are of most importance to the wool market and also is convenient, for, being monthly, it can be converted to a seasonal basis.

Another difficult aspect of the data for this model is that wool is a seasonal product, the season for most countries running from September to June, and for the United States being highly concentrated in the three months, April, May and June. Thus data on wool production should be expressed in terms of the seasonal rather than calender year outputs. Data on wool stocks are for stocks existing at the end of the season, around June 30, for most countries. Fiber consumption data, however, are available only on the basis of calender years as are income data. This difference should cause us no problems, for there is a lag between wool production and consumption apparently of from four to ten months caused mainly by the lag between sale and shipment of the raw wool and the transportation lag. Thus the seasonal production and

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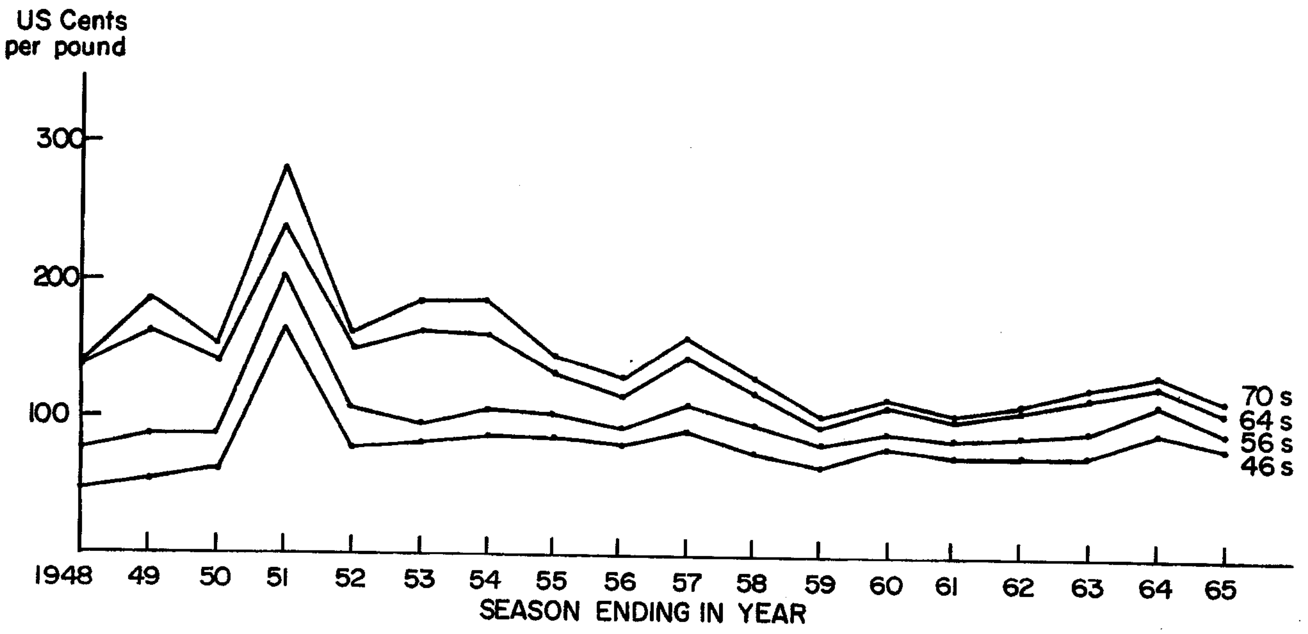
[1] See, for example, B. P. Philpott, Fluctuations in Wool Prices 1870-1963, Publication No. 13, Agricultural Economics Research Unit, Lincoln College, University of Canterbury, (New Zealand, 1965).

Figure 3.1. Dominion Wool Prices for Seasons 1947-48 to 1964-65.



Source: United States Department of Agriculture. Wool Statistics and Related Data: 1920-1964. Statistical Bulletin No. 363, Washington, D.C.: U.S. Government Printing Office, July, 1965. Tables 260, 261, 264 and 267.

producer stock data will be given the subscript t equal to the last year of the season, and it will be this production minus any change in producer stocks and noncommerical stocks at the end of the season which will be assumed to be equal to consumption plus change in consumer stocks in calender year t. As stated above, the wool price variables will be annual averages for the wool production seasons, for these averages will be those that are relative to the production and carry-over stocks decisions of the wool producers. Also due to the lag between purchase and consumption of wool, these prices, being lagged a half a period behind consumption, are probably more relevant to calender year consumption than calender year prices. However, due to lack of adequate monthly series, the prices of substitute and complementary products are on a calender year basis.

Let us defer further discussion of the particular time series used in each equation until the discussion of these equations and now turn to the supply side of the annual world model.

CHAPTER 4

WORLD PRODUCTION OF WOOL

1. Introduction and some Theoretical Considerations

The annual model will contain equations explaining the production of raw wool in the five major exporting countries, Australia, New Zealand, South Africa, Argentina and Uruguay, in the United States, which imports about as much wool as it produces, and in the "Rest-of-the-World" sector. In this section a theoretical model of the seasonal production of wool is described. Some of the statistical problems faced in fitting this model to time series data are discussed in Section 2, and the results of fitting this model to data for the seasons 1948-49 to 1964-65 for the above five countries and the "Rest-of-the-World" sector are described in Sections 3 through 8. Finally, in Section 9, comparisons between the results for the different countries are made and some general conclusions about the nature of seasonal world wool production are given.

The product, raw wool, is obtained from the shearing of sheep which have an average life of a little more than five years. The sheep are usually shorn first within one year after they are born and yearly thereafter. While a single wool grower could purchase or sell a large percentage of his flock to increase or decrease his wool output rapidly, the country as a whole cannot, there being little international trade in live sheep. Thus, an essential dynamic aspect of the wool market is that the level of a country's production of wool cannot be changed rapidly in response to changing economic conditions. In building this dynamic aspect into our production equations, we follow the approach first used extensively by Nerlove in his studies of agricultural supply functions for the

United States.[1] Equation (4.1) is a general version of the specification of the adjustment of actual production of country j in season t, W_{jt}, to desired or equilibrium production, W_{jt}^*, assumed in this study.

$$(4.1) \qquad W_{jt} - W_{jt-1} = \delta_j (W_{jt}^* - W_{jt-1}) + b_j R_{jt}$$

In (4.1), the actual change in production in season t is specified to be equal to a fraction, δ_j, the "coefficient of adjustment", of the desired or equilibrium change in production plus $b_j R_{jt}$, the effect of exogenous, probably noneconomic, factors in season t such as weather and/or technological change. Such factors will vary for different countries. The size of the fraction δ_j is a measure of the speed with which actual production adjusts in response to factors determining desired production and is determined not only by the biologically determined production lag indicated above but also by a number of institutional, technological and behavioral rigidities. Equation (4.1) states that production takes time, that "Between one period and the next you will travel only a fraction of the distance which separates you from where you are and where you would like to be if you could adjust instantaneously, where you would want to be if adjustments were painless and costless, and if you really believe that the current data (prices) would persist..."[2]

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[1] See, for example, Marc Nerlove The Dynamics of Supply: Estimation of Farmers' Response to Price (Baltimore, Maryland: Johns Hopkins Press, 1958); Marc Nerlove, "Distributed Lags and Estimation of Long-Run Supply and Demand Elasticities: Theoretical Considerations," Journal of Farm Economics, Vol. XL (May, 1958), pp. 301-311; and Marc Nerlove and William Addison, "Statistical Estimation of Long-Run Elasticities of Supply and Demand," Journal of Farm Economics Vol. XL (November, 1958), pp. 861-880.

[2] Zivi Grilliches, "The Demand for Fertilizer: An Economic Interpretation of a Technological Change," Journal of Farm Economics, Vol. XL (August, 1958), p. 598.

It should be noted that, if the output variables, W_{j_t}, are expressed in terms of deviations from output in time zero and if the term $b_j R_{j_t}$ and the arbitrary constant of the difference equation (4.1) equal zero, the solution of (4.1) is

$$(4.2) \qquad W_{j_t} = \sum_{\lambda=0}^{t} \delta_j (1 - \delta_j)^{t-\lambda} W^*_{j_\lambda} ,$$

that is, actual output in year t is a distributed lag function of past desired or equilibrium outputs.

The desired or equilibrium level of production in season t, $W^*_{j_t}$, is a function of prices and other economic and noneconomic factors in the seasons preceding season t. An important problem faced in this study is the choice of the subset of these factors which are most important in determining desired wool production in year t. Although we would prefer to include these variables in the form of distributed lags, estimating explicitly the complicated way that expectations may enter these functions, we are limited by seventeen observations to fairly simple functional forms. A two-year lag appears to be the shortest lag that is reasonable to be looked for in wool production because of the technological rigidities mentioned above. We have found that, for most cases, the assumptions of one-year and two-year lags yield quite similar results with the two-year lag having a slight edge with respect to both a priori assumptions and statistical significance of the results. In (4.3) below, we have the general functional form of the equations describing the formation of desired or equilibrium wool production, where the lag is assumed to be two years.

$$(4.3) \qquad W^*_{j_t} = \alpha_{j0} + \alpha_{j1} Pw^*_{j_t} + \alpha_{j2} Pl_{t-2}$$

In equation (4.3), Pw^*_{jt} is the expected normal price of wool for season t, these expectations being formed in season t-2. This expected price is denoted as "normal" rather than "actual" for season t, for producers probably do not attempt to forecast actual short-run variations in price but instead some mean or normal price around which the short-run price will vary. The variable Pl_{t-2} represents any other economic or noneconomic variables affecting these decisions. For example, Pl_{t-2} may be the price of lambs in season t-2, included because producers have the option of selling the lambs in season t-2 for Pl_{t-2} or keeping them to increase wool and lamb production in subsequent seasons.

The specification given in (4.1) and (4.3) illustrates the Marshallian distinction between short and long-runs, the use of the term "long-run" here corresponding to Marshall's use of the term "normal".[3] In the short-run, the supply of factors to the firm, for example, a wool ranch, is relatively fixed, while as longer and longer runs are considered, the supply of factors becomes more and more variable and more alternative courses of action become available. "Thus, from any point in a long-run supply schedule, we may think of a fan of short-run supply curves which gradually approach the long-run supply schedule from the right above it and from the left below it."[4] We have depicted this concept graphically below in Figure 4.1 in a manner similar to Nerlove's.[5]

In Figure 4.1, S_LS_L is the long-run supply curve; and S_1S_1, S_2S_2, and S_3S_3 are representatives of the fan of short-run supply curves which pass through any typical point, a, on the long-run supply curve, where S_1S_1 corresponds to a shorter adjustment period

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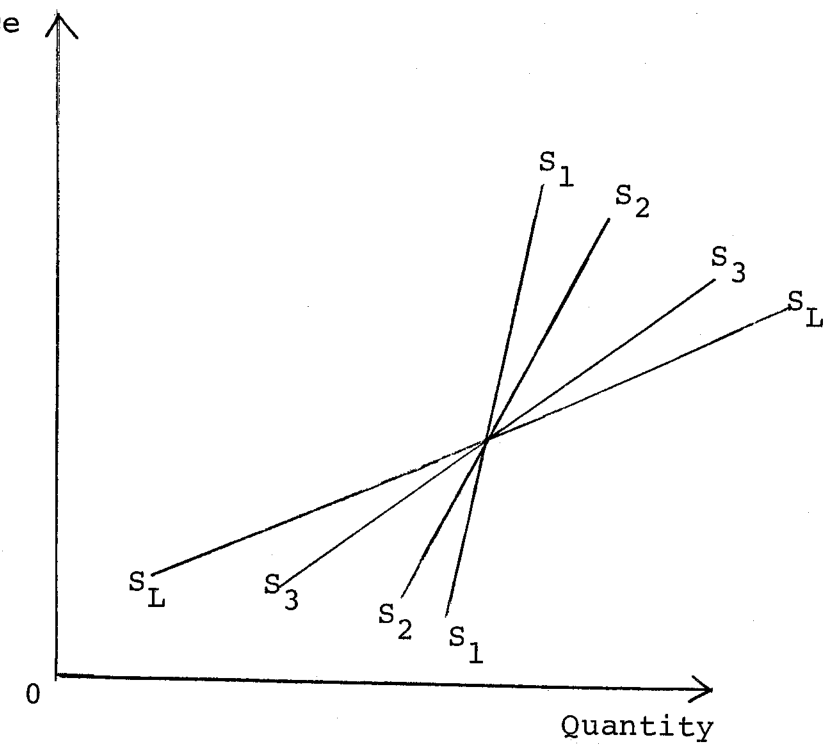
[3] Alfred Marshall, Principles of Economics (8th ed.; London: MacMillan and Company, Limited, 1938), pp. 378-379.

[4] Marc Nerlove, "Adaptive Expectations and Cobweb Phenomena," The Quarterly Journal of Economics, Vol. LXXIII (May, 1958), p. 235.

[5] Marc Nerlove, "Distributed Lags and Estimation of Long-Run Supply and Demand Elasticities: Theoretical Considerations," Journal of Farm Economics, Vol. XL (May, 1958), p. 305, Figure 1.

Figure 4.1. Relation Between Short-Run and Long-Run Supply Curves.



than does S_2S_2 and hence rises more steeply due to a smaller price elasticity of supply. Our specification, (4.1) and (4.3), indicates we are concentrating on two curves in this fan of supply curves, the "short-run" supply curve, (4.1), corresponding to an adjustment period of two seasons, and the "long-run" or equilibrium supply curve, (4.3), corresponding to S_LS_L in Figure 4.1. Clearly, since there is no one distinct "short-run" supply curve, the choice of which short-run supply curve to estimate is quite arbitrary based, in our case, on the purposes of the study and the nature of the statistical results achieved. The biological production lag alone implies that production decisions made in season t will not significantly affect the actual level of production until season t+2; and the cumulative effect of such decisions will be distributed over a number of the future seasons. Moreover, what is observed is not the long-run supply curve but instead, since the situation is constantly changing, points on the various short-run curves corresponding to no one supply curve. However, if the specification of (4.1) and (4.3) is correct, estimates of the long-run supply curve and of a "short-run" supply curve can, in many cases, be obtained.

If we let Pwj_t^*, the expected normal price of wool in season t, be Pw_{t-2}, the actual price of wool in season t-2 (i.e., if we assume "naive" expectations about wool prices, these expectations formed just after season t-2), then substituting (4.3) into (4.1) yields the following equation which can be estimated:

$$(4.4) \quad W_{jt} = \delta_j \alpha_{jo} + (1 - \delta_j) W_{jt-1} + \delta_j \alpha_{j1} Pw_{jt-2} + \delta_j \alpha_{j2} Pl_{t-2} + b_j R_{jt}$$

Equation (4.4) is in terms of actual wool production in seasons t and t-1, actual prices of wool and of lamb in season t-2 and rainfall in season t (remembering that Pl_{t-2} and Rj_t represent typical economic and noneconomic factors entering the supply relationships). If (4.4) were to be estimated using the logarithms of the values of the variables, then, in terms of the above discussion, the coefficient $\delta_j \alpha_j$ would be an estimate of the "short-run" elasticity of supply with respect to wool prices, that is, a measure of the proportional change in production of wool that would occur two seasons after a change in wool prices, while α_j would be an estimate of the "long-run" or "equilibrium" elasticity of supply corresponding to the period of time it would take production to fully adjust to a sustained change in wool prices. The difference between the two elasticities is the coefficient of adjustment, δ_j.

The formation of price expectations is affected by a multitude of influences which we assume can be summarized in actual past prices. The specification of naive expectations states that the actual price in the period in which the expectations are formed is the only relevant past price. It would be interesting to consider other specifications of the formation of price expectations besides the "naive expectations" specification used above. Yet, it should be noted again that the limited length of our time series and the degree of aggregation we use limits our choice of alternative specifications to a few simple formulations. Also, the small degree of variation over time of annual wool production in most countries may be an indication of the relative unimportance of price expectations in the formation of wool production decisions. On the other hand, this low variability may mean that wool producers are able to filter out most of the "noise" in wool prices when they form their expectations.

One specification of expectations formation used by Goodwin and many other is the following:[6]

$$(4.5) \qquad Pwj^{*}_{t} = Pw_{t-2} + \beta_j (Pw_{t-2} - Pw_{t-3})$$

We have used the case of a two-year lag between expectation formation and the realization of actual prices. Muth calls such expectation formulation "extrapolative expectations", for the specification states that the decision-maker estimates future prices by extrapolating the current prices, adjusting by a factor, β_j, for the most recent observed change in price.[7] Letting $\Delta Pw_{t-2} = Pw_{t-2} - Pw_{t-3}$, substituting (4.5) into (4.3) and then substituting (4.3) into (4.1) yields the following equation which is suitable for estimation:

$$(4.6) \quad Wj_t = \delta_{jo}\,\alpha_{jo} + (1-\delta_j)Wj_{t-1} + \delta_j\,\alpha_{j1}\,Pw_{t-2} + \delta_j\,\alpha_{j1}\,\beta_j\,\Delta Pw_{t-2} + \delta_j\,\alpha_{j2}\,Pl_{t-2} + b_j Rj_t.$$

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[6] Richard M. Goodwin, "Secular and Cyclical Aspects of the Multiplier and Accelerator," in Income, Employment and Public Policy: Essays in Honor of Alvin M. Hansen, Lloyd A. Metzler, et al. (New York: W. W. Norton and Company, Inc., 1948), pp. 108-132.

[7] John F. Muth, Rational Expectations and the Theory of Price Movements, O.N.R. Research Memorandum No. 65, Carnegie Institute of Technology (1958), p. 6.

Note that $\beta_j = 0$ yields the case of "naive expectations" and $\beta_j = 1$ yields the case where the price change in season t - 2 is extrapolated, unadjusted, to the present. Such expectation formation certainly would not filter out short-run "noise" in prices.

Nerlove has given an alternative rational to the specification (4.4) which makes use of the notion of "adaptive expectations" due originally to Cagan.[8] We first abstract from the problem of distinguishing between short-run and long-run adjustments to expected price and consider the following form of the supply function:

$$(4.7) \qquad Wj_t = \alpha_{jo} + \alpha_{j1} Pwj_t^* + \alpha_{j2} Pl_{t-1} + \alpha_{j3} Rj_t,$$

where actual wool production by country j is a function of the expected wool price in season t, the actual price of lambs in season t - 1, and rainfall in season t. (We are assuming a one-year lag here for the purpose of simplicity of exposition only.) According to the notion of "adaptive expectations", the difference between the price of wool expected in season t and the price of wool expected in season t-1, that is, the revision of last season's expected price, is proportional to the error made in forecasting last season's price,

$$(4.8) \qquad Pwj_t^* - Pwj_{t-1}^* = \beta_j(Pw_{t-1} - Pwj_{t-1}^*),$$

where β_j is called the "coefficient of expectations".[9] Note that if $\beta_j = 0$, then actual values of past prices have no effect on expected prices; while if $\beta_j = 1$, then the actual value of price in season t-1

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[8] Marc Nerlove, "Adaptive Expectations and Cobweb Phenomena," op. cit.; and Phillip Cagan, "The Monetary Dynamics of Hyper-Inflation," in Studies in the Quantity Theory of Money, ed. Milton Friedman (Chicago: University of Chicago Press, 1956), pp. 27-117.

[9] John F. Muth, op. cit., pp. 14-16, shows that adaptive expectations are optimal if the time series is a result of a single period ("transistory") random component and a long-run ("permanent") random component lasting through all subsequent time periods.

is projected as the forecast price in season t; that is, expectations are "naive". Nerlove shows that, if logarithms are used, β_j corresponds to Hicks' "elasticity of expectations".[10] This specification leads to the following representation of expected wool price as a geometrically weighted average of actual prices in preceding years:

$$(4.9) \quad Pwj^*_t = \beta_j \, Pw_{t-1} + (1 - \beta_j)\beta_j \, Pw_{t-2} + (1 - \beta_j)^2 \beta_j \, Pw_{t-3} + \ldots$$

If we solve (4.7) for Pwj^*_t, lag (4.7) one period and solve for $Pwj_{t-1}{}^*$, substitute for Pwj^*_t and Pwj^*_{t-1} in (4.8), multiply them by α_{j1} and solve for W_{jt}, we get

$$(4.10) \quad W_{jt} = \beta_j \, \alpha_{jo} + (1 - \beta_j) W_{jt-1} + \beta_j \, \alpha_{j1} \, Pw_{t-1} + \alpha_{j2} \, Pl_{t-1} + \alpha_{j2} \, (1 - \beta_j) Pl_{t-2} + \alpha_{j3} \, R_{jt} + \alpha_{j3} \, (1 - \beta_j) R_{jt-1} .$$

It is important to note that specifying expectations as adaptive results in only one value of the past prices, Pw_{t-1}, entering the final form of the equation, but it results also in the inclusion of two past values of all other exogenous variables. Adding the distinction between short- and long-run supply adjustment given in (4.1) to the assumption of adaptive price expectations results in addition of the term W_{jt-2} to (4.10). Realistic forms of these models would be very difficult to estimate due to the limited number of degrees of freedom available and to the high degree of multicollinearity that is bound to be present among the explanatory variables. Because of the complexity of these models and the importance of supply adjustment rigidities in wool production, we concentrate in this chapter on models based on naive or extrapolative price expectations. The specification of adaptive expectations

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[10] Marc Nerlove, The Dynamics of Supply: Estimation of Farmers' Response to Price, op. cit., pp. 52-53.

does prove to be useful in the study of supply stocks of wool discussed in the next chapter.

2. A Short Note on Estimation

The various forms considered in this chapter of the equations describing the production of wool all exclude current variables endogenous to the rest of the world market model. Hence, the methods of ordinary least squares and a form of generalized least squares are used.[11] While the method of ordinary least squares is well known and warrants no exposition here, the particular variant of generalized least squares used should be discussed. One of the basic assumptions of the method of ordinary least squares is that

$$E(u_t , u_{t+s}) = 0 \quad \text{for all } t \text{ and all } s \neq 0 ,$$

where u_t is the t^{th} period disturbance term of the equation and u_{t+s} is the $(t+s)^{th}$ disturbance term. This assumption of zero correlation between all disturbance terms of different periods is often violated in the analysis of economic time series, especially if variables omitted from the equations are important to the equation and their values change in a nonrandom way (e.g., they have an important common trend); for the effect of these variables tends to get picked up by the estimated disturbance term. Johnson notes that when the method of ordinary least squares is used in a case where the residuals are autocorrelated, the resulting estimates are unbiased but may have unnecessarily large sample variances relative

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[11] Both methods are available as part of the Bimed-34 stepwise regression program package at the Princeton University Computation Center and were run on that center's IBM 7094 computer. Bimed-34 was originally written at the Health Sciences Computing Facility of the School of Medicine at U.C.L.A. and was modified by Hodson Thornber at the Center for Mathematical Studies in Business and Economics at the University of Chicago.

to those of estimates obtained by generalized least squares.[12] Moreover, the usual least squares formulas for the estimates of the sample variances are likely to underestimate the real value of these variances. Finally, these estimates will lead to inefficient predictions. When the lagged dependent variable is used as an explanatory variable, the estimates also will be biased.

The Durbin-Watson d statistic[13] was developed as a test of the hypothesis that the residuals are uncorrelated. If we let z_t $(t = 1, \ldots, n)$ be the residuals from an equation fitted by least squares over n observations, the statistic is

$$d = \frac{\sum_{t=2}^{n} (z_t - z_{t-1})^2}{\sum_{t=1}^{n} z_t^2} .$$

Note that this statistic considers only first order serial correlation. If no serial correlation is present, this statistic tends to be about two, while presence of positive serial correlation yields values less than two and presence of negative serial correlation yields values greater than two. The significance tables computed by Durbin and Watson are not valid for equations containing lagged forms of the dependent variable. Hence, while we compute the value of this statistic for all of our equations, in most cases we are not able to perform any statistical tests of the absence of

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[12] J. Johnston, Econometric Methods (New York: McGraw-Hill Company, Inc., 1960), p. 179.

[13] J. Durbin and G. S. Watson, "Testing for Serial Correlation in Least Squares Regression, II," Biometrika, Vol. XXXVIII (June, 1951), pp. 159-178.

significant autocorrelation. However, in cases where this statistic appears to be "unusually" high or low, we reestimate the equation by an approximate form of generalized least squares considered by Johnston.[14] In order to use this method, we must assume that the variance-covariance matrix of residuals of the equation is of a very simple form, specifically, that the residuals follow a simple Markov scheme. We may assume, for example, a first order Markov scheme with parameter ρ_1 ,

$$u_t = \rho_1 u_{t-1} + e_t \quad ,$$

where e_t satisfies

$$E(e_t, e_{t+s}) = 0 \qquad \text{for all } t \text{ and for all } s = 0.$$

Letting our equation be denoted by

$$y_t = x_t \beta + u_t \quad ,$$

where y_t is the t^{th} observation of the dependent variable, x_t is a vector of the t^{th} observations of the explanatory variables and β is the vector of their coefficients, we estimate this equation by ordinary least squares, obtaining the estimated residuals, $\hat{u}_t$, and then estimate ρ_1 from

$$\hat{u}_t = \rho_1 \hat{u}_{t-1} + e_t \quad .$$

This estimated Markov coefficient, $\hat{\rho}_1$, is then used to transform the original variables into $(y_t - \hat{\rho}_1 y_{t-1}), (x_t - \hat{\rho}_1 x_{t-1})$, for $t = 2, \ldots, n$; and we then estimate

$$(y_t - \hat{\rho}_1 y_{t-1}) = x_t - \hat{\rho}_1 x_{t-1}) \beta_1 + v_t \quad .$$

[14]J. Johnston, op. cit., pp. 193-194 and 197-199.

If our assumption about the Markov scheme was correct and if we have a good estimate of ρ_1, then the residuals from this regression should be uncorrelated.[15] This procedure can be done iteratively, although one observation is lost at each step. Because the number of available observations is small, only first and second-order Markov schemes are considered; and for most cases, these simple schemes appear to be adequate.

3. Australian Wool Production

Australia produces about 33 percent of the world's wool production of which about 70 percent is Merino wool and 30 percent is crossbred wool. Wool production has risen fairly steadily in the last seventeen seasons from 575.3 million pounds (clean basis) in 1948-49 to 1,031.5 million pounds (clean basis) in 1964-65. The major cause of this growth appears to be the technological improvements which have occurred throughout the time period, in particular, the increased use of superphosphate fertilizers on pastures and the control of rabbits by the planned spread of the disease, myxomatosis, and by poisoning. Year to year variations in Australian wool production depend, in a complicated way, on the weather. Drought, floods and severe winters can affect both the size of the sheep population and the average fleece weight per sheep to different extents in different areas of the country. The main economic factors appear to be the prices farmers receive for wool, lambs and mutton and for wheat, a major substitute crop in the large wheat-sheep areas of the country.

The first equations explaining wool production that were estimated correspond to two alternative specifications of formation of expected wool prices, "naive" expectations, for which Pwj_t^* is

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[15] Note that if the original equation contained a constant term, α, then the estimate of α, $\hat{\alpha}$, is $\hat{\sigma}/1 - \hat{\rho}_1$, where $\hat{\sigma}$ is the constant term estimated for the second equation. Note also that our estimates of ρ_1 will be biased because the lagged value of the dependent variable, $\hat{u}_{t-1}$, is used as an explanatory variable in the estimation.

set equal to Pw_{t-2}, and extrapolative expectations, for which Pwj_t^* is set equal to $Pw_{t-2} + \beta \Delta Pw_{t-2}$. The dependent variable, Wau_t, is Australian production of wool in millions of pounds (clean basis) for season t. This series and the corresponding series for other countries were derived by applying conversion factors, developed by the Commonwealth Economic Committee, to grease basis wool production series that are published by the United States Department of Agriculture.[16] This transformation is necessary, for it is wool measured on a clean basis which is most relevant to the market and in terms of which the Dominion wool price series are stated. The explanatory variables in these first two equations are Wau_{t-1}, Pw_{t-2}, the deflated "world" price of wool in United States cents per pound for season t-2,[17] ΔPw_{t-2}, $Pwhau_{t-2}$, a deflated representative Australian wheat price in United States dollars per metric ton for the first calender year of season t-2,[18] and Fau_{t-1}, the use of commercial super-phosphate fertilizers measured in thousands of metric tons in Australia in season t-1.[19] All price variables for Australia are deflated by the Sauerbeck index of commodity prices. The fertilizer usage variable is used as a proxy variable for technological change in the wool production equation because it is

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[16]United States Department of Agriculture, Wool Statistics and Related Data: 1920-1964, Statistical Bulletin No. 363 (Washington, D.C.: U.S. Government Printing Office, 1965).

[17]The construction of this series was described in Chapter 3.

[18]The series used is the Australian Wheat Board's export price for fair-average quality, bulk basis, f.o.b. at ports, as reported in the United Nations, Food and Agriculture Organization, Production Yearbook (Rome, Annual), various issues.

[19]This series is published in the United Nations, Food and Agriculture Organization, ibid.

an important component of the progress that has occurred in Australia and it is really the only component for which adequate data exist. Bernard Oury in his study of the French wheat and feedgrain economy found that a similar variable performed well as such a technological variable.[20]

Using the above series and the alternative specifications (4.4) and (4.6), equations (4.11) and (4.12) were estimated by ordinary least squares.[21]

$$(4.11)\quad Wau_t = \underset{(0.151)}{0.689}\, Wau_{t-1} + \underset{(0.439)}{1.148}\, Pw_{t-2} - \underset{(1.562)}{1.359}\, Pwhau_{t-2} + \underset{(0.233)}{0.405}\, Fau_{t-1}$$

$$R^2 = 0.92,\quad F=49.83.\quad D.W. = 2.44,\ \delta = 0.311$$

$$(4.12)\quad Wau_t = \underset{(0.198)}{0.764}\, Wau_{t-1} + \underset{(0.595)}{0.911}\, Pw_{t-2} + \underset{(0.530)}{0.323}\, \Delta Pw_{t-2} - \underset{(1.676)}{1.060}\, Pwhau_{t-2} + \underset{(0.281)}{0.314}\, Fau_{t-1}$$

$$R^2 = 0.92,\ F=34.50\quad D.W. = 2.57,\ \delta = 0.236$$

where R^2 is the coefficient of multiple correlation, F is the F-test statistic, D.W. is the Durbin-Watson statistic and δ is the coefficient of adjustment.[22]

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[20] Bernard Oury, A Production Model for Wheat and Feed Grains in France (Amsterdam: North-Holland Publishing Company, 1966).

[21] The numbers in parentheses beneath the coefficients are their estimated standard errors.

[22] The above equations and all other Australian equations are forced through the origin because estimates obtained when this restriction was dropped resulted in intercepts not statistically different from zero and equations having worse statistical properties and, in some cases, coefficients which contradict *a priori* assumptions based on economic theory. When other equations in this study appear with no constant terms, it is for these same reasons.

These equations yield quite similar results, the signs of all coefficients confirming a priori assumptions. The estimated coefficient of adjustment values of 0.311 and 0.236 demonstrate the importance of the assumption of technological and institutional rigidities in the supply relationship. Philpott suggests that the complete adjustment lag in Australia is not less than five years.[23] While a significant lag will be found in all countries due to the nature of the product, this lag was thought to be relatively longer in Australia because, in many regions, there are little if any alternative uses of the resources and perhaps because sheep raising in Australia has become a traditional "way of life" for so many people. However, this assumption proved to be false, for the adjustment lag was significant for all countries studied and, in many cases, longer than that for Australia.

The estimated wool price elasticities of wool production that result from (4.11) are + 0.1467 for the "short-run" (two year) elasticity and + 0.5414 for the "long-run" or "equilibrium" elasticity. All elasticities computed from this model are evaluated at the mean values of the respective time series. Here, the short-run elasticity is computed by multiplying the coefficient of Pw_{t-2}, $\delta \alpha_1$ by the ratio of the mean value wool prices to the mean value of wool production, $\overline{Pw}_{t-2}/\overline{Wau}_t$. That is

$$\delta \alpha_1 \cdot \frac{\overline{Pw}_{t-2}}{\overline{Wau}_t} = (1.148) \frac{(104.56)}{(818.20)} = + 0.1467$$

To get the long-run or equilibrium price elasticity, first, the coefficient of Pw_{t-2} is divided by δ and then the result is multiplied by the ratio of the mean values of wool price and wool

[23] B. P. Philpott, Fluctuations in Wool Prices, 1870-1963, Publication No. 13, Agricultural Economics Research Unit, Lincoln College, University of Canterbury, (New Zealand, 1956), p. 4.

production. That is, the estimated long-run elasticity of wool production to wool prices is calculated as

$$\frac{1}{\delta}\ \delta\alpha.\ \frac{\overline{Pw}_{t-2}}{\overline{Wau}_t} = \left(\frac{1}{0.311}\right)\ (1.148)\ \frac{(104.56)}{(818.20)} = 0.5415$$

Thus, the estimated long-run price elasticity is somewhat greater than the short-run elasticity, the difference being determined by the size of the adjustment coefficient.

The specification of extrapolative expectations in (4.12) does not seem as satisfactory as that of naive expectations in (4.11), for the coefficient of ΔPw_{t-2} is not statistically significant.[24] Also the specification of extrapolative expectations tends to decrease the significance of the estimates of the other coefficients in the supply equation and seems to increase the negative serial correlation of the residuals. Similar results were found when extrapolative expectations were assumed for the other forms of the Australian supply equation discussed below. That is, we were unable to isolate a significant price expectation effect (other than that of naive expectations) in the Australian wool production equations. Since the assumption of extrapolative expectations yields estimates of β not significantly different from zero, which is the special case of naive expectations, only one wool price variable, Pw_{t-2}, is used in the remaining part of the Australian wool production study.[25]

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[24] Re-estimation of (4.11) and (4.12) by the approximate form of generalized least squares yielded similar results.

[25] The importance of expectations about future prices is actually already included implicitly in (4.11), for one of the behavioral factors determining the size of δ is the degree to which wool growers assume that currently observed price changes are permanent as opposed to transitory.

Looking at the other coefficients in (4.11), we find that the fertilizer variable contributes positively to wool production, a certeris paribus increase in the use of superphosphate fertilizer by one thousand metric tons implying an increase in wool production of 405 thousand pounds (clean basis). The estimated short-run and long-run cross-elasticities of wool supply to the price of wheat are - 0.03542 and - 0.11389, respectively. However, the coefficient of $Pwhau_{t-2}$ is not statistically significant, having a corresponding t-value of only .8701. It is interesting to compare the two-year elasticity estimate obtained here with that obtained by Dahlberg for wool production in the Wheat-Sheep Zone.[26] Concentrating on the important Wheat-Sheep Zone of Southern Australia and using ratios of annual seasonal indicies of wool prices received by farmers, Pw_o, wheat prices received by farmers, Pwh, fat lamb prices received by farmers, P_f, and a technological change variable, Z_1, which is the seasonal acreage sown to improved pasture, he estimates the following equation explaining seasonal wool production on a grease basis in the Wheat-Sheep Zone, x_1, for the seasons 1945-46 to 1960-61:

$$x_t = \underset{(59)}{216}\frac{Pw_{ot-1}}{Pwh_{t-1}} - \underset{(91)}{324}\frac{Pw_{ot-1}}{Pf_{t-1}} + \underset{(37)}{88.9}\frac{Pw_{ot-2}}{Pf_{t-2}} + \underset{(3.6)}{8.42}Z_1 \quad .$$

$$R^2 = 0.90$$

From this equation he derives supply elasticities of - 0.47 and + 0.13 for Pw_o/Pf lagged one and two years respectively and + 0.42 for Pw_o/Pwh lagged one year. He then considers a certeris paribus one-percent change in wool prices, which the equation implies would lead to a change in wool supply of - 0.05 percent

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[26] D. L. Dahlberg, "Supply Responses for Wool in South Australia, 1949-61," Australian Journal of Agricultural Economics, Vol. VIII (June, 1964), p. 58.

(i.e., 0.42 - 0.47) in the first year after the change and an overall change of 0.08 (i.e., - 0.05 + 0.13) over the two years following the change. He concludes the "long-run" (two-year) elasticity is + 0.08, which is a little lower than our estimate. His estimate of the "short-run" (one-year) cross-elasticity of wool production with respect to wheat prices is - 0.42, which indicates that a considerably stronger substitution effect between wool production and wheat prices exists in the Wheat-Sheep Zone than in the country as a whole. This result is to be expected, for it is in this region that most of the wheat is grown. Dahlberg also attempted to use a "Nerlove-type" distributed lag model, incorporating both the supply adjustment lag and adaptive expectations, but was not successful in estimating an equation which satisfied the implied parameter constraints on the model. He suggests, as was suggested in Section 2, that one cause of the failure was probably the presence of significant multicollinearity.

The next Australian wool production equation that was estimated was one that included a deflated Australian lamb price variable in United States cents per pound for the first calendar year of season t-2, $Plau_{t-2}$, as a factor determining desired wool production.[27] Since the Durbin-Watson statistic of the ordinary least squares version of the equation, (4.13a), is high, 2.88, the equation was reestimated using approximate generalized least squares of order two with estimated first and second-order residual autocorrelation coefficients of - 0.580 and - 0.019, respectively; and the resulting estimate is equation (4.13b)

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[27] The series used is the whole sale price, slaughter weight at Melbourne, for first and second export quality lamb as published in The United Nations, Food and Agriculture Organization, _op. cit._

$$(4.13a) \quad Wau_t = \underset{(0.196)}{0.468}\, Wau_{t-1} + \underset{(0.426)}{0.975}\, Pw_{t-2} - \underset{(1.604)}{2.416}\, Pwhau_{t-2} + \underset{(2.050)}{3.370}\, Plau_{t-2} + \underset{(0.238)}{0.558}\, Fau_{t-1}$$

$R^2 = 93$, $F = 41.50$, D.W. = 2.88, $\delta = 0.532$.

$$(4.13b) \quad Wau_t = \underset{(0.162)}{0.455}\, Wau_{t-1} + \underset{(0.337)}{0.514}\, Pw_{t-2} - \underset{(1.082)}{1.526}\, Pwhau_{t-2} + \underset{(1.453)}{3.874}\, Plau_{t-2} + \underset{(0.197)}{0.602}\, Fau_{t-1}$$

$R^2 = 0.98$, $F = 110.05$, D.W. = 2.62, $\delta = 0.545$.

Adding $Plau_{t-2}$ to the equation has resulted in a smaller coefficient for wool prices, larger coefficients for fertilizer usage and wheat prices and a larger coefficient of adjustment. Unfortunately, this specification also resulted in a higher Durbin-Watson statistic, even after the equation was estimated by second-order approximate generalized least squares. Lagged lamb prices enter with a significant positive coefficient of 3.874, suggesting that high lamb prices encourage the raising of more lambs, that is, the creation of larger flocks, rather than having the effect of decreasing sheep numbers as producers attempt to reap short-run profits from the then current high lamb prices. This result is quite reasonable if the producers assume future lamb prices will be high if the current price is high. To slaughter more lambs would be to disinvest in lambs just when expected future returns from lambs rises. The short- and long-run cross-elasticities of wool production with respect to lamb prices estimated from (4.13b) are + 0.2056 and + 0.3772, respectively. These estimates are comparable with Dahlberg's estimate of a two-year cross-elasticity of + 0.34 for the Wheat-Sheep Zone of

Southern Australia.[28] The estimates of the short and long-run elasticities of supply to wool price implied by (4.13b) are + 0.0657 and + 0.1206, respectively, which are considerably lower than those obtained from (4.11). The significance of the wool price coefficient has dropped somewhat also. The short and long-run cross-elasticities of supply to wheat prices are estimated as - 0.0398 and - 0.0730, respectively, which are similar to those estimated from (4.11). The coefficient of wheat prices in (4.13b) does have a higher value of the t-test statistic, 1.4107, than does the corresponding coefficient of (4.11), .8701. It is difficult to choose between equations (4.11) and (4.13b) on statistical grounds. Lamb prices seem to have an important effect on wool production but their inclusion in the wool production equation yields estimates of short and long-run wool price elasticities of wool supply that are unexpectedly low and increases the estimated amount of negative serial correlation in the residuals of the equation. Instead of attempting to choose between these equations at this point, let us turn to a consideration of the effects of weather on the production of wool.

As was mentioned above, the specification of the effect of weather on wool production is quite difficult on an aggregate basis; indeed, in some years weather may have opposite effects on wool production in different areas of the country. Yet rainfall does appear to be a very important aspect of weather in that it is droughts which are most frequently cited as causes for decreased wool production. The Australian Bureau of Agricultural Economics has constructed an annual index of rainfall on a seasonal basis in which the rainfall indices for each state are weighted by the average percentage of Australian sheep in each state. This index, Rau_t, was added to equations (4.11) and (4.13) to include the

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[28] D. L. Dahlberg, *op. cit.*, p. 60.

effect of "weather" in season t on wool production in the same season. Estimating equation (4.11) with the weather variable resulted in a Durbin-Watson statistic of 2.68. The equation was re-estimated by approximate generalized least squares of order one with the estimated first-order residual autocorrelation coefficient of - 0.417, resulting in equation (4.14) below.[29] Similarly, the ordinary least squares estimate of (4.13) with the "weather" variable added resulted in a Durbin-Watson statistic of 2.92, and the approximate generalized least squares estimate of order two of the equation with first and second-order residual autocorrelation coefficients of - 0.588 and - 0.020, respectively, is given below as equation (4.15).

$$(4.14)\quad Wau_t = \underset{(0.141)}{0.695}\, Wau_{t-1} + \underset{(0.399)}{0.660}\, Pw_{t-2} - \underset{(1.360)}{1.749}\, Pwhau_{t-2} + \underset{(0.208)}{0.381}\, Fau_{t-1} + \underset{(0.387)}{0.569}\, Rau_t$$

$$R^2 = 0.96, \quad F = 88.00, \quad D.W. = 2.40, \quad \delta = 0.305.$$

$$(4.15)\quad Wau_t = \underset{(0.174)}{0.470}\, Wau_{t-1} + \underset{(0.354)}{0.491}\, Pw_{t-2} - \underset{(1.185)}{1.653}\, Pwhau_{t-2} + \underset{(1.758)}{3.550}\, Plau_{t-2} + \underset{(0.212)}{0.584}\, Fau_{t-1} + \underset{(0.384)}{0.138}\, Rau_t$$

$$R^2 = 0.98, \quad F = 88.20, \quad D.W. = 2.63, \quad \delta = 0.530.$$

The rain index enters with the expected (positive) sign in both equations, but its coefficient is considerably less significant in (4.15). Again, inclusion of the $Plau_{t-2}$ variable increases the estimated presence of negative serial correlation and yields

[29]A second-order generalized least squares version of (4.14) showed no improvement in the Durbin-Watson statistic and otherwise was very similar to the first-order version.

lower estimates of the coefficient of adjustment and the wool price coefficient. The estimates of the short and long-run wool price elasticities of supply are + 0.0843 and + 0.2764, respectively, for equation (4.14) and + 0.0627 and + 0.1183, respectively, for equation (4.15). The estimates of short and long-run cross-elasticities of supply to wheat prices are - 0.04569 and - 0.1495, respectively, for equation (4.14), and - 0.0431 and - 0.0813, respectively, for equation (4.15). The estimates of the short and long-run cross-elasticities of supply to lamb prices are + 0.1884 and + 0.3555, respectively, for equation (4.15). Estimates of the coefficient of adjustment are 0.305 for equation (4.14) and 0.530 for equation (4.15). Again, there seems to be little basis for a choice between these equations on statistical grounds. But since an equation has to be picked for the world model, the choice must be based on a priori notions and the purpose of the model, and, therefore, the choice must be fairly arbitrary. Since we are most interested in the effect of wool price on wool production, we will choose equation (4.14), for it appears to give a more "reasonable" (on a priori grounds) estimate of the coefficient of wool price and also give an estimate of the coefficient of the weather variable which is more statistically significant, (i.e., the corresponding t-test statistic is 1.4727 versus 0.3590 for equation (4.15). Finally, the problem of serial correlation appears to be worse in equation (4.15).

All the Australian equations yield similar qualitative results. The adjustment of actual to desired wool production is quite slow. Wool production is affected positively by wool prices, lamb prices, fertilizer usage (a variable indicating the impact of technological change) and rainfall and negatively by wheat prices. The elasticities of supply to wool and wheat prices are very small. Wool production in Australia does not appear to be very sensitive, especially in the short run, to economic factors.

One weakness of this part of the study is that the effects of changing costs on wool production have not been considered, partly because of a lack of sufficient data. The relation between costs and returns has been changing considerably. For example, data gathered by the Australian Bureau of Agricultural Economics indicate that the average rate of return per property on capital in the sheep industry of the Pastoral Zone fell from 16.63 percent in 1952-53 season to 2.8 percent in the 1957-58 season and then rose to 8.6 percent in the 1962-63 season. The costs of all major inputs to wool production (labor, materials, and services) have been rising while wool prices have been falling.[30] Clearly, the relevance of these cost changes to past and future wool production is an important area for future research. An adequate treatment of this relationship would have to take into account the importance of wool production in determining agricultural costs, especially wages, in a country in which the sheep industry is such an important component of the agricultural sector. In Australia, when the revenue received from the wool clip is high, this high revenue probably serves as a target for labor in their arguments for higher wages; that is, the more important casual flow is

Large wool clip ⟶ high revenues from sale of wool clip ⟶ high agricultural wages.

Thus a simultaneous model would be needed for such a study. Let us now turn to a consideration of wool production in New Zealand.

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[30] G.D.A. Chislett in A Review of Factors Influencing Production in the Sheep and Wool Industry (Sydney, Australia: Graziers' Federal Council, 1960) studied this factor for the period 1952 to 1959 and concluded that, if nothing is done to relieve this squeeze between rising costs and falling prices, Australian wool production may stagnate and perhaps even decline.

4. New Zealand Wool Production

The New Zealand sheep industry, which is the second largest producer of apparel wool in the world, has a number of characteristics that differentiate it from the Australian sheep industry. First, the major proportion of the New Zealand wool clip is of the crossbred variety with practically the whole of the clip in the 46s, 48s and 50s quality range. The major reason for the prevalence of the crossbred sheep is the comparatively rainy climate and the rich pasture lands; in fact, only a small area in the South Island is arid enough to be really suitable for the raising of Merino sheep. Because of this climate, annual wool production does not experience fluctuations due to changing weather to the same degree as does that of Australia or South Africa. A related important characteristic of the New Zealand sheep industry is the importance of fat lamb production for export, mainly to the United Kingdom. Lamb and crossbred wool are joint products in just about all areas, with lamb being the more important crop of the two in many areas. There are no significant substitute farm crops. Another important aspect of the New Zealand sheep industry is the Reserve Price Scheme for wool (described in Chapter 2), which has been in operation since January 1, 1952. Through this scheme, New Zealand wool producers have been protected from the more extreme drops in world wool prices. Because of this floor under wool prices received by producers and because of the relative unimportance of droughts, we would expect New Zealand wool production to vary considerably less, year to year, than that of Australia; and indeed, this has been the case over the time period considered.

The data used in this section are similar to those used in the Australian section, that is, Wnz_t and Wnz_{t-1}, New Zealand wool production in millions of pounds, clean basis, in seasons t and t-1, Pw_{t-2}, the deflated "world" wool price in United States cents per pound for season t-2, ΔPw_{t-2}, $Plnz_{t-2}$, the deflated New Zealand lamb price in United States cents per kilogram for the first year of season t-2[31] and RP_{t-1}, the deflated reserve price for season t-1 in United States cents per pound. The deflator used in all price series is the Sauerbeck commodity price index. The reserve price is lagged only one year because it is announced midway in the season preceding the season in which it is to become effective.

The New Zealand wool production equations are specified to be of the Nerlove lagged adjustment form as given by (4.4) and (4.6) of section 1 and as used for the Australian sheep industry study in section 3. In order to find out whether it is the reserve price or actual wool price that is most relevant to decisions about wool production in New Zealand, equations (4.16) and (4.18) were estimated by approximate generalized least squares of order two, where equation (4.16) is specified in terms of the actual price of wool in season t-2 and equation (4.18) is specified in terms of the reserve price of wool in season t-1.[32] Equation (4.17), also estimated by generalized least squares of order two,[33] is an attempt to build extrapolative price expectations into the equation.

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[31]The price series used is the opening schedule price for top grade lamb determined by the New Zealand Meat Producers' Board as reported in the United Nations, Food and Agriculture Organization, op. cit.

[32]Ordinary least squares estimates of (4.16) and (4.18) resulted in high Durbin-Watson statistics, 2.91, and 3.17, respectively. The estimated first and second-order residual autocorrelation coefficients are - 0.6499 and - 0.2844 for (4.16) and - 0.9594 and - 0.5424 for (4.18).

[33]The ordinary least squares estimate of (4.17) resulted in a high Durbin-Watson statistic of 2.91 and estimated first and second-order residual autocorrelation coefficients of - 0.6521 and - 0.3006.

$$(4.16) \quad Wnz_t = \underset{(.021)}{1.003}\, Wnz_{t-1} - \underset{(.086)}{0.086}\, Pw_{t-2} + \underset{(.260)}{0.406}\, Plnz_{t-2}$$

$$R^2 = 0.99, \quad F = 594.00, \quad D.W. = 1.71, \quad \delta = -0.003$$

$$(4.17) \quad Wnz_t = \underset{(0.021)}{1.001}\, Wnz_{t-1} - \underset{(0.090)}{0.074}\, Pw_{t-2} - \underset{(0.120)}{0.079}\, \Delta Pw_{t-2}$$

$$+ \underset{(0.255)}{0.389}\, Plnz_{t-2}$$

$$R^2 = 0.99, \quad F = 366.67, \quad D.W. = 1.77, \quad \delta = -0.001$$

$$(4.18) \quad Wnz_t = \underset{(0.020)}{0.961}\, Wnz_{t-1} + \underset{(0.057)}{0.155}\, RP_{t-1} + \underset{(0.090)}{0.296}\, Pl_{t-2}$$

$$R^2 = 0.99, \quad F = 594.0, \quad D.W. = 1.86, \quad \delta = 0.039$$

The high values of the R^2 statistic here are an indication of the stability of New Zealand wool production and indicate that it probably will be difficult to get good estimates of what must be quite weak effects of economic and noneconomic factors.

Equations (4.16) and (4.17) are not very promising, for the coefficients of the wool price variable are both of the "wrong" sign (in respect to our *a priori* notions about the sign of these coefficients); and the Nerlove model specification seems to break down, this specification implying that the coefficient of Wnz_{t-1} be ≤ 1. Equation (4.18) indicates that the reserve price variable has considerably more explanatory power with respect to wool production, probably because New Zealand wool producers are more concerned about a floor to their probable future earnings from wool sales instead of attempting to forecast the fluctuations in world wool prices. Such behavior would be most probable for producers who consider lamb their main crop. If this inference is correct, then one of the main objectives of the Reserve Price Scheme is being achieved, that of protecting wool producers from some of the extreme variations of the market and thereby stabilizing and encouraging production. The estimated short-run (two year) and long-run (equilibrium) elasticities of wool production to the reserve price are + 0.0280 and + 0.7179, respectively. Because of the very small estimated value of the adjustment coefficient, the equilibrium elasticity is that corresponding to quite a long period of adjustment. Thus, while wool production appears to be stabilized by the Reserve-Price Scheme, the inelasticity of wool production with respect to the reserve price implies that it would be difficult for the New Zealand Wool Commission to use this policy variable to increase, significantly, average wool production in the short run. However, since the New Zealand reserve price has been set quite conservatively throughout the existence of the Reserve Price Scheme, it is difficult to estimate the effects of a less conservative policy. Such a policy change might cause a structural change in the elasticity of wool production with respect to the reserve price. The estimated short and long-run cross-elasticities of production to lamb prices are + 0.04418 and + 1.1328, respectively. These results indicate that New Zealand wool production is more sensitive to lamb prices in the long run than that of Australia, as was expected, but the short-run effect is surprisingly low.

McMahnon indicates that the impact of technological change in New Zealand wool production has been quite impressive, with the stock-carrying capacity of some pastures being doubled in the last twenty years.[34] The principal problems of including the effect of technological change in the equations are the lack of relevant data and, again, the small year to year variation in wool production. One available series is the use of commercial superphosphate fertilizers measured in thousands of metric tons for the season t-1,[35] Fnz_{t-1}, a series similar to that used for Australia.

[34] P. R. McMahon, "A Second Look at the New Zealand Sheep Industry," Wool Technology and Sheep Breeding, Vol. X (July, 1963), p. 38.

[35] This series is published in the United Nations, Food and Agriculture Organization, op. cit.

Equation (4.19) below resulted from the inclusion of this variable in (4.18) and estimating by generalized least squares of order two.[36]

$$\text{(4.19)}\quad Wnz_t = \underset{(0.036)}{1.001}\, Wnz_{t-1} + \underset{(0.046)}{0.162}\, RP_{t-1} + \underset{(0.090)}{0.332}\, Plnz_{t-2} - \underset{(0.064)}{0.084}\, Fnz_{t-1}$$

$$R^2 = 0.99, \quad F = 366.67, \quad D.W. = 2.08, \quad \delta = -0.001$$

This equation does not satisfactorily isolate the effect of technological change, for the Fnz_{t-1} variable enters the equation with the wrong sign, and its inclusion results in the constraint on the coefficient of Wnz_{t-1} being violated. A successful study of the effect of technological change on New Zealand wool production will require the gathering of more relevant data, and we must use equation (4.18) in the final world model. Like the Australian equation, this equation suffers from the absence of cost factors.

5. South African Wool Production

The wool industry of the Union of South Africa is, in many ways, quite similar to that of Australia. The climate in most sheep farming areas is very dry, with seasonal wool production being affected by droughts in many years. Because of this climate, most of the sheep raised are Merino, which are grown only for wool production. Thus no lamb price variable is included in the South African wool production equations. Wheat is a substitute crop for sheep farming in some areas, but many areas are too dry for growing wheat. Cattle raising is of very little importance in almost all the sheep raising areas, and hence no beef price variable will be included. South African wool production has not grown at the rate of that of Australia or of New Zealand, principally because of the prevalence of infectious and erosion diseases

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[36] The ordinary least squares estimate of (4) resulted in a Durbin-Watson statistic of 3.20 and estimated first and second order residual autocorrelation coefficients of - 0.9830 and - 0.5530.

of sheep, the effects of vermin and the periodic droughts mentioned above. The diseases and vermin have proven very difficult to control, but some progress has been made. It is in this area and in improving water resources and fencing of pastures that technological improvements have taken place; but due to a lack of data, this factor is not included in the regressions.

As was mentioned in Chapter 2, South Africa began a Reserve Price Scheme in March, 1958, similar to that of New Zealand. Unlike the New Zealand Wool Commission, the South African Wool Commission has not varied its reserve price since 1958. However, the "real" value of this price has changed due to changes in the deflator price index.

The data used are Wsa_t and Wsa_{t-1}, the seasonal production of wool in South Africa in millions of pounds, clean basis, for seasons t and t-1, Pw_{t-2}, the deflated South African price of wheat in United States dollars per metric ton for the first calendar year of season t-2,[37] $RPsa_{t-1}$, the deflated reserve price for wool for season t-1 in United States cents per pound, and Rsa_{t-1}, a rainfall index for season t-1. The one year lag in this rainfall series was necessitated by the time period of the available series; and, as a result, the effect of droughts may be underestimated. This rainfall index was constructed from South African Weather Bureau data by the International Wool Secretariat in a manner similar to that used by the Commonwealth Economic Commission in deriving the index for Australia; that is, rainfall indices for two major zones were weighted by the zones' average shares of the annual wool clip to form an aggregate index. All price series were deflated by the Sauerbeck commodity price index.

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[37] The price series used is the Government fixed price for wheat as reported in the United Nations, Food and Agriculture Organization, op. cit.

Using the Nerlove lagged supply adjustment model, equations (4.20) and (4.21) were estimated by ordinary least squares. Equation (4.20) contains just one wool price variable, the "world" price; while equation (4.21) contains also the reserve price variable, which is lagged only one year because this price is announced mid-way in the preceding season. Because of the poor performance of the extrapolative expectations specification in the Australian and New Zealand studies, no such specification was attempted here. Since the portion of the observation period for which the Reserve Price Scheme was in operation is small, no equation was estimated with the reserve price as the only wool price variable.

$$(4.20) \quad Wsa_t = \underset{(0.047)}{0.900}\, Wsa_{t-1} + \underset{(0.062)}{0.108}\, Pw_{t-2} - \underset{(0.068)}{0.079}\, Pwhsa_{t-2} + \underset{(0.074)}{0.141}\, Rsa_{t-1}$$

$$R^2 = 0.92, \quad F = 49.83, \quad D.W. = 2.20, \quad \delta = 0.100$$

$$(4.21) \quad Wsa_t = \underset{(0.065)}{0.868}\, Wsa_{t-1} + \underset{(0.072)}{0.133}\, Pw_{t-2} + \underset{(0.060)}{0.044}\, RPsa_{t-1} - \underset{(0.070)}{0.085}\, Pwhsa_{t-2} + \underset{(0.076)}{0.151}\, Rsa_{t-1}$$

$$R^2 = 0.92, \quad F = 34.50, \quad D.W. = 2.08, \quad \delta = 0.132$$

Equation (4.20) appears to be quite good. The signs of all coefficients coincide with *a priori* assumptions, and the value of the Durbin-Watson statistic, 2.20, is acceptable. The low value of the coefficient of adjustment, 0.100, indicates that the adjustment of production in South Africa in response to changing economic factors is indeed a slow process. The rainfall index variable enters significantly, the coefficient of 0.141 indicating that a drop in the index of 1.00 in one season causes a drop in wool production in the next season of 141 thousand pounds (clean basis). Over the observation period, this index has varied between a low of 51 and a high of 135. The estimated short and long-run elasticities of wool production to wool price are + 0.076 and + 0.764, respectively, values similar to those estimated for New Zealand. The estimated short and long-run cross-elasticities of wool production to wheat prices are - 0.050 and - 0.497, respectively, the short-run elasticity being similar to that estimated for Australia.

In equation (4.21), an estimate is made of the effect of the Reserve Price Scheme on South African wool production. The small estimated coefficient of $RPsa_{t-1}$ and its large standard error implies that the value of the reserve price has not had a great effect on wool production. The estimated short and long-run elasticities of wool production to the reserve price are + 0.010 and + 0.072, respectively. However, this coefficient is not statistically significant. These results suggest that the South African Reserve Price Scheme has not yet built up confidence in the minds of the growers to the same degree as has that of New Zealand. Another indication of this is that the South African Wool Commission has had to enter the market and make actual purchases in support of its reserve price to a much greater extent than has the New Zealand Wool Commission which, while frequently making bids, only very infrequently has had actually to purchase the wool. Two causes of this difference probably are, first, the much stronger market position of New Zealand in the types of wool it sells, and, second, the comparatively weaker capital position of the South African Wool Commission, which may have led some growers and buyers to question whether the announced reserve prices could always be maintained. The effectiveness of the South African Reserve Price Scheme should increase if the Wool Commission continues its record of supporting the reserve price.

Equation (4.21) yields essentially the same coefficients for the other variables as does (4.20); but, due to the uncertainty about having correctly specified the effect of the Reserve Price

Scheme, equation (4.20) is used in the final model. This equation, unfortunately, does not explain the effects of costs and technology on wool production.

6. Wool Production in Argentina and Uruguay

Argentina and Uruguay produce about 10 percent of the world's wool, with Argentina producing wool of all qualities and Uruguay producing mainly crossbred wool. Wool production in Uruguay has remained fairly constant while production in Argentina has declined despite some attempts by the government to encourage production. A major factor in both these countries has been the unstable political climate accompanied by frequently changing export policies of governments which, in their attempts to fight inflation, balance of payments deficits and other problems commonly faced by developing countries, sometimes have followed policies designed for revenue purposes and other times, policies designed to stimulate exports. Another policy objective in Argentina has been to keep the cost of raw materials low for the growing Argentine textile industry. The principal forms of government control have been export taxes, export licenses, controlled exchange rates and export bonuses.

While in Chapter 5 dummy variables are used to reflect the general impact of these changing policies on producers' carry-over stocks decisions, which are essentially short-run decisions, it did not appear to be possible to specify the way that these factors affect the long-run decisions of the wool producers. The omission of these factors makes the estimation of these equations difficult.

There is, in fact, a general problem in collecting adequate data for this part of the study. For example, no useable lamb price series was discovered for the countries. Also, no proxy variable for technological change was found for these countries. While in Argentina there has been little application of new production techniques, in Uruguay considerable pasture improvement in the last ten years has contributed significantly to production.[38] The major substitute products in Argentina are wheat and beef and in Uruguay are beef and hides (of cattle). Wool is Uruguay's most important product, accounting for as much as 60 percent of the country's export earnings in some years; and hence the importance of substitute crops is fairly small. The importance of substitute crops in Argentina appears to be greater except for the regions in the far South. While weather is not usually a critical factor in Uruguay, variations in the weather do frequently affect Argentina's wool production; and hence a rainfall variable constructed by the International Wool Secretariate in the same manner as that for South Africa is used in the Argentina equations.

The variables used for Argentina are Wag_t, Argentine wool production in millions of pounds (clean basis) in season t, Wag_{t-1}, Pw_{t-2}, the deflated "world" price of wool variable in United States cents per pound for season t-2, $Pwhag_{t-2}$, the deflated price of Argentine wheat in United States dollars per bushel for the first calendar year of season t-2,[39] $Pbag_{t-2}$, a deflated price of Argentine beef in United States dollars per hundred pounds for the first calendar year of season t-2,[40] and Rag_t, the rainfall index. The deflator used for the wheat and beef series is an index of agricultural export prices for years 1951 to 1964; and for years 1948 - 1950, an index of Latin American export prices was grafted on to the Argentine index.[41] The wool price

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[38]P. R. McMahon, "Sheep and Wool Production in Argentina and Uruguay," Wool Technology and Sheep Breeding, Vol. X (December, 1964), p. 14.

[39]This series is the support price for years 1947 to 1950 and unit value of exports for years 1951 to 1965 as reported in the International Monetary Fund, International Financial Statistics (Washington, D.C., annual), various issues.

[40]This series is the unit value of exports of frozen beef as reported in the International Monetary Fund, ibid.

[41]Both indices are given in the International Monetary Fund, ibid.

series is deflated by the Sauerbeck commodity price index. The data used for Uruguay are Wur_t, wool production in Uruguay in millions of pounds (clean basis) for season t, Wur_{t-1}, Pw_{t-2}, $Phur_{t-2}$, a deflated index of prices of Uruguayan hides for the first calendar year of season t-2,[42] and $Pbur_{t-2}$, a deflated index of prices of Uruguay beef for the first calendar year of season t-2.[43] The wool price series is deflated by the Sauerbeck commodity price index, and the other price series are deflated by an index of export prices for Uruguay.[44] The first attempts at estimating equations explaining wool production in Argentina and Uruguay by a Nerlove lagged adjustment model with a two-year lag were unsuccessful. Because of the limitation of data available, these equations were estimated for the seasons 1950-51 through 1964-65. Equations (4.22) and (4.23) below are examples of the bad results obtained. Equation (4.22) for Argentina was estimated by ordinary least squares and equation (4.23) for Uruguay was estimated by generalized least squares of order two with estimated first and second-order residual autocorrelation coefficients of - 0.467 and - 0.352, since the ordinary least squares version of this equation resulted in a Durbin-Watson statistic of 2.64.

$$(4.22)\quad Wag_t = \underset{(0.1690)}{0.7651}\, Wag_{t-1} - \underset{(0.179)}{0.078}\, Pw_{t-2} + \underset{(21.650)}{12.660}\, Pwhag_{t-2} + \underset{(2.146)}{0.683}\, Pbag_{t-2} + \underset{(0.247)}{0.326}\, Rag_t$$

$$R^2 = 0.61,\quad F = 43.01,\quad D.W. = 1.51,\quad \delta = 0.235$$

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[42]This series is an index of unit value export prices of cattles and sheep hides as published in the International Monetary Fund, ibid.

[43]This series is an index of unit value export prices of frozen and canned beef published in the International Monetary Fund, ibid.

[44]This index is published in the International Monetary Fund, ibid.

$$(4.23)\quad Wur_t = \underset{(0.106)}{0.798}\, Wur_{t-1} - \underset{(0.075)}{0.046}\, Pw_{t-2} - \underset{(0.099)}{0.019}\, Pbur_{t-2} + \underset{(0.086)}{0.299}\, Phur_{t-2}$$

$R^2 = 0.71$, $F = 9.79$, $D.W. = 2.46$, $\delta = 0.203$

These equations are unsatisfactory because the estimated coefficients of wool prices have the "wrong" sign in both equations and high estimated standard errors. Also, wheat prices and beef prices enter the Argentina equation with what appear to be "wrong" signs and have little explanatory power. The sign of the beef price variable in the Uruguay equation is what was expected, but the coefficient is not statistically significant. Interpretation of the hide price coefficient is difficult because the index used includes both cattle and sheep hide prices and hence probably represents a mixture of complementary and substitution effects. The rain price index is significant in explaining Argentina production.

Because these equations did not seem to be a good representation of the Argentine and Uruguayan sheep industries and yet no other data series were available, some experimentation was done to test whether the two-year lag assumed in (4.22) and (4.23) is the best lag to use for these industries.[45] Most experiments resulted in similar or worse results, but equations (4.24) and (4.25) below do seem to give representations of these industries that are better than those given by (4.22) and (4.23). These results must be considered with considerable reservation due to the experimentation involved in obtaining these estimates.

[45] Also, equations using first differences of the price variables and using ratios of the price variables were estimated. The results in all cases were highly unsatisfactory.

Equation (4.24) for Argentina estimated by ordinary least squares incorporates a one-year lag, with the wheat and beef price series being for the first calendar year of season t-1. Equation (4.25) for Uruguay was estimated by approximate generalized least squares of order two with estimated first and second order residual autocorrelation coefficients of - 0.2212 and - 0.2796 and incorporates a one-year lag, with the hide and beef price series being for the second calendar year of season t-1. These lags are not really that much shorter than those used for the other countries in this study, for shearing in these two countries occurs later in the season; that is, the shearing for season t, which spans calendar years t-1 and t, is not completed until September of year t.

$$(4.24)\quad Wag_t = \underset{(0.178)}{0.791}\, Wag_{t-1} + \underset{(0.168)}{0.101}\, Pw_{t-1} - \underset{(20.490)}{11.974}\, Pwhag_{t-1} + \underset{(1.883)}{1.769}\, Pbag_{t-1} + \underset{(0.227)}{0.305}\, Rag_t$$

$$R^2 = 0.62,\quad F = 4.50,\quad D.W. = 1.51,\ \delta\ 0.209$$

$$(4.25)\quad Wur_t = \underset{(0.123)}{0.561}\, Wur_{t-1} + \underset{(0.109)}{0.251}\, Pw_{t-1} + \underset{(0.093)}{0.103}\, Pbur_{t-1} + \underset{(0.087)}{0.194}\, Phur_{t-1}$$

$$R^2 = 0.66,\quad F = 7.77,\quad D.W. = 1.86,\ \delta = 0.439$$

The Argentina wool production equation has the "right" signs for the wool and wheat price series but still has the "wrong" sign for the beef price series. Again the estimated standard errors of these coefficients are very high; so that it is questionable that this equation is really "better" than (4.22). However, the coefficients estimated in (4.22) not only lack statistical significance but also do not correspond with economic theory. The weak explanatory power of these variables in both equations is probably due to the fact that wheat and beef are not significant substitute crops in the important sheep raising region of Patagonia. The rainfall index variable has considerable explanatory power, a decrease in the index of 1.000 implying a decrease in wool production of 305 thousand pounds (clean basis). The estimated short-run (here one-year) and long-run elasticities of wool production to wool prices are + 0.042 and + 0.202, respectively. The estimated short and long-run cross-elasticities of production, first, with respect to wheat prices are - 0.078 and - 0.372, and second, with respect to beef prices are + 0.112 and + 0.535, respectively. In a recent study of the Argentine economy, C. Alejandro, using somewhat different data and no lagged production variable, estimated the short-run (one-year) cross-elasticity of wool production to cereal prices to be - 0.58, which is slightly larger than our estimates.[46]

Equation (4.25) for Uruguay has the "right" sign for the wool price coefficient, this coefficient being statistically significant. The coefficient of the beef price variable has a positive sign, which was not expected but which coincides with the result achieved for Argentina. Possibly sheep and beef are complementary products in South America, but no explanation of such complementarity could be found in the literature. The coefficient of the hide price variable is positive. The estimated short and long-run elasticities of production with respect to wool prices are + 0.212 and + 0.481, respectively. The estimated cross-elasticities of wool production, first, with respect to beef prices are + 0.074 and + 0.168 and, second, with respect to hide prices are + 0.170 and + 0.387. The estimated coefficients of adjustment for both countries are similar to those estimated for other countries in this study.

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[46] Carlos F. Diaz Alejandro, Exchange-Rate Devaluation in a Semi-Industrialized Country: The Experience of Argentina, 1955-61 (Cambridge, Massachusetts: The M.I.T. Press, 1965), p. 79.

Equations (4.24) and (4.25) are included in the final model. The major problem with these equations is that they omit the very important factors of political unrest, instability of the economies and the strong and variable government export policies. A related problem may be that the "world" wool price variable is not the relevant price variable for these countries, especially for Argentina. However, no useable alternative price series have been found. Omission of a technological progress variable may have biased the results for Uruguay. Finally, both equations lack cost variables.

7. United States Wool Production

In a number of ways, the United States sheep industry is quite different from the sheep industries considered thus far. United States has a fully developed, highly industralized economy. The agricultural sector does not dominate the economy, and the sheep industry is not the most important component of this sector. Also, United States wool is not produced for export. United States is a net importer of wool, producing only about thirty percent of the amount consumed. Wool is grown and marketed in many different ways in the United States; and thus, in aggregating production of "fleece wools" grown on small eastern farms with the production of "territory wools" grown on the western ranges and with the production of "Texas wools" grown on fenced pastures, the resulting equation explaining aggregate production of wool in the United States may not be as satisfactory as the results for other countries where this problem was not so severe. A final distinguishing characteristic of the United States sheep industry is that, for the period observed, United States wool production has been encouraged to some degree by the Government, with farmers being paid an "incentive price" greater than the market price for their wool in the years 1955-65. In spite of such incentives, wool production has stagnated, falling slightly from 122.5 million pounds (clean basis) in the 1948-49 season to 119.1

pounds (clean basis) in the 1964-65 season.

Because of the government support schemes that have been used, the wool producers have been partially protected from the world market; and a new wool price variable had to be developed for use in the United States equations. First it must be noted that, since United States wool production (shearing) takes place in the spring of the year, data are collected on a calendar year basis. Hence, in this study, United States production for calendar year t is considered to have occurred in the season t. For the years 1955 to 1965, the wool price variable most relevant to wool production appears to be the government incentive price for wool that is administered under the National Wool Act of 1954.[47] During this period, this price was always greater than the average price received by United States farmers. Incentive or support prices of some sort existed in the years 1948 to 1954, but these prices were always lower than the average price received. Thus the wool price series used, $Pwus_t$, is the average price received in cents per pound by farmers for the years 1948 to 1954 and the National Wool Act incentive price for wool in cents per pound for the years 1955 through 1965.[48]

The Nerlove lagged adjustment model is used to explain United States wool production, and it was anticipated that the adjustment process would be found to be more rapid than that of most of the countries previously studied. Mobility of factors is much greater in the United States, both within the agricultural sector and between the agricultural and other sectors. There is no large group in the economy strongly attached to the sheep industry by tradition and ownership of factors unusable for other

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[47]See Section 4.G, Chapter 2.

[48]These series are reported by the United States Department of Agriculture, op. cit.

production processes. However, there is still a significant biologically determined production lag, and thus explanatory variables are lagged two years. Using similar models with one-year lags, Nerlove has had considerable success in estimating the supply response equations for many United States agricultural crop type commodities.[49] For a large segment of the United States sheep industry, lamb seems to be the major product with wool a secondary joint product. The two most important substitute products are wheat and beef. The weather factor differs so much over the United States that it proved impossible to develop an adequate weather variable. No way was found to isolate technological change in wool growing, but the omission of this factor does not seem as important for the United States in the period 1948-1965 as for the other countries studied.

The first equation estimated explains Wus_t, United States wool production in millions of pounds (clean basis) in year t (or season t) as a function of Wus_{t-1}, $Pwus_{t-2}$, the deflated United States effective wool price in cents per pound clean for year t-2, $Pwhus_{t-2}$, the deflated United States price of wheat in dollars per bushel for year t-2,[50] $Pbus_{t-2}$, the deflated United States price of beef in dollars per hundred pounds for year t-2,[51] and $Plus_{t-2}$, the deflated United States price of lamb in dollars per hundred pounds for year t-2.[52] All of the above prices were deflated by the United States wholesale price index for farm

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[49] See, for example, Marc Nerlove, The Dynamics of Supply: Estimation of Farmers' Response to Price, op. cit.

[50] This series is the price of number 2 hard winter wheat in Kansas City as reported in the International Monetary Fund, op. cit.

[51] This series is the average price received by farmers as reported in the United Nations, the Food and Agriculture Organization, op. cit.

[52] The average price received by farmers as reported in the United Nations, the Food and Agriculture Organization, op. cit.

products.[53] Estimating the equation specified above for the years 1949 through 1965 with ordinary least squares yielded[54]

$$(4.26)\quad Wus_t = \underset{(77.348)}{83.592} + \underset{(0.309)}{0.606}\, Wus_{t-1} + \underset{(0.180)}{0.294}\, Pwus_{t-2}$$

$$- \underset{(0.168)}{0.211}\, Pwhus_{t-2} - \underset{(0.768)}{0.695}\, Pbus_{t-2} + \underset{(1.327)}{0.297}\, Plus_{t-2},$$

$$R^2 = 0.67, \quad F = 4.87, \quad D.W. = 1.54, \quad \delta = 0.394$$

All variables enter equation (4.26) with the expected sign, and the estimated coefficients appear to have "reasonable" values. Yet the standard errors of most of the coefficients are quite high. The estimated coefficient of adjustment is 0.394, which indicates that the estimated rate of adjustment in the United States sheep industry is not as high as was anticipated, in fact, only a little higher than that estimated for Australia. The biological aspect of this adjustment lag is certainly the most important, and perhaps countries cannot shorten this lag much more than has been achieved in Australia and the United States.

The estimated short and long-run (or equilibrium) elasticities of wool production to the United States wool price variable are + 0.1362 and + 0.3457, indicating that also in the United States wool production is highly inelastic to price. The estimated short and long-run cross-elasticities of production with respect, first to wheat prices are - 0.3671 and - 0.9317 and, second, to beef prices are - 0.1083 and - 0.2749. Wheat appears to be a relatively strong substitute product and beef a weak substitute. The estimated short and long-run cross-elasticities of wool production to

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[53] This series is reported in the United States, Council of Economic Advisors, <u>The Annual Report of the Council of Economic Advisors</u> (Washington: U.S. Government Printing Office, 1966).

[54] Equation (4.26) contains a constant term because all United States equations performed considerably better with than without such a term.

lamb prices are + 0.0476 and + 0.1208, which indicate that wool and lamb are very weakly complementary.

All of the above interpretations must be qualified by pointing out again the large standard errors of the estimated coefficients. The lack of significance of the lamb price variable is the most surprising and suggests perhaps that lamb production itself is not particularly responsive to lamb prices or that the wrong lamb price variable was used.[55] More general problems of equation (4.26) are the aggregation problem discussed above, the lack of a specification of the effect of costs and weather on wool production and an inadequate representation of the effects of actual and anticipated government action in the market. The United States sheep industry certainly merits further research on a disaggregated basis if the true causes of its stagnation are to be isolated. But, for the purposes of our model, equation (4.26) will have to do. The coefficient of the United States wool price variable does indicate that a certeris paribus increase in the incentive price of wool of ten cents a pound would lead to an increase of about 2.9 million pounds (clean basis) in United States wool production in two years and a "long-run" increase of about 7.6 million pounds. This price has been held at the same level in money terms since 1955, its "real" value varying only due to changes in the wholesale index of farm products. It appears that a more vigorous use of this policy variable would help the United States sheep industry; but, due to the price inelasticity of production, the cost of increasing production adequately by this means may be considered too great.

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[55] Using price ratios in (4.26) did not yield better results.

8. "Rest-of-the-World" Wool Production

In order to complete the production side of the model, a study of wool production in the "Rest-of-the-World" sector was made. This area covers such diverse areas as the Soviet Union, Europe, China, England, Afghanistan, and so on. If the aggregation involved in previous equations could be termed, at the best, bold, the amount of aggregation involved here will probably cause many to question why the attempt was made at all. Yet to the extent that the sheep industries in the countries in this sector are linked to a world wool market, then some aggregate response to the "world" price of wool may be estimatable.

A Nerlove lagged adjustment model is used with the dependent variable, Wrw_t, the production of wool in the "Rest-of-the-World" in millions of pounds (clean basis) for season t derived by subtracting the productions of Australia, New Zealand, South Africa, Argentina, Uruguay and the United States from world seasonal production of wool as estimated by the United States Department of Agriculture.[56] The explanatory variables used are Wrw_{t-1}, Pw_{t-2}, the deflated "world wool price" in United States cents per pound for season t-2, $Pwhus_{t-2}$, the deflated United States price of wheat in United States dollars per bushel for the first year of the season t-2, and $Plnz_{t-2}$, the deflated New Zealand lamb price in United States cents per kilogram for year t-2. The United States wheat price and the New Zealand lamb price series were chosen as representative of world wheat and lamb prices. All prices were deflated by the Sauerbeck commodity price index. Ordinary least squares estimation of the above equation for seasons 1948-49 through 1964-65 resulted in a high Durbin-Watson statistic of 2.85. The equation was re-estimated by approximate generalized

[56] This series is published in United States Department of Agriculture, op. cit.

least squares of order one with an estimated first-order residual autocorrelation coefficient of - 0.5565 yielding equation (4.27).

$$(4.27) \quad Wrw_t = \underset{(0.023)}{0.950}\, Wrw_{t-1} + \underset{(0.253)}{0.550}\, Pw_{t-2} - \underset{(0.907)}{1.564}\, Pwhus_{t-2} + \underset{(0.859)}{1.127}\, Plnz_{t-2}$$

$$R^2 = 0.99, \quad F = 369.00, \quad D.W. = 2.15, \quad \delta = 0.0497$$

Equation (4.27) indicates that the adjustment lag for the "Rest-of-the-World" sector is extremely long, as would be expected with much of this wool being produced on small farms. The price variables all have the "right" signs and are fairly significant. The estimated short and long-run elasticities of production to the "world wool price" variable are + 0.0553 and + 1.1126, the former figure being reasonable and the latter a little high.[57] The estimated short and long-run cross-elasticities of production with respect, first, to wheat prices are - 0.0364 and - 0.7324, respectively, and, second, to lamb are + 0.0551 and + 1.1087. The "Rest-of-the-World" sector's production of wool does appear to be affected to some degree by the same factors and in the same way as does that of the countries on which we have concentrated. Equation (4.27) is included in the world model.

9. Conclusions

This study of the sheep industries of the six major wool producing countries of the world and of the "Rest-of-the-World" sector has resulted in some interesting equations which explain the production side of the world market for raw wool. Since these

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[57] However, this estimated "long-run" elasticity is for a very long adjustment period and hence is not very informative.

equations yield quite similar results for the countries studied, it is possible to make some general observations about world wool production. First, by using a model incorporating an adjustment lag, this study shows that wool production is indeed quite stable, varying only slightly and after a long lag in response to changing economic factors. The estimates of the elasticity of wool production to wool prices vary from + 0.04 to + 0.21 for the short-run and from + 0.20 to + 1.11 for the long-run. The inelasticity of wool supply to wool price in all but the very long-run is, therefore, an important aspect of the world wool market. The effects of substitute products (wheat, cattle) and of the joint product, lamb, on wool production also are estimated to be quite small. Thus we would not expect to find in wool production the strong cycles that have been observed in the production of other agricultural products for which the supply responses to changing economic factors are considerably stronger.[58] Instead, we would expect weaker cycles of fairly long duration, and such cycles are detected in the analysis of the complete world wool market model in Chapter 7 and the spectral analysis of the wool market in Chapter 8. As for noneconomic variables, rainfall was found to be an important variable in Australia, South Africa and Argentina; and fertilizer usage proved to be a useful way of including the effect of technological change in Australia.

Statistically, the estimated equations for most countries are quite good, the exceptions being the equations for the South American countries and for the United States. Serial correlation of the residuals did not prove to be too much of a problem except

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[58] An example of these cycles is the strong recurring cycle in the production of hogs in the United States. See, for example, Gerald W. Dean and Earl O. Heady, "Changes in Supply Response and Elasticity for Hogs," Journal of Farm Economics, Vol. XL (November, 1958), pp. 845-860.

that some equations had to be estimated by approximate generalized least squares. From the view point of economic theory, the main deficiency in all the equations is the absence of cost variables. A considerable amount of future research should be done on the sheep industries of each country if these cost factors are to be analyzed adequately, but those who undertake such research will certainly have problems obtaining the necessary data. Another deficiency of all but the Australian equation is the lack of a variable for technological change. However, despite these deficiencies, these equations do seem to give the approximate structure of the production side of the world wool market and should be adequate for the world market model.

CHAPTER 5

WORLD RAW WOOL STOCKS

1. Introduction

One of the basic results of this study is that both the production and the consumption of raw wool are quite inelastic with respect to wool prices. Thus it appears that changes in the holdings of raw wool stocks are the main means of clearing the world market and play a major role in the simultaneous determination of wool prices. In this chapter, the relationships between wool stocks and prices are studied and equations explaining the central dynamic role of these variables are estimated.

A difficult problem, both conceptual and statistical, that one faces in studying wool stocks is that stocks are held by many different people and organizations for many different purposes. For example, significant amounts of stocks of raw wool are held by producers, dealers, government organizations and strategic reserves, wool commissions, importing merchants, wool scourers and fellmongers, top makers, and manufacturers, these stocks being held in both producing and consuming countries. A further complication is that stocks of semi-finished and finished wool products also have a significant effect in the market; but since there unfortunately are no adequate data on these stocks, the relationship of these stocks to the world market could not be studied.

For purposes of analysis, the many types of holdings of raw wool stocks were aggregated into three classes, "producer stocks", "commercial stocks " and "non-commercial stocks". While in theory it could be decided which stocks belong in each category, the availability of data is in many cases the deciding factor. In section 3 producer stocks are defined and equations explaining producer carry-over stocks in Australia, New Zealand, South Africa, Argentina and Uruguay are given. In section 4 commercial stocks are defined, and equations explaining commercial stocks in the United States, United Kingdom and Japan are given. The difficult problem of estimating an equation to explain wool prices is discussed in section 5.

Non-commercial stocks enter the model as an exogenous variable. These stocks are defined as the sum of the stocks held by the Commodity Credit Corporation in the United States, by the British Wool Marketing Board, the strategic stockpile and the Joint Organization in the United Kingdom and by the Wool Commissions of New Zealand and South Africa. The levels of these stocks are determined by groups which either are part of, or are closely associated with, the corresponding governments and which base their decisions on a host of factors, many of which are non-economic.

2. The Method of Estimation

The stock and price equations considered here were estimated simultaneously with equations explaining the net comsumption of raw wool in nine major wool-consuming countries and in a "Rest-of-the-World" sector. This system of simultaneous stock, price, and consumption equations was estimated by the method of two-stage least squares with principal components of all predetermined variables as instrumental variables.[1] The use of some form of instrumental variables for the first stage was necessitated by the dimensions of the model. Ordinarily in the first stage of two-stage least squares, an estimate of the variance-covariance matrix of the reduced-form disturbances is obtained by regressing the vector of the dependent variables which enter as explanatory variables in the equation being estimated on

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[1] The program used was written by Morris Norman of the University of Pennsylvania and was run on the IBM 7094 computer at the Princeton Computer Center of Princeton University.

all the predetermined variables in the system, this regression requiring the inverse of the matrix of sums of squares and products of the predetermined variables. However, for the forms of the world wool market model considered here, the number of predetermined variables varies from 34 to 48 while the number of observations is only 16. Thus, for these models, the matrix of the sums of squares and products of the predetermined variables is singular.

In order to avoid this problem of singularity, the method of principal components of all predetermined variables, as discussed by Kloek and Mennes,[2] was used to obtain an estimate of the residual disturbances. In this method a small number of instrumental variables which are mutually orthogonal are constructed as linear combinations of the predetermined variables and are those linear functions which also have maximum variance. For the final form of the model estimated in this study, nine principal components were used, these nine components explaining 97.6 percent of the variance of the predetermined variables. The vector of included explanatory variables was then regressed on these instrumental variables to obtain estimates of the residual disturbances. With these resulting estimates, the second stage of two-stage least squares was carried out in the usual manner. As the method of principal components as applied to two-stage least squares estimation is fairly new, it is described in more detail in the Appendix to this chapter. Fisher has suggested an alternative approach, that of systematically choosing a subset of the predetermined variables as instrumental by taking account of the recursive structure of the system.[3] As his method is

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[2]T. Kloek and L.B.M. Mennes, "Simultaneous Equations Estimation Based on Principal Components of Predetermined Variables," Econometrica, Vol. XXVIII (January, 1960), pp. 53-55.

[3]Franklin M. Fisher, "Dynamic Structure and Estimation in Economy-Wide Econometric Models," in The Brookings Quarterly Econometric Model of the United States, eds. J. S. Dusenberry, et. al. (Chicago Rand McNally and Co., 1965), pp. 589-650.

considerably more time-consumming for a large model and since, when a large system is followed through recursively, the errors may cumulate, Fisher's approach was not used.

For all equations of the model, parameter estimates and their estimated standard errors, the multiple correlation coefficients, the F-test statistics and Durbin-Watson statistics are reported. However, the standard t-, F- and Durbin-Watson tests are not valid for structural estimates of simultaneous equation models, especially when many of the equations reported contain the lagged value of the dependent variable. The limited evidence available on the small sample properties of two-stage least squares estimates suggest that this method tends to underestimate the significance of the parameter estimates.[4] However, these statistics are included so that we may have a systematic way of comparing the equations estimated. The inapplicability of the standard tests means that a greater reliance has to be placed on a priori specifications of the model.

In determining the final forms of the equations for the complete model, there was a certain amount of experimentation with different forms of each equation. Because of the size of the model, the whole model was not re-estimated for each form of each equation. However, when the final specification of the model was determined, all equations in the model were re-estimated; and it is these estimates that are given for these equations. As has been the case in other econometric studies,[5] small changes in the specification of the model caused little change in the estimates of equations whose specifications were not changed.

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[4]Stephen M. Goldfeld and Richard E. Quandt, Nonlinear Simultaneous Equations: Estimation and Prediction, Research Memorandum No. 79, Econometric Research Program, Princeton University (October 21, 1965).

[5]See, for example, Stephen M. Goldfeld, Commercial Bank Behavior and Economic Activity (Amsterdam: North-Holland Publishing Company, 1966), p. 138.

3. Producer Stocks of Raw Wool

A small amount of wool, from two to eight percent of the world clip, is carried over at the end of the season in producing countries. These stocks are withheld from sale mainly for speculative reasons. Some are never offered for sale during the season, some are offered for sale but with too high a limit price below which the producer desires not to sell and some are offered too late in the season. These latter stocks result from producers who, thinking the price will get better at the end of the season, wait too long before offering their clips for sale. The majority of the wool growers cannot afford to carry their wool over to the next season because they need the returns to pay current expenses. Also they are constantly exhorted by the wool brokers to "meet the market" and to "sell and repent but sell."[6] That is, the brokers have pushed the position that speculative stock holding hurts the functioning of the free auction markets in which most wool is sold. Thus, in most cases, it probably is the larger and more sophisticated growers that hold these stocks. One of the major factors affecting producer carryover stocks in Uruguay and Argentina, where sales are by private treaty, is the government export policy; and hence we will include an index of government export policy in the stock functions for these countries. While the size of the producer stocks are relatively small, changes in these stocks are thought to have a significant affect on the level of world wool prices; and hence a study of the factors determining these stocks is central to the world wool market model being constructed.

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[6] Alan Barnard, "A Century and a Half of Wool Marketing," in The Simple Fleece, ed. Alan Barnard (Parkville, Victoria, Australia: Melbourne University Press, 1962), p. 480.

The stock data used as "producer stocks" are the Commonwealth Economic Committee's series of stocks of unsold wool in the main exporting countries at the end of the season in millions of pounds (clean basis).[7] These figures are for the first of July for Australia, New Zealand and South Africa and for the first of October for Argentina and Uruguay. The New Zealand and South African series do not include stocks held by their respective Wool Commissions. No producer stock data exist for countries other than the five main producer countries studied here. Since such stocks are negligible both in quantity and in their effect on the world market, they are specified to be equal to zero in this model. This is certainly not a bad approximation in the case of the United States since, due to the high fixed incentive price received by growers, there is no reason for these growers to hold wool stocks for speculative reasons.

Since the principal reason producers carry stocks over to the next season is apparently that of speculation, the main explanatory variables are the current and expected future price of wool, Pw_t and Pwj^*_{t+1}. The simple model used to explain the level of carry-over stocks in country j at the end of season t, Sj_t, is

$$(5.1) \quad Sj_t = \alpha_{j0} + \alpha_{j1} Pw_t + \alpha_{j2} Pwj^*_{t+1} \quad .$$

As is described below, a government export policy variable was added to (5.1) in the equations for Argentina and Uruguay. While "naive" expectations, that is, $Pwj^*_{t+1} = Pw_t$, were found to be useful in the equations explaining wool production, a more complex form of expectation formation is assumed for the producer stock equations. This specification of a more complex form of

[7] This series is published in Commonwealth Economic Committee, Wool Intelligence (London, Monthly).

expectation formation is consistent with the specification of the wool production equations because it is assumed that carry-over stocks are held by only a small subset of the country's wool producers, this subset consisting of the larger, more sophisticated producers and brokers who have the capital to permit carrying these stocks. It is for this subset that the more complex form of expectations formation is assumed to hold. A related important difference between the stock and the production equations is that producers are assumed to be able to adjust desired stocks to actual stocks completely in the course of a season while they cannot adjust production so rapidly. Thus, while expectations are implicitly included in the lagged-adjustment production equations, they are included explicitly in the stock equations.

The expectations of future prices of wool are based on information available in period t. While a great many economic and noneconomic variables are observed, it is assumed that the market has acted in such a way that the effects of all these variables on the wool market are contained in current and past wool prices. The basic assumption of the first producer stocks equations estimated is that the wool price expected for season t+1 is a distributed lag function of the current price and all past prices, that is

$$(5.2) \quad Pwj^{*}_{t+1} = \beta_j \sum_{i=0}^{\infty} (1-\beta_j)^i \, Pw_{t-i} \quad .$$

This specification implies that the present price has the greatest influence on the price expected in the next period and that the effect of past prices declines exponentially with time.[8]

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[8]Marc Nerlove in "Adaptive Expections and Cobweb Phenomena," The Quarterly Journal of Economics, Vol. LXXIII (May, 1958), p. 232, shows that (5.2) will result if expectations are specified as "adaptive," that is if expectations are revised periodically by some portion of the error between last period's expectation and what actually occurred:

$$Pwj^{*}_{t+1} - Pwj^{*}_{t} = \beta(Pw_t - Pwj^{*}_{t}) \quad .$$

Substituting (5.2) into (5.1) yields

$$(5.3) \quad Sj_t = \alpha_{j0} + \alpha_{j1}Pw_t + \alpha_{j2}\ \beta_j \sum_{i=0}^{\infty} (1-\beta_j)^i\ Pw_{t-i} \quad .$$

Lagging (5.3) by one period, multiplying by $(1-\beta_j)$, and subtracting the result from (5.3) yields the reduced equation

$$(5.4) \quad Sj_t = \beta_j\ \alpha_{j0} + (1-\beta_j)\ Sj_{t-1} + (\alpha_{j1} + \alpha_{j2}\ \beta_j)\ Pw_t - (1-\beta_j)\ \alpha_{j1}Pw_{t-1} \quad ,$$

a linear equation in the observed variables Sj_t, Sj_{t-1}, Pw_t and Pw_{t-1}, which can be estimated. From the estimation of (5.4), estimates of the parameters of (5.1) and (5.2) can be obtained. Note that this specification of the reduced equation (5.4) may introduce serial correlation in the residuals.

Specification (5.4) was applied to Australian, New Zealand and South African data yielding equations (5.5), (5.6) and (5.7), below. Wool stocks are measured in millions of pounds (clean basis). The "world wool price," described in Chapter 3, deflated by the Sauerbeck Index of commodity prices, is in United States cents per pound (clean basis). All equations were first estimated with constant terms. Since the constant terms were very insignificant for (1) and (3), these two equations were re-estimated without a constant term. The estimates of the parameters of (5.1) and (5.2) are given below each equation,

$$(5.5) \quad Sau_t = \underset{(.132)}{.978}\ Sau_{t-1} + \underset{(.047)}{.075}\ Pw_t - \underset{(.048)}{.054}\ Pw_{t-1}$$

$$R^2 = .72,\ F = 16.339,\ D.W. = 1.92,\ \beta = .022,$$

$$\alpha_1 = .056,\ \alpha_2 = .860$$

$$(5.6)\quad Snz_t = \underset{(11.583)}{-19.856} + \underset{(.245)}{.631}\, Snz_{t-1} + \underset{(.082)}{.662}\, Pw_t - \underset{(.155)}{.402}\, Pw_{t-1}$$

$$R^2 = .85,\ F = 22.420,\ D.W. = 1.82,\ \beta = .369,$$

$$\alpha_0 = -53.809,\ \alpha_1 = .637,\ \alpha_2 = .069$$

$$(5.7)\quad Ssa_t = \underset{(.261)}{.594}\, Ssa_{t-1} + \underset{(.004)}{.029}\, Pw_t - \underset{(.007)}{.023}\, Pw_{t-1}$$

$$R^2 = .77,\ F = 21.435,\ D.W. = 1.46,\ \beta = .406,$$

$$\alpha_1 = .038,\ \alpha_2 = -.038$$

These equations are quite interesting in that they indicate slightly different formation and importance of expectations in the three countries studied. If we assume that specification (5.2) is true and that expectations are adaptive, then equations (5.5), (5.6) and (5.7) imply the following three expectation formation equations:

$$(5.8)\quad \text{Australia} \quad (Pwau^*_{t+1} - Pwau^*_t) = .022\ (Pw_t - Pwau^*_t)$$

$$(5.9)\quad \text{New Zealand} \quad (Pwnz^*_{t+1} - Pwnz^*_t) = .369\ (Pw_t - Pwnz^*_t)$$

$$(5.10)\quad \text{South Africa} \quad (Pwsa^*_{t+1} - Pwsa^*_t) = .406\ (Pw_t - Pwsa^*_t)$$

Apparently the adaptive process is much weaker in Australia than in the other two countries. Equation (5.8) implies that, for Australia, equation (5.2) is

$$(5.11)\quad Pwau_{t+1} = (.022) \sum_{i=0}^{\infty} (.978)^i\, Pw_{t-i} \quad ;$$

that is, the effect of past prices on the expected price declines fairly slowly as we move backward in time. This analysis indicates that Australian producers are attempting to forecast the "long-run" or "normal" price and filter out short-run price variations. For New Zealand and South African producers, recent price movements appear to have a relatively greater effect on expectations, the effect of these prices dying out fairly rapidly. The estimate of the importance of current prices for New Zealand may be biased upward because, in the season 1950-51, a season of very high wool prices, some of the New Zealand carry-over stocks were the result of a long dock strike, which tied up shipping.

Equations (5.5), (5.6) and (5.7) yield the following three estimates of equation (5.1):

$$(5.12) \quad Sau_t = .056\ Pw_t + .860\ Pwau^*_{t+1}$$

$$(5.13) \quad Snz_t = -53.809 + .637\ Pw_t + .069\ Pwnz^*_{t+1}$$

$$(5.14) \quad Ssa_t = .038\ Pw_t - .038\ Pwsa^*_{t+1}$$

The expected price variable is most important for Australia, perhaps because producers in the other two countries know that there is a floor to the wool prices in their countries as a result of their respective Reserve Prices Schemes. The coefficient for expected price in South Africa is quite small and is unexpectedly negative. The current wool price enters all equations with a positive sign. It was expected that the sign of these coefficients would be negative, indicating that, with all else being equal, a lower current price would make producers more willing to hold their stocks until the next season. Perhaps due to misspecification these coefficients are picking up some expectational effects; or, what is more likely, in times of high expected future prices, current prices are rising. This latter interpretation, in fact, is implied by the specification of expectations formation.

When specification (5.4) was applied to Argentina and Uruguay, the results were very unsatisfactory with negative estimates of β being obtained. A simpler form of (5.1) was used stating that producer carry-over stocks are a function of the current price, the change in price over that of last period, and a dummy variable, Dj_t, explained below.

$$(5.15) \quad Sj_t = \alpha_{j0} + \alpha_{j1} Pw_t + \alpha_{j2} \Delta Pw_t + \alpha_{j3} Dj_t.$$

The price change variable is included to indicate the effect of price expectations, the rational being that short-run price movements appear to be very important for holders of stocks in these countries due to instability of the political and market systems.

As has been stated above, a very important factor affecting producer stocks in these two countries has been the frequently changing relationship of government economic policy towards wool exports. Changing taxes, exchange rates, export license policies and general political instability have resulted in great variations in the carry-over stocks held in these countries. It became evident fairly early in the study of these countries that some necessarily quite crude attempt would have to be made to construct a variable indicating the "favorableness" of government economic policy towards raw wool exports if any success were to be achieved in estimating equations explaining producers' wool stocks. Initially, the idea was to construct an index which systematically accounted for changes in the "free" and the effective exchange rates[9] for wool exports and for export taxes. A study of the economic policies of the period in these two countries showed that this approach was futile, expecially since for many periods it is difficult to determine what the effective exchange rate on raw wool exports was.[10] The method finally

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[9]All references to exchange rates in this section are for the exchange rates of pesos to United States dollars.

[10]An excellent study of economic policy in Argentina for the period 1955 - 1961 is Carlos F. Diaz Alejandro, Exchange-Rate Devaluation in a Semi-Industrialized Country: The Experience of Argentina, 1955-61 (Cambridge, Massachusetts: The M.I.T. Press, 1965).

chosen was to go through issues of a major trade journal, The World Wool Digest, (which is published by The International Wool Secretariate and the Wool Bureau, Inc.) for this period to discover seasons which were reported to have been periods for which the government policies in Argentina and Uruguay were particularly "unfavorable" for raw wool exports. Then, dummy variables, Dag_t and Dur_t, were constructed having the value 1.00 for the "unfavorable" seasons and 0.00 for the other years. The seasons which were unfavorable for Argentina wool exports were the following: a) 1948-49, a season during which the Government first required export permits in order to protect the Argentine textile industry's source of raw materials and also during which the "free" exchange rate doubled, while the effective official exchange rate for wool exports remained constant; b) 1951-52, a season during most of which the Government refused to grant export licenses at prices less than the boom prices that existed earlier in the season and also during which the "free" exchange rate doubled, while the effective official exchange rate for wool exports changed only slightly; and c) 1957-58, another season during which the "free" exchange rate doubled, the official rate remaining almost constant. The seasons which were unfavorable for Uruguayan exports were the following: a) 1948-49, a season during which the Government imposed a ban on wool exports to the Sterling Area, wishing to divert trade to the Dollar Area; b) 1951-52, a season during which the effective official exchange rate for wool exports was about 55 percent lower than the "free" rate; c) 1954-55, a season during which the effective official exchange rate for wool exports was about 46 percent lower than the "free" rate and also during which a 7 percent export tax on wool went into effect; d) 1957-58, a season during which the "free" exchange rate more than doubled, while the effective official rate for wool exports changed only slightly; and e) 1963-64, a season during which the retention tax on wool was raised significantly and also during which the producers complained strongly that the galloping inflation in Uruguay made it uneconomical to export wool. While in other seasons some of the objective policy variables stated here appeared to be restrictive, there was considerably less comment on the "unfavorableness" of government policy in the trade literature.

The choice of which years to include in these indices is obviously subjective. More objectively defined indices would be preferable. Yet, in the absence of such indices, these policy dummy variables do improve the equation estimates, giving some indication of the importance of changing policies on producers' wool stocks and also permitting an estimation of the effects of current and expected prices. An attempt was made to apply <u>a priori</u> information to the estimation procedure in the way outlined by F. Fisher, who has noted the necessity of making use of such information in econometric studies and of stating fully the way this information was obtained and incorporated into the study.[11]

Using specification (5.15), equations (5.16) and (5.17) were estimated for Argentina and Uruguay.[12]

$$(5.16) \quad Sag_t = \underset{(19.905)}{-53.700} + \underset{(.196)}{.927}\, Pw_t - \underset{(.172)}{.475}\, \Delta Pw_t + \underset{(11.142)}{98.479}\, Dag_t$$

$$R^2 = .95, \; F = 70.589, \; D.W. = 2.10$$

$$(5.17) \quad Sur_t = \underset{(.028)}{.131}\, Pw_t - \underset{(.080)}{.206}\, \Delta Pw_t + \underset{(5.601)}{22.342}\, Dur_t$$

$$R^2 = .73, \; F = 17.650, \; D.W. = 1.95$$

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[11]Franklin M. Fisher, <u>op. cit.</u> See, especially, Chapter 1.

[12]Both equations were estimated with constant terms. The constant term in the Uruguay equation was highly insignificant, and the equation was re-estimated without the constant term.

The Argentine equation fits the data considerably better than that for Uruguay, but the estimated standard errors of the coefficients of both equations are quite small. The government policy variables are very significant for both equations as expected. In the equations for both Argentina and Uruguay, the current wool price enters with a positive sign; and the change in prices enters with a negative sign. This may mean that producers extrapolate current price as future price and feel that the most recent change in price will be reversed, indicating a belief that most variation in wool prices is in the high frequency range. If a producer followed such a form of expectation formation during the period studied, he might not have done too badly; for eleven times interseasonal price changes were followed by changes of the opposite sign, while changes of the same sign followed only four times.

Because of the subjective nature of the policy dummy variables, equations (5.16) and (5.17) were estimated for comparison purposes without these variables, yielding equations (5.18) and (5.19 below.

$$(5.18) \quad Sag_t = \underset{(49.871)}{-121.690} + \underset{(.470)}{1.752}\, Pw_t - \underset{(.357)}{1.439}\, \Delta Pw_t$$

$$R^2 = .58,\ F = 9.135,\ D.W. = 1.84$$

$$(5.19) \quad Sur_t = \underset{(.031)}{.199}\, Pw_t - \underset{(.099)}{.377}\, \Delta Pw_t$$

$$R^2 = .41,\ F = 9.652,\ D.W. = 2.52$$

These equations have considerably less explanatory power than (5.16) and (5.17) due to the omission of the dummy variables, but the same qualitative results about the wool price variables are obtained. The absolute values of the price coefficients are somewhat higher, perhaps picking up some of the effect of the government policies.

Our estimates of the manner in which wool prices enter the carry-over stock decisions of producers in Argentina and Uruguay do not seem to have been affected significantly by our use of the somewhat arbitrary government policy dummy variables. We have found that producers in these countries seem to have a rather different idea of the relative important of short-run variations in the wool market than that held by producers in the other three countries studied. This difference is perhaps attributable to the general difference in the economic and political stabilities of the two groups of countries, that is, the general climate under which the speculation has taken place.

4. Commercial Stocks of Raw Wool

The stocks of raw wool held in consumer countries by wool manufacturers and dealers are denoted in this study as "commercial" stocks and are held mainly for present and expected future mill consumption of wool but also, in some cases, for speculation or price-hedging. The relationship between stocks of raw materials and mill-consumption or activity can be stated in its simplest form as the assumption that "manufacturers and merchants are both desirous and able to maintain inventories in constant ratio to their output or sales,"[13] that is, as the assumption of a simple accelerator relationship. However, it seems clear that the accelerator in this form is too simple.

One modification which is used in this study is the flexible accelerator concept suggested by Goodwin, which states that producers adjust actual stocks in period t, SC_t, only a fraction, δ, of the distance to equilibrium or desired stocks, SC_t^e, in any

[13] Moses Abramovitz, Inventories and Business Cycles with Special Reference to Manufacturers' Inventories, National Bureau of Economic Research (New York: The Gallery Press, 1950), p. 20.

one period;[14] that is[15]

$$(5.20) \quad (SC_t - SC_{t-1}) = \delta(SC_t^e - SC_{t-1}).$$

It is equilibrium or desired stocks which are assumed to be linearly related to mill consumption of wool.

Assuming the flexible accelerator, (5.20), yields the following expression,

$$(5.21) \quad SC_t = \delta \sum_{i=0}^{\infty} (1-\delta)^i \, SC_{t-1}^e \quad ,$$

which states that current inventory stocks are a weighted average of all past equilibrium inventory stocks. Lovell, in his excellent review of econometric studies of the determinants of inventory behavior, states that producers may adjust only partially to equilibrium inventories in any one time period because of lags in ordering and in delivery of raw materials, significant savings that can be obtained by large bulk purchases, limited means of running down inventories in times of slack demand or limited warehouse space in times of expansion.[16] The adjustment lag in the wool industry might be expected to be relatively large

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[14]Richard M. Goodwin, "Secular and Cyclical Aspects of the Multiplier and Accelerator," in Income, Employment and Public Policy: Essays in Honor of Alvin M. Hansen, Lloyd A. Metzler, et. al. (New York: W. W. Norton and Company, Inc., 1948).

[15]In order to simplify notation, the country subscript, j, is not used in equations (5.20) through (5.30).

[16]Michael Lovell, "Determinants of Inventory Investment," in Models of Income Determination, Studies in Income and Wealth Vol. XXVIII, National Bureau of Economic Research (Princeton, N.J.: Princeton University Press, 1964), p. 180.

because the supply of the raw material is highly seasonal and the order and delivery lags are significant since most major consuming countries are in the Northern Hemisphere and most major supply countries are in the Southern Hemisphere.

Another reason that observed inventory behavior may deviate from that indicated by the simple accelerator principle is that equilibrium inventory stocks depend on anticipated mill consumption of wool, and errors in these anticipations will lead to discrepancies between the actual and the desired level. If we let SC_t^p be planned stocks in period t, then (5.20) can be rewritten as

$$(5.22) \qquad (SC_t^p - SC_{t-1}) = \delta(SC_t^e - SC_{t-1})$$

or

$$(5.23) \qquad SC_t^p = \delta SC_t^e + (1-\delta)\ SC_{t-1}$$

and

$$(5.24) \qquad SC_t = SC_t^p + MC_t^* - MC_t$$

where MC_t^* is expected or anticipated mill consumption in period t, these anticipations being made at the beginning of the period, and MC_t is the actual mill consumption in period t. Specification (5.24) is that of a buffer-stock inventory model first formulated by Metzler[17] and later combined with the flexible accelerator model, (5.22), by Lovell.[18] It is the combination of a flexible accelerator model with a buffer-stock model as given in (5.22) and (5.24) that is used to explain commercial stocks of raw wool in

[17]Lloyd A. Metzler, "The Nature and Stability of Inventory Cycles," Review of Economics and Statistics, Vol. III (August, 1941), pp. 113-129.

[18]Michael Lovell, "Manufacturers' Inventories, Sales Expectations, and the Acceleration Principle," Econometrics, Vol. XXIX (July, 1961), pp. 293-314.

this study.

As was noted above, some of the commercial stocks of raw wool held in consuming countries may be held for hedging or speculating on wool prices, especially that wool held by dealers. A true test of whether such speculative stock holding is significant would require knowledge of expected prices. However, we are limited to using some proxy for expected prices. Other studies of inventories using various proxy variables for expected future prices obtained mixed results. Klein and Popkin found a significant positive relationship between aggregate inventory investment and changes in the GNP deflator;[19] while Lovell found the relationship for stocks of purchased goods and goods in process to be of the right sign but insignificant.[20] Both of these studies were of the United States economy. In this study, the price of wool for the season spanning the calendar years t-1, t, Pw_t, is used as a proxy for the expected price in the calendar year t. Lovell suggests that a useful way of including expectations about mill consumption is the following general specification:[21]

$$(5.25) \qquad MC_t^* = \beta MC_{t-1} + (1-\beta)MC_t .$$

This specification will yield a measure of the ability of

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[19]Lawrence R. Klein and Joel Popkin, "An Econometric Annalysis of the Post-War Relationship Between Inventory Fluctuations and Changes in Aggregate Economic Activity," Part III of Inventory Fluctuations and Economic Stabilization, U.S. Congress, Joint Economic Committee, 87th Congress, 1st Session (Washington, D.C.: U.S. Government Printing Office, 1961), pp. 69-89.

[20]Michael Lovell, "Determinants of Inventory Investment," loc. cit.

[21]Michael Lovell, "Manufacturers' Inventories, Sales Expectations, and the Acceleration Principle," op. cit., p. 305.

producers and dealers to forecast and is not a specification of how these expectations are formulated. If MC_{t-1} is subtracted from both sides of (5.25), we get

$$MC^{*}_{t} - MC_{t-1} = (\beta-1)MC_{t-1} + (1-\beta)MC_{t}$$

or

$$(5.26) \quad MC^{*}_{t} - MC_{t-1} = (1-\beta)\ (MC_{t} - MC_{t-1}),$$

indicating that the forecast change equals $(1-\beta)$ times the actual change. Thus if $\beta = 0$, there is no systematic tendency either to over or to underestimate the actual change. If $\beta=1$, then, by (5.25), expectations are static. If $0<\beta<1$, there is a tendency to underestimate the size of the change, but the sign of the change is estimated correctly. If $\beta>1$, the sign of the change is estimated incorrectly. Finally, if $\beta<0$, there is a tendency to overestimate the change, but again the sign is estimated correctly. Studying inventory investment in durable and nondurable finished goods on a quarterly basis, Lovell estimated β to be between .09 and .16, indicating that firms tend to have expectations which, on the whole, are quite precise with a small tendency to underestimate these changes.[22]

If we specify equilibrium inventory stocks of raw wool as being determined by

$$(5.27) \quad SC^{e}_{t} = \alpha_0 + \alpha_1\ MC^{*}_{t} + \alpha_2\ Pw^{*}_{t},$$

and substitute Pw_t for Pw^{*}_{t} and (5.25) for MC^{*}_{t}, we get

$$(5.28) \quad SC^{e}_{t} = \alpha_0 + \alpha_1\ \beta MC_{t-1} + \alpha_1\ (1-\beta)MC_{t} + \alpha_2\ Pw_{t}.$$

[22] Ibid., p. 301.

Substituting (5.23) and (5.25) into (5.24) yields

$$(5.29) \quad SC_t = \delta SC_t^e + (1-\delta)SC_{t-1} + \beta MC_{t-1} + (1-\beta)MC_t - MC_t.$$

substituting (5.28) into (5.29) yields

$$SC_t = \delta\alpha_0 + \delta\alpha_1 \beta MC_{t-1} + \delta\alpha_1 (1-\beta)MC_t + \delta\alpha_2 Pw_t + (1-\delta)SC_{t-1} + \beta MC_{t-1} - \delta MC_t,$$

or

$$(5.30) \quad SC_t = \delta\alpha_0 + (1-\delta)SC_{t-1} + \delta\alpha_1 MC_t - (\delta\alpha_1 + 1)\beta\Delta MC_t + \delta\alpha_2 Pw_t.$$

Specification (5.30) is in terms of observed variables and can be estimated. The coefficients of these variables can be unscrambled to yield estimates of the parameters of (5.22), (5.25) and (5.27).

We are limited in applying (5.30) to the world wool market in that there are data over the time period covered, 1948-1964, only for three countries, the United States, the United Kingdom and Japan. However, these countries are the most important wool consuming countries. Another important problem is that the data and the model are on an annual basis, while inventory stock decisions generally are made on the basis of a shorter time period. Yet the seasonality of wool supply probably does lengthen the horizon over which such decisions are made relative to those in other industries. The main consequences of using annual data will be that estimated adjustment coefficients will be higher and short-run variations of stocks will be omitted. Also, to the extent that price speculation is based on a time period less than one year, the effects of speculation on stocks will not show up in these annual equations. The stock data used are in terms of millions of pounds (clean basis) of stocks of raw wool held by merchants and manufacturers as reported by the Commonwealth

Economic Committee.[23] The data for the United Kingdom and Japan are for June 30 of the year; while the data for the United States are for April 1 for years 1948 through 1957 and for January 1 for years 1958 through 1964. The mill consumption data is in millions of pounds (clean basis) of raw wool per calendar year as reported by the United States Department of Agriculture,[24] who receive much of this data from the Commonwealth Economic Committee. The commercial wool stocks equations include the world wool price variable used elsewhere in the study. This price is in United States Cents per pound and is deflated by the seasonal Sauerback Index of commodity prices.

Specification (5.30) was used for the three countries, United States, United Kingdom and Japan, for the years 1949 to 1964; and the resulting two-stage least squares (with principle components) estimates are[25]

$$(5.31)\quad SCus_t = \underset{(.247)}{.125}\, SCus_{t-1} + \underset{(.149)}{.257}\, MCus_t - \underset{(.155)}{.079}\Delta MCus_t + \underset{(.346)}{.143}\, Pw_t$$

$$R^2 = .64,\ F = 7.214,\ D.W. = 1.97,\ \delta = .875,\ \beta = .063,\ \alpha_1 = .244$$

$$(5.32)\quad SCuk_t = \underset{(.206)}{.228}\, SCuk_{t-1} + \underset{(.073)}{.271}\, MCuk_t - \underset{(.135)}{.137}\Delta MCuk_t + \underset{(.193)}{.057}\, Pw_t$$

$$R^2 = .59,\ F = 5.686,\ D.W. = 2.04,\ \delta = .875,\ \beta = -.108,\ \alpha_1 = .351$$

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[23]Commonwealth Economic Committee, Wool Intelligence (London, Monthly), various issues.

[24]United States Department of Agriculture, Wool Statistics and Related Data: 1920-1964, Statistical Bulletin No. 363, (Washington, D.C.: U.S. Government Printing Office, July, 1965).

[25]All equations were estimated with and without a constant term. In all cases the equations with a constant term were poorer, with the estimated constant terms having very large estimated standard errors.

$$\text{(5.33)}\quad SCj_t = \underset{(.229)}{.763}\, SCj_{t-1} + \underset{(.032)}{.007}\, MCj_t + \underset{(.109)}{.148}\Delta MCj_t + \underset{(.032)}{.040}\, Pw_t$$

$$R^2 = .75,\ F= 11.940,\ D.W.= 1.94,\ \delta=.237,\ \beta= -.147,\ \alpha_1= .030$$

Although the estimated standard errors of most of the coefficients in these three equations are rather high, the results are fairly interesting. The estimates of the reaction lag coefficient, δ, the equilibrium accelerator coefficient, α_1, and the accuracy coefficient, β, are given below each equation. The results for the United States imply that the annual adjustment of actual stocks to desired stocks is fairly complete, about 87 percent. Also, expectations about annual levels of mill consumption are estimated to be quite accurate with a slight tendency to underestimate changes. This estimate might be biased downward because of the early date in the time period at which United States stocks were measured. The wool price coefficient has the correct sign but is statistically insignificant and lends little support to the hypothesis that a significant amount of wool stocks held in the United States are held for the purpose of speculating or hedging on year-to-year price changes. Clearly, however, the test used is quite crude. Probably there is more speculation and hedging on shorter-run price changes and on relative price changes between different qualities of wool. Also, while producers may feel capable of forecasting short-run, e.g., seasonal, price fluctuations, they may not attempt to forecast year-to-year price changes. The lack of activity in the wool futures markets in the United States lends further support to these results.

The results for the United Kingdom indicate that the annual adjustment process of desired to actual stocks in this country is a little less complete than that for the United States, about 77 percent. Again, manufacturers appear to be estimating annual levels of mill consumption fairly accurately with a slight tendency to overestimate the size of the annual changes. The estimated equilibrium accelerator coefficient is .351, which is close to that for the United States, .294. The coefficient of the wool price variable again is insignificant, a result somewhat more surprising for the United Kingdom where the manufacturers were thought to speculate more than those in the United States. For example, Rainnie states that "In the United Kingdom, apart from merchants whose function it is to speculate on price, there are many processors who welcome price fluctuations and the opportunity they give to play the market."[26] Perhaps our result is due to the length of the time period studied and the crudeness of the test.

The Japanese estimates differ markedly from those of the other two countries. The estimated reaction coefficient, .237, is significantly lower than those for the other two countries. The estimated equilibrium accelerator is small, .030, and is estimated from a coefficient having a very large estimated standard error. Finally, the wool price variable enters with considerably greater significance. The small size of the estimated equilibrium accelerator suggests that the importance of the accelerator principle for Japan is not very great. Perhaps because of the rapid growth of the Japanese wool industry in the last twenty years, producers have not developed a strong idea of the ideal or equilibrium relation of stocks to mill consumption but instead have had to concentrate on catching up to their expanding output. This interpretation is supported by the small estimated value of δ, .237, which indicates a slow adjustment to equilibrium. The estimated coefficient of the accuracy of expectations, -.147, is similar to that of the United Kingdom, indicating fairly accurate expectations with some tendency to overestimate changes.

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[26]G. F. Rainnie, "Raw Materials and Markets," in <u>The Woolen and Worsted Industries: An Economic Annalysis</u>, ed. G. F. Rainnie (Oxford, England: Clarendon Press, 1965), p. 15.

Because the wool price variable performed so badly for the United States and the United Kingdom, equations (5.31) and (5.32) were re-estimated using the change in wool prices and then re-estimated again using both current and lagged wool prices. There was no evidence of any speculation in any of these equations, and the equations were generally less satisfactory than (5.31) and (5.32). As speculation on year-to-year price changes appears to be relatively unimportant for the United States and the United Kingdom, equations (5.31) and (5.32) again were re-estimated without a price variable, the results being equations (5.34) and (5.35) below. Since the coefficient of lagged stocks for the United States is essentially zero in (5.34), equation (5.36) was estimated with this variable also omitted. Since the coefficient of mill consumption is so small and insignificant in (5.33), the Japanese equation was re-estimated without this variable, the result being equation (5.37).

(5.34) $$SCus_t = \underset{(.191)}{.064}\, SCus_{t-1} + \underset{(.069)}{.311}\, MCus_t - \underset{(.083)}{.132}\Delta MCus_t$$

$R^2 = .64$, $F = 11.545$, $D.W. = 1.87$, $\delta = .936$, $\beta = .101$, $\alpha_1 = .332$

(5.35) $$SCuk_t = \underset{(.171)}{.186}\, SCuk_{t-1} + \underset{(.065)}{.300}\, MCuk_t + \underset{(.119)}{.074}\Delta MCuk_t$$

$R^2 = .59$, $F = 9.426$, $D.W. = 1.93$, $\delta = .815$, $\beta = .057$, $\alpha_1 = .368$

(5.36) $$SCus_t = \underset{(.010)}{.334}\, MCus_t - \underset{(.053)}{.162}\Delta MCus_t$$

$R^2 = .63$, $F = 24.073$, $D.W. = 1.76$, $\delta \equiv 1.000$, $\beta = .121$, $\alpha_1 = .334$

(5.37) $$SCj_t = \underset{(.096)}{.812}\, SCj_{t-1} + \underset{(.090)}{.176}\Delta MCj_t + \underset{(.031)}{.034}\, Pw_t$$

$R^2 = .73$, $F = 17.470$, $D.W. = 1.93$, $\delta = .188$, $\alpha_1 = .936$

Equation (5.34) indicates that the flexible form of the accelerator is not necessary for the United States when applied to annual data because the adjustment process apparently takes less than a year. Equation (5.36), a simple accelerator model with buffer stocks, gives an estimate of .334 for the accelerator and an estimate of .121 for the accuracy of expectations coefficient, both estimates being similar to those already obtained. The results for the United Kingdom are almost identical to those obtained in (5.32). The Japanese equation can be interpreted best by assuming that equilibrium stocks are linearly related to the change in mill consumption and to prices, that is, ΔMCj_t is substituted for $MCj_t{}^*$ in (5.27), and assuming planned stocks equal actual stocks. The resulting model is

$$(5.38) \quad SCj_t = (1-\delta)SCj_{t-1} + \delta\alpha_1 \Delta MCj_t + \delta\alpha_2 Pw_t .$$

Using this model, equation (5.37) yields an estimate of .936 for the change-in-mill-consumption accelerator. Equations (5.36), (5.35) and (5.37) are the commercial raw wool stocks equations for the United States, the United Kingdom and Japan that are used in the final world wool market model.

Lovell indicates that it may be more accurate to replace specification (5.24) with (5.39) below,

$$(5.39) \quad SC_t = SC_t^p + \sigma(MC_t^* - MC_t),$$

where σ is an inventory adaptation coefficient which indicates the degree to which the original inventory plan can be modified when the level of mill consumption is incorrectly estimated.[27]

[27]Michael Lovell, "Manufacturers' Inventories, Sales Expectations, and the Acceleration Principle," op. cit., pp. 306-307.

Specification (5.24) is for the special case $\sigma = 1$, that is, the case of complete inflexibility. Another important reason to prefer specification (5.39) over (5.24) for our study is that stocks are measured within the period covered by the mill consumption variable, not at the end of the period. Therefore, even if inventory plans were completely inflexible, the identity (5.24) would not hold; for only a fraction of the error in estimating annual mill consumption has been observed at the time stocks are measured. Thus the term σ in (5.39) is really a combination of both of these factors in our case.

If specification (5.39) is used, the equation estimated becomes

$$(5.40)\quad SC_t = \delta\alpha_0 + (1-\delta)SC_{t-1} + \delta\alpha_1 MC_t - (\delta\alpha_1 + \sigma)\beta\Delta MC_t + \delta\alpha_2 Pw_t,$$

which is linear in the same variables as (5.30). Hence our estimated equations (5.36), (5.35) and (5.33) can be considered to be estimates of (5.40). Unfortunately, it is impossible to unscramble the estimates of β, the coefficient of accuracy of expectations, and σ, the inventory adaptation coefficient. It is clear that, by assuming $\sigma = 1$, the unbiasedness of expectations may have been overstated.

It is interesting to see how the estimates of β vary when a smaller value of σ is assumed. If $\sigma = .5$, then the corresponding estimates of β for the United States, the United Kingdom and Japan are .194, -.092 and -.293, respectively, which still indicate quite accurate expectations for the United States and the United Kingdom. The expectations of Japanese producers appear to be more strongly biased towards overestimating changes, but this result may be due to a poor estimate of $\delta\alpha_1$, the coefficient of MC_t. If $\sigma = 0$, the respective estimates of β become .488, -.246 and -20.873. The value for Japan is implausibly large and indicates that setting $\sigma = 0$ is probably not justified in Japanese case. The net effect of these experiments is that we have not isolated a unique measure of the accuracy of expectations. But it does appear that σ would have to be quite small to indicate significant bias in expectations. With a long observation period such as that used in this study, a smaller value of σ is more appropriate than when monthly or quarterly data are used. Also a value of σ less than one is indicated in our case because stocks are measured during the consumption period. However, the seasonality and inelasticity of supply of raw wool suggests a higher value of σ for a given time period relative to that used for other industries. Thus it is difficult to determine what a "reasonable" value for σ is for these equations.

The estimates obtained for the equilibrium accelerators, the adjustment coefficients and the coefficients of the wool price variable are not affected by the assumption of a value of σ less than one. Annual levels of commercial raw wool stocks appear to be determined mainly by an accelerator relationship between stocks in mill consumption and stocks in the United States and the United Kingdom, while wool prices are a much more important determinant of stocks in Japan. The short-run (one year) and long-run or equilibrium elasticities estimated from (5.37) (equal to $1/\delta$ times the short-run elasticity) of Japanese commercial stocks with respect to price are 1.139 and 6.052, respectively.[28] These estimates are considerably greater than those for the United States, .070 and .080, as estimated from (5.31), and those for the United Kingdom, .035 and .045, as estimated from (5.32). An adequate study of speculation in all three countries would require monthly or at least quarterly stock data, preferably disaggregated into wool stocks of different qualities and also into stocks held by dealers and stocks held by manufacturers of wool products. These

[28] These elasticities are measured at the mean levels of the variables for the time period studied.

relationships should be estimated simultaneously with equations explaining production, stocks and sales of semifinished and finished wool products and should be related to activities in the futures markets for raw wool and semifinished wool products. Unfortunately, data limitations did not permit such an analysis to be included in this study. The equations given here do appear to give a good measure of the relative importance of the long-run accelerator and long-run price speculation in determining wool stocks in the three countries considered.

5. World Wool Prices

There are two ways in which the formation of wool prices could be included in the model. First, we could specify an equation which explicitly states the way in which changes in supply, demand and stocks interact to generate world wool prices. Second, we could normalize one of the equations for consumption or stocks on the wool price variable and then find the equation for wool prices by solving the reduced form of the model. The former approach was tried first.

It has been demonstrated thus far in our study that both the production of wool and the holding of commercial wool stocks are quite inelastic to the price of wool. In another part of this study we show that consumption of raw wool also is quite inelastic to wool prices. Producers' carry-over stocks of raw wool are somewhat more affected by wool prices. The unresponsiveness of final demand and supply to price implies that small imbalances between these two factors would lead to large variations in the wool price. These results suggest that, in part, changes in wool prices can be thought to be determined simultaneously by changes in a residual variable which we call "implied residual stocks," ΔSR_t. This variable is defined to clear the market; that is, this variable is defined as equal to world wool supply minus the sum of world wool consumption and changes in commercial stocks of wool stocks in the United States, the United Kingdom and Japan.

World wool supply is defined as world wool production minus the change in end-of-the-season producer stocks and non-commercial stocks.

Earlier studies have attempted to explain wool prices by similar measures of the divergence between supply and demand.[29] However, all of these studies ignored the simultaneous aspect of the determination of these "residual stocks" and wool prices. Hermie relates annual wool prices to annual wool production, a "demand shifter," which is an index of income for the six major consuming countries, (United States, United Kingdom, France, Germany, Japan and Italy) and a time trend variable. He finds wool prices negatively related to wool production and positively related to the demand-shifter variable and an insignificant time trend over the period 1921-37.[30] Philpott carries out a similar analysis for 1920-1964 using five year moving averages of the variables and including the price of cotton.[31] He gets similar results, with the price of cotton being positively related to the wool price. Phipott also estimates an annual equation without taking five year moving averages.[32] In this "short-run" equation he adds beginning-of-the-season commercial wool stocks in the United States and the United Kingdom to the wool production variable, drops the cotton price variable and adds an index of annual

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[29]Albert M. Hermie, Prices of Apparel Wool, Technical Bulletin No. 1041, U.S. Department of Agriculture (Washington, D.C.: U.S. Government Printing Office, 1951); and B. P. Philpott, Fluctuations in Wool Prices, 1870-1963, Publication No. 13, Agricultural Economics Research Unit, Lincoln College, University of Canterbury (New Zealand, 1965).

[30]B. P. Philpott, ibid., pp. 28-32.

[31]Ibid., p. 44.

[32]Ibid., p. 45.

raw material prices. Instead of an income index, he uses an index of wool textile activity. He gets a positive coefficient for wool textile activity and the index of general raw material prices and a negative coefficient for "wool supply" (which he defines as production plus beginning of the season commercial stocks in the United States and the United Kingdom). These studies are perhaps useful for purposes of prediction but do not get at the real simultaneous structure of the market.

In our study, changes in commercial stocks are considered to be a dynamic factor on the demand side of the model. Also, for the form of the model which includes equation (5.42) below, the change in the "residual stocks" variable is specified to be a dependent variable in the simultaneous equation model of the market. The equation estimated for this relationship was

$$(5.41)\quad Pw_t = \alpha_0 + \alpha_1 Pw_{t-1} + \alpha_2 \Delta SR_t + \alpha_3 KWD_t \quad ,$$

where KWD_t is a dummy variable equaling one for the season 1951-52, during which the market appear to have been distorted by an extreme speculative boom caused, in part, by the Korean War, and equal to zero for the other years. Estimating (5.41), with price measured in United States dollars per pound (clean basis) and ΔSR_t measured in millions of pounds (clean basis), by two-stage least squares with principal components yielded

$$(5.42)\quad Pw_t = \underset{(13.516)}{82.776} + \underset{(.130)}{.170}\, Pw_{t-1} + \underset{(.095)}{.139}\, \Delta SR_t + \underset{(15.499)}{81.459}\, KWD_t$$

$$R^2 = .82,\ F = 18.385,\ D.W. = 1.61 \quad .$$

Equation (5.42) seems to do reasonably well in explaining seasonal wool prices <u>within the sample studied</u>. The positive sign of the change in residual stocks is interesting, for it indicates that increased residual stocks are associated with increased wool prices. These stocks consist chiefly of manufacturer and dealer stocks in countries other than the three major consuming countries. The estimated positive coefficient may be an indication that many of these stocks are held for speculative purposes. This result coincides with the analysis of commodity price fluctuations by Rowe, who states that commodity stocks held by merchants on both the supply and demand sides of the market will move in the same direction as the price of the commodity when these merchants expect that prices will continue to move in the same direction.[33] Because of this behavior, fluctuations of price arising from variations in supply or final demand are likely to be accentuated.

The choice of an adequate wool price equation is very important for the estimates of the reduced form of the final model because the inclusion of current wool prices as an explanatory variable in demand and stock equations is the main simultaneous link in the model. When equation (5.42) was included in the final model and the reduced form was estimated, the deficiencies of this equation became evident; for the reduced-form equations for all variables for which current price is an explanatory variable were adversely affected. (For example, the resulting reduced-form equation for United States wool consumption predicted a consumption of -334.1 million pounds for 1965). The statistical error component of the ΔSR_t variable is probably much too great. Moreover, the estimated coefficient of this variable has a t-test value of 1.46, which makes this coefficient surely a weak peg on which to hang the simultaneity of the model.

Because of these bad results obtained from the explicit price equation approach, the second approach suggested at the beginning of this section, that of normalizing one of the other equations in the model on the wool price variable, was attempted. The New

[33] J. W. Rowe, Primary Commodities in International Trade (London: The Cambridge University Press, 1965), pp. 66-76.

Zealand carry-over stocks equation (5.6) was chosen and was re-estimated with current prices as the dependent variable yielding equation (5.43) below.[34]

$$(5.43)\quad Pw_t = \underset{(15.899)}{33.676} + \underset{(\ .165)}{1.333}\ Snz_t - \underset{(.308)}{.976}\ Snz_{t-1} + \underset{(.195)}{.605}\ Pw_{t-1}$$

$$R^2 = .88,\ F = 29.689,\ D.W. = 1.82.$$

When this equation is included in the world model along with an identity defining New Zealand wool stocks, the resulting reduced form and the reduced-form forecasts, which are reported in Chapter 7, are much more reasonable. By solving for the reduced form, we get an equation explaining wool prices which includes the effects all of the simultaneous relationships build into the model.

[34] Re-estimation was necessary because, unfortunately, two-stage least square estimates are not invarient to the choice of the variable on which the equation is normalized.

Two-State Least Squares with Principal Components of all Predetermined Variables.

Consider the general linear structural equation

$$(1) \quad y_1 = Y_2 \beta_1 + X_1 \delta_1 + u_1 ,$$

where y_1 is a T x 1 vector of T observation on the endogenous variable to be explained, Y_2 is a T x m matrix of T observations on m explanatory endogenous variables, X_1 is a T x L matrix of T observations on L explanatory predetermined variables, u_1 is a T x 1 vector of disturbances and β_1 and δ_1 are the m x 1 and L x 1 vectors of coefficients to be estimated. Equation (1) is one equation of a system of n simultaneous equations in n currently endogenous variables and m predetermined variables. Letting the T x K matrix of all predetermined variables in the system be X, the two-stage least squares estimates of β_1 and δ_1, $\hat{\beta}_1$ and $\hat{\delta}_1$, are given by

$$(2) \quad \begin{bmatrix} \hat{\beta}_1 \\ \hat{\delta}_1 \end{bmatrix} = \begin{bmatrix} Y_2' Y_2 - V'V & Y_2' X_1 \\ X_1' Y_2 & X_1' X_1 \end{bmatrix} \begin{bmatrix} Y_2' - V' \\ X_1' \end{bmatrix} y_1$$

where

$$(3) \quad V = Y_2 - X(X'X)^{-1} X' Y_2 \quad ;$$

that is, V is the estimated T x m matrix of reduced-form residuals for the m endogenous variables, Y_2.[35]

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[35]J. Johnston, Econometric Methods (New York: McGraw-Hill Book Company, Inc., 1960), pp. 258-260.

However, if the total number of predetermined variables in the model, K, is greater than the number of observations, T, the matrix (X'X) is singular; and V cannot be estimated by the method given by (3). Even if K is less than T but is relatively quite large, the estimate of the reduced form may be of a bad quality due to there being a small number of degrees of freedom, T-K, available for this estimation. It was for such cases that Kloek and Mennes developed the methods of two-stage least squares based on principal components of predetermined variables.[36] The method used in this study is described below.

The object of the principal components method of two-stage least squares is to replace the T x K matrix of observations on the predetermined variables, X, in (3) by a T x R matrix of R instrumental variables, Z, where R is some number small enough to leave sufficient degrees of freedom for the estimation of the reduced form equations. In this study, principal components of all predetermined variables are used to estimate the system.[37] First a decision has to be made as to how many principal components are to be used, that is, the value of R, or alternatively, what percentage of the total variance of the predetermined variables are to be explained by the principal-component variables that are used. While this choice is fairly arbitrary, R should not be less than m, the number of included endogenous variables and must not be so great as to cause unreliable estimates of the reduced form. Kloek and Mennes show that, for the model they consider, a limited number of principal components appear to be sufficient.[38] The

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[36] T. Kloek and L. B. Mennes, op. cit.

[37] This is "method 4" of Kloek and Mennes, ibid., pp. 53-55.

[38] Ibid., pp. 60-61.

problem is to construct R new variables, Z_{1t}, which are linear functions of the predetermined variables x_j, that is

$$Z_{1t} = \sum_{j=1}^{k} \alpha_{1j} x_{jt}$$
$$\vdots$$
$$Z_{Rt} = \sum_{j=1}^{k} \alpha_{Rj} x_{jt} \qquad t = 1,\ldots,T$$

such that the constructed variables are mutually orthogonal over the sample, that is, for the sample covariances,

$\sum_{t=1}^{T} Z_{it} Z_{jt} = 0$, for all i and j such that $i \neq j$, holds, and

such that the following normalization holds:

$$\alpha_i' \alpha_i = 1 \quad \text{for all } i.$$

Given these constraints, the variables are constructed to be those linear functions of the predetermined variables with maximum variance.

The solution of this maximization problem is the extraction of the roots, λ_i, of the following characteristic equation:

$$|X'X - \lambda| = 0.$$

The characteristic vector, α_1, associated with the largest root, λ_1, will be the first principal component, that is, will be the weights used to form the first variable Z_1, and so on. Since it is easily shown that λ_1 is the variance of the first principal component and the trace of X'X divided by T is the variance of the predetermined variables,

$$\frac{\lambda_1}{\frac{TrX'X}{T}}$$

is the variance of the X variables accounted for by the first principal component. Since the components are orthogonal,

$$\frac{\lambda_1 + \lambda_2}{\frac{TrX'X}{T}}$$

is the variance of the X variables accounted for by the first and second principal components. For the final model of this study, the first nine principal components were constructed; and together these variables explained 97.6 percent of the variance of the predetermined variables.

Once the matrix Z is computed, the rest of the estimation procedure is straightforward. First Z is substituted for X in (3); that is, we compute

$$V = Y - Z(Z'Z)^{-1} Z'Y.$$

This value of V is substituted into (2), yielding the estimates β_1 and δ_1.

Since the use of principal components in two-stage least squares is a fairly new method of estimation, there are few published results of applying this method to small samples such as the sample considered in this study. In the cases considered by Kloek and Mennes, the method of principal components appears to give good results.[39] Amemiya has shown that principal components estimation may lead to a smaller mean square forecast error and a reduction of bias.[40] Clearly, one of the most important attributes of this method for time series analysis is that it eliminates the problem of multicollinearity in the first stage of estimation.

[39] Ibid., pp. 55-61.

[40] Takeshi Amemiya, "On the Use of Principal Components of Independent Variables in Two-Stage Least-Squares Estimation," International Economic Review, Vol. VII (September, 1966), pp. 291-299.

CHAPTER 6

THE WORLD DEMAND FOR WOOL

1. Introduction

Wool products are produced in most developed and developing countries of the world and are consumed in just about all of them. The concentration found on the supply side is not found on the demand side. Yet in this study we will have to restrict the analysis to the following eight principal consuming countries: the United States, the United Kingdom, Japan, France, Italy, West Germany, Belgium and the Netherlands and a "Rest-of-the-World" sector. In 1963, the eight principal consuming countries listed above accounted for about 50 percent of the world's consumption of wool.[1]

The objective of this part of the study is to identify the determinants of the net consumption of wool in each of these eight countries and the "Rest-of-the-World" sector, this variable being measured as the mill consumption of raw wool in the country plus the net imports of semifinished and finished wool products in terms of wool fiber content. This variable measures the country's demand for consumption of finished wool products and also for additions to stocks of semifinished and finished wool products. Unfortunately, there exist no data that would permit the separation of these two aspects of demand. Since annual data are considered, the importance of movements in stocks of semifinished and finished wool products held in the different levels of the wool textile industry and by final consumers is less than would be the case if monthly or even quarterly data were considered; but

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[1]The lack of adequate data prohibited the analysis of wool consumption in the Union of Soviet Socialist Republics and the other Communist countries in which the consumption of wool in 1963 was 24 percent of the total world consumption.

the omission of these factors will still affect the estimated demand equations to some degree. Another simplification dictated by data limitations is that there is no breakdown of wool demand into demands for different types or grades of wool. In particular, wools used for apparel, wools used for carpets and wools used for industrial products are aggregated together, although these different components of the total demand probably are determined by somewhat different processes. When better data become available, the study of a more disaggregated model should be undertaken. One step in this direction is a study by Donald, Lowenstein and Simon in which they disaggregated United States net consumption of wool into the consumption of apparel wool and the consumption of carpet wool, using ordinary least squares and neglecting the simultaneous relationship of these equations with each other and the rest-of-the-world wool market.[2] They found carpet wool consumption has been steadier than apparel wool consumption and more elastic with respect to income and wool prices. Even this simple disaggregation is not feasible for our world model.

2. Specification of the Net Consumption Demand Equations

As was the case for the supply equations, the distinction between "short-run" and "long-run" or "equilibrium" relationships is important in studying the demand for a product. This distinction has been made by many economists in the past [3] but really had not been successfully applied to the estimation of demand

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[2] J. Donald, F. Lowenstein, M. Simon, The Demand for Textile Fibers in the United States, Technical Bulletin No. 1301, U.S. Department of Agriculture (Washington, D.C.: U.S. Government Printing Office, 1963), pp. 69-82.

[3] See, for example, Alfred Marshall, Principles of Economics (8th ed.; London: MacMillan and Company Limited, 1938), pp. 378-379; and Elmer Working, Demand for Meat (Chicago: Institute for Meat Packing, 1954).

equations until the work of Nerlove on the demand for agricultural products in the United States and the United Kingdom.[4] The models considered here are of the same type as those estimated by Nerlove and are similar to the lagged adjustment production equations considered in Chapter 4.

The necessity of distinguishing between demand equations that involve different adjustment periods is caused by the fact that the effect of a change in an explanatory variable, say price, on demand is not felt just during the time period it is observed but is distributed over a number of the future time periods. Nerlove notes that in most demand relationships there are a number of institutional and technological rigidities which prevent the immediate adjustment of actual consumption to desired or equilibrium consumption. The longer the adjustment period considered, the less important these constraints become. Thus the country demand curves can be considered to be the results of aggregations of the solutions of individual consumer utility maximization problems subject to constraints, these constraints becoming less restrictive and fewer in number for the cases of longer adjustment periods. An example of the effect of such rigidities is the impact of lower priced synthetics on wool consumption in the last twenty years. This impact was not felt all at once but cumulatively over most of the time period studied. It takes time to adjust to new methods of production, to encourage acceptance of new products and to adjust to new levels of income. The existence of contractual agreements at many levels of the textile

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[4]Marc Nerlove, Distributed Lags and Demand Analysis for Agricultural and Other Commodities, Agricultural Handbook No. 141, U.S. Department of Agriculture (Washington, D.C.: U.S. Government Printing Office, 1958); and Marc Nerlove and William Addison, "Statistical Estimation of Long-Run Elasticities of Supply and Demand," Journal of Farm Economics, Vol. XL (November, 1958), pp. 861-880.

market is another source of such rigidities. A related cause of lagged response to changing explanatory variables is the existence of uncertainty. Consumers are thought not to react immediately to a change in income or price but instead are assumed to distribute their response over the following periods as, and to the degree that, the observed income or price proves to be "permanent" instead of "transitory". Such rigidities caused by uncertainty are included <u>implicitly</u> in the model given below and, at the expense of great computational difficulty, could be included explicitly.

The distinction between short-run and long-run or equilibrium demand curves is built into the specification of demand equations by first noting the existence of a long-run or equilibrium net consumption of wool for country j in year t, Cj_t^e, which is the amount that would be consumed if there were no rigidities constraining demand response or is the equilibrium amount that would be consumed at some future date if the present values of the explanatory variables continued indefinitely into the future. However, the quantity, Cj_t^e, in fact, never actually is observed because the values of the explanatory variables do change and adjustment rigidities do exist. In the short run, say one observation period, consumers adjust actual consumption Cj_t, a fraction, δ, of the distance towards equilibrium consumption; that is,

$$(6.1) \quad Cj_t - Cj_{t-1} = \delta \, (Cj_t^e - Cj_{t-1}) \quad ,$$

and this fraction will be larger, the longer the time period considered. Note that (6.1) implies that actual consumption in period t is a distributed-lag function of past desired or equilibrium consumptions; that is, solving (6.1) for C_{jt} yields

$$(6.2) \quad Cj_t = \sum_{i=0}^{t} \delta (1-\delta)^i \, Cj^e_{t-1} \quad .$$

Thus there is no unique short-run demand curve and correspondingly no unique short-run price or income elasticity of demand. These elasticities vary with the position from which we start and the length of time allowed for adjustment. However, by specifying an equation for equilibrium or long-run consumption demand and combining this equation with specification (6.1), we can obtain estimates of the particular short-run elasticities that correspond to the adjustment period assumed in (6.1) and can derive from these estimates estimates of the long-run equilibrium elasticities.

The equilibrium net annual consumption demand for wool by country j in year t, Cj^e_t, is specified to be a linear function of the price of wool, Pw_t, disposable income, Yj_t, the change in disposable income over what it was in the previous year, ΔYj_t, a variable indicating the competitive effect of synthetic fibers, NSj_t, and, for some cases, the dummy variables, KWP_t and Df_t, which take account of some of the special effects of the Korean and Algerian wars; that is

$$(6.3) \quad Cj^e_t = \alpha_0 + \alpha_1 Pw_t + \alpha_2 Yj_t + \alpha_3 \Delta Yj_t + \alpha_4 NSj_t \quad .$$

All price and income variables are deflated to get the equation in "real" terms. The ΔYj_t variable is included to test the relationship of deviations of income from recent levels to consumption; for wool textile goods are semi-durable goods, the purchase of which can be postponed if "transitory" income deviates downward from "permanent" income or can be increased if the deviation is upward.

The choice of a variable indicating the competitive effect of synthetics is very difficult because many of the more important synthetic fibers were introduced in the middle of the observation period covered by this study and also because there are few reliable data on synthetic fiber prices. Moreover, Polasek and Powell have found that, for the wool market, technological factors rather than economic factors dominated the process of the wool market's adjustment to synthetic fibers.[5] Shortages of supply of synthetics have been a major constraint on this adjustment process with supplies of polyester fibers being rationed in Continental Europe as late as 1961.[6] The technological aspects of this process have been accompanied by vigorous promotional activity by the synthetic fiber producers. The above mentioned study found that "relative wool-synthetic prices have played virtually no role in the technological adjustment to synthetic fibers in the United States."[7] They found a similar absence of relative price effects for all countries except Italy for which such an effect may be important.[8] The Italian case is difficult to analyze, however, because of the relatively greater importance of reprocessed wools and of fashion changes in that country. The final choice of a variable, NSj_t, was the net consumption of non-cellulosic fibers (staple and yarn) in country j in year t. These synthetic fibers compete most strongly with wool because of their physical characteristics and adaptability to the requirements of the wool textile industry; and they include fibers marketed under the trade

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[5]Metodery 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; and Metodery Polasek, "Synthetic Fibres and Australia's Economic Future," Economic Record, Vol. XLI (March, 1965), pp. 23-37.

[6]Metodery Polasek and Alan Powell, ibid., p. 59.

[7]Metodery Polasek, op. cit., p. 35.

[8]Certainly, however, the synthetic fiber prices had to be favorable enough to permit the absorption of the new technology.

marks of Nylon (polyamide), Dacron and Terylene (polyesters) and Orlon, Acrilan and Courtell (acrylics). This variable should pick up the market penetration of synthetics into the wool market. Unfortunately, since the causes of this penetration are chiefly technological and promotional, it has not proved possible to make this variable endogenous to the model.

Polasek and Powell studied the adoption of synthetics in the fiber markets of the United States, the United Kingdom, France, West Germany, Italy and Japan by fitting logistic curves to the ratio of consumption of non-cellulosic staples to consumption of virgin wool plus non-cellulosic stables, calling this ratio the "synthetics' share of the market."[9] Their results were quite good, statistically, for all countries except Italy and indicated ceilings on the market share of between 21 and 33 percent for France, West Germany, Italy and the United Kingdom, of 45 percent for the United States (when carpet wool was excluded from wool consumption) and a high of 58 percent for Japan. The estimated rates of adoption are highest for West Germany and the United States; and for these countries, the computed market shares in 1963 were not much below their estimated ceilings. The adjustment process in the other countries was estimated to be far from completed. These results are quite interesting but are limited for purposes of prediction because of the abstraction of their study from future changes in technology. One implication of their study is that in countries where the technological aspects of product adaptation have just about worked themselves out, relative price effects will begin to have more significance.

Since fibers other than synthetics compete with wool, it would be preferable to analyze the demand for wool in the context of the whole industrial fibers market. However, it is the

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[9] Metodery Polasek and Alan Powell, op. cit., p. 52.

synthetic fibers which are the primary substitutes for wool.[10] Moreover, since the other substitutes for wool have existed for a long time, "...it is likely that the relative market shares of these traditional fibers are in long-term equilibrium, and hence that wool's share of this sector of the market is essentially stationary."[11] Variations in relative fiber prices do affect wool consumption but are relatively less important than the factors included in (6.3). Thus, in order to avoid an unmanageably large model, synthetic fibers are the only competative fibers considered.

A variable significantly affecting wool consumption that is omitted from (6.3) is population. The principal reason for excluding this variable is the extremely high multicollinearity of population with income for the countries considered here. The first-order correlation of population with income is above .85 for all countries and is above .97 for most. One possible way of avoiding this problem was thought to be using per capita income and population, but the correlation between these two variables is still very high. Thus it was decided to omit the population variable in order to avoid the problem of multicollinearity, and the resulting estimates for the effects of income probably pick up some of the effects of population changes. In order to separate the effects of income and population on wool demand, a study would have to be made for an observation period or for countries for which population and income had some significant independent variation.

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[10] J. Donald, F. Lowenstein, and M. Simon, op. cit., p. 72. See also: G. O. Gutman, "Competition Between Fibres: Economic," in The Simple Fleece, ed. Alan Barnard (Parkville, Victoria, Australia: Melbourne University Press, 1962), pp. 550-573.

[11] Metodery Polasek and Alan Powell, loc. cit.

If equation (6.3) is substituted into (6.1) and the result is solved for Cj_t, the following equation results which is suitable for estimation:

$$(6.4) \quad Cj_t = \delta\,\alpha_0 + (1-\delta)Cj_{t-1} + \delta\,\alpha_1\,Pw_t + \delta\,\alpha_2\,Yj_t + \delta\,\alpha_3\,\Delta Yj_t + \delta\,\alpha_4\,NSj_t$$

From (6.4) we can obtain estimates of the "short-run" (equal to one year) elasticity of demand with respect to price at the mean values of these variables in the observation period by multiplying the estimated coefficient of Pw_t, $\widehat{\delta\alpha_1}$, by the ratio of the mean values of price and consumption. An estimate of the long-run or equilibrium price elasticity, that is, the elasticity corresponding to equation (6.1), can be derived from the estimated short-run elasticity by dividing this estimate by the estimated value of δ. Similarly, short-run and long-run income elasticities of demand can be obtained from estimates of (6.4). Brandow notes that specification error may bias the estimates of δ and hence may affect estimate of the long-run elasticities.[12] The estimates of long-run elasticities obtained in this study should be considered with this reservation in mind.

3. Data: Sources and Limitations

The net domestic consumption figures used in this study are, for the years 1948 to 1963, the series constructed by the Food and Agriculture Organization entitled "available for home

[12] G. E. Brandow, "A Note on the Nerlove Estimate of Supply Elasticity," Journal of Farm Economics, Vol. XL (August, 1958), pp. 719-722. However, Marc Nerlove in "On the Nerlove Estimate of Supply Elasticity: A Reply," Journal of Farm Economics, Vol. XL (August, 1958), pp. 723-728, notes that bias in the estimate of δ need not imply bias in the estimates of the long-run elasticities.

consumption".[13] There are two sources of error in these figures for wool consumption besides that of data sources: a) the foreign trade adjustment figure is based on the total weight of "predominantly wool" manufacturers, no attempt being made to estimate the actual wool fiber content, and b) the foreign trade adjustment figure includes net trade in wool waste, which is not included in the mill consumption figure. However, these figures are the only figures available for net consumption over the observation period considered and are believed to be better, for the purpose of estimation of demand relationships, than mill consumption figures for which no trade adjustment has been made. Since when the equations were estimated only mill consumption figures had been published for 1964, net domestic consumption figures for wool were estimated for that year by assuming that the same percentage relationships between net domestic consumption and mill consumption would hold in the countries studied in 1964 that was measured in 1963. Net domestic consumption of non-cellulosic fibers figures for 1964 were taken from series published in the Textile Organon.[14] All net consumption figures are in millions of pounds (clean basis in the case of wool).

The wool price variable used in the demand equations, Pw_t, is the "world" wool price variable described in Chapter 3 for the wool season t, which spans calendar years t and t-1 and thus is lagged about six months from the annual consumption data. This price is

[13]United Nations, Food and Agriculture Organization, Per Caput Fiber Consumption Levels, 1948-1958, Commodity Bulletin No. 31 (Rome, 1960); "Per Caput Fiber Consumption Levels, 1958-1960," Monthly Bulletin of Agricultural Economics and Statistics, Vol. XI (Rome, January, 1962); and Fiber Consumption, 1961 to 1963 (Rome, 1965).

[14]Textile Economics Bureau, Inc., Textile Organon (New York, Monthly), various issues.

deflated by the Sauerbeck commodity price index converted to a seasonal basis and is expressed in United States dollars per pound (clean basis).

The net disposable income variables for the United States and the United Kingdom are published by the respective Governments.[15] For the other six major consuming countries, substitute series had to be used, the national income figures as reported by the International Monetary Fund.[16] All income figures were converted to billions of United States dollars at the annual average exchange rates for each year.[17] Then each series was deflated by the best available price index for each country, each index having the base year 1958 = 100. The United States disposable personal income series was already in terms of 1958 prices so no further adjustment was needed. The prices indices used for the other countries are the wholesale price indices for Japan, West Germany, Italy, France, Belgium and the Netherlands and the cost-of-living index for the United Kingdom.[18]

Since no income variable exists for the "Rest-of-the-World" sector, a "world income" index was constructed by adding together the deflated or "real" incomes of the eight countries listed above, dividing these values by the sum for the base year, 1958,

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[15]United States, Council of Economic Advisers, The Annual Report of the Council of Economic Advisers (Washington, D.C.: U.S. Government Printing Office, 1966); and Great Britain, Central Statistics Office, Monthly Digest of Statistics (London: Her Majesty's Stationary Office, Monthly).

[16]International Monetary Fund, International Financial Statistics (Washington, D.C., Annual).

[17]Ibid.

[18]These indices are published in the International Monetary Fund, ibid.

and multiplying all values by 100. This index, being constructed from the incomes of the most developed countries, probably overstates world income growth but does correspond fairly closely to the United Nations index of incomes of all countries.[19] Unfortunately, the latter index begins in 1950 and hence was not usable. Actually, the major amount of the wool consumption by the countries in the "Rest-of-the-World" sector is by fairly developed countries, so the index constructed here is probably adequate for the purposes of this study.

The outbreak of the Korean War caused a speculative boom in the wool market in the 1950-51 season. This event resulted in the accumulation of stocks by private dealers who anticipated increased government purchases. Because this accumulation of stocks happened at a time when consumption was exceeding production, prices soared upward. Since this speculation produced an abnormal situation in the wool markets of many countries, particularly the United States, a dummy variable, KWD_t, is included in the equations for these countries, this variable having the value 1.000 for 1951 and 0.000 for the other years. This Korean War dummy variable was included in the equations for the United States, the United Kingdom, France and the Netherlands. For the other countries and the "Rest-of-the-World" sector, this variable proved to have little explanatory power.

In France in 1956 and 1957, government purchases of apparel wool products almost doubled over that of 1955 and accounted for about half of the increased consumption of wool in this category. These increased purchases were due to increased French military action in North Africa. Since these government purchases distorted the French wool market in those years, a dummy variable,

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[19]This index is given in the United Nations, Department of Economic and Social Affairs, Statistical Office of the United Nations, Statistical Yearbook (New York, Annual).

Df_t, was included in the French equation, this variable having the value 1.000 for 1956 and 1957 and the value 0.000 for all other years.

4. The Estimated Net Consumption Equations

Specification (6.4) was applied to data for the eight major wool consuming countries and for the "Rest-of-the-World" sector; and estimates of the net consumption equations were obtained by two-stage least squares with principal components, these equations being estimated simultaneously with the stock equations and the price equation described in Chapter 5. The resulting equations are the following:[20]

$$(6.5)\quad Cus_t = \underset{(388.944)}{419.931} + \underset{(.228)}{.897}\, Cus_{t-1} - \underset{(1.176)}{4.250}\, Pw_t + \underset{(1.105)}{.167}\, Yus_t + \underset{(1.716)}{9.298}\, \Delta Yus_t - \underset{(.150)}{.210}\, NSus_t + \underset{(94.401)}{266.329}\, KWD_t$$

$$R^2 = .85,\ D.W. = 2.12,\ F = 8.287,\ \delta = .121$$

$$(6.6)\quad Cuk_t = \underset{(.279)}{.147}\, Cuk_{t-1} + \underset{(.706)}{.029}\, Pw_t + \underset{(1.899)}{6.038}\, Yuk_t - \underset{(1.715)}{1.516}\, \Delta Yuk_t - \underset{(.195)}{.523}\, NSuk_t - \underset{(67.874)}{48.376}\, KWD_t$$

$$R^2 = .49,\ D.W. = 2.66,\ F = 1.895,\ \delta = .853$$

$$(6.7)\quad Cj_t = \underset{(.294)}{.283}\, Cj_{t-1} - \underset{(.271)}{.091}\, Pw_t + \underset{(3.286)}{5.931}\, Yj_t + \underset{(4.587)}{9.109}\, \Delta Yj_t - \underset{(.167)}{.246}\, NSj_t$$

$$R^2 = .92,\ D.W. = 2.34,\ F = 31.831,\ \delta = .717$$

[20] Equations appearing with no constant terms were first estimated with constant terms and were found to have constant terms not significantly different from zero.

$$(6.8)\quad Cf_t = \underset{(.271)}{-.027}\, Cf_{t-1} + \underset{(.381)}{.850}\, Pw_t + \underset{(1.113)}{.055}\, Yf_t - \underset{(2.137)}{1.132}\, \Delta Yf_t + \underset{(.116)}{.028}\, Nsf_t + \underset{(15.852)}{34.010}\, Df_t - \underset{(37.600)}{110.008}\, KWD_t$$

$R^2 = 82$, D.W. $= 2.39$, $F = 5.254$, $\delta = 1.027$

$$(6.9)\quad Ci_t = \underset{(57.057)}{132.546} + \underset{(.215)}{.538}\, Ci_{t-1} - \underset{(.321)}{.378}\, Pw_t - \underset{(3.196)}{5.831}\, Yi_t + \underset{(15.333)}{19.671}\, \Delta Yi_t + \underset{(.538)}{.921}\, NSi_t$$

$R^2 = .60$, D.W. $= 1.79$, $F = 3.008$, $\delta = .462$

$$(6.10)\quad Cg_t = \underset{(61.778)}{108.429} + \underset{(.340)}{.160}\, Cg_{t-1} - \underset{(.300)}{.411}\, Pw_t + \underset{(3.336)}{4.496}\, Yg_t - \underset{(4.568)}{4.565}\, \Delta Yg_t - \underset{(.501)}{.610}\, NSg_t$$

$R^2 = .92$, D.W. $= 2.60$, $F = 24.421$, $\delta = .840$

$$(6.11)\quad Cb_t = \underset{(33.262)}{84.627} + \underset{(.361)}{.210}\, Cb_{t-1} - \underset{(.154)}{.231}\, Pw_t - \underset{(3.631)}{3.324}\, Yb_t - \underset{(6.533)}{4.028}\, \Delta Yb_t - \underset{(.608)}{.450}\, NSb_t$$

$R^2 = .75$, D.W. $= 2.33$, $F = 5.973$, $\delta = .791$

$$(6.12)\quad Cn_t = \underset{(.277)}{.597}\, Cn_{t-1} + \underset{(.128)}{.183}\, Pw_t + \underset{(2.305)}{1.317}\, Yn_t - \underset{(5.655)}{5.846}\, \Delta Yn_Y - \underset{(.429)}{.091}\, NSn_t - \underset{(13.705)}{50.311}\, KWD_t$$

$R^2 = .65$, D.W. $= 2.67$, $F = 3.638$, $\delta = .403$

$$(6.13) \quad Crw_t = \underset{(.200)}{.930} Crw_{t-1} \underset{(.579)}{-.459} Pw_t + \underset{(3.078)}{2.327} Yrw_t \underset{(3.983)}{-2.818} \Delta Yrw_t - \underset{(.219)}{.212} NSrw_t$$

$$R^2 = .95, \text{ D.W.} = 2.03, \text{ F} = 54.204, \delta = .070$$

The equations for each country are discussed separately below; and since most of these equations are unsatisfactory, improved forms of the equations are given. One general observation that can be made is that, for most countries, the hypothesis of incomplete adjustment of actual to desired net consumption in a year, that is, of $\delta < 1$, is not supported by the results for many of the countries considered. However for the United States, Italy, Netherlands and the "Rest-of-the-World" sector, there does seem to be incomplete adjustment.

A. The United States

Specification (6.4) seems to work fairly well for the United States net consumption equation (6.5), with the signs of all coefficients corresponding to our *a priori* expectations. The estimated coefficient of adjustment, .121, is surprisingly low and implies that United States consumers respond to changes in the explanatory variables quite slowly. The statistical insignificance of the income variable, which was not expected, is probably caused by the change-in-income variable picking up most of the income effect. The estimated short-run elasticities of demand to price and income are -.932 and +.117, respectively. It is interesting to compare these estimates with those obtained by Donald, Lowenstein, and Simon, who estimated by ordinary least squares separate equations for United States annual net consumption of apparel and of carpet wool.[21] Their equations do not contain

[21]J. Donald, F. Lowenstein, and M. Simon, *op. cit.*, pp. 69-90.

lagged dependent variables. Using a six month lag for apparel wool prices and a nine month lag for carpet wool prices, they estimated price elasticities of net demand to be -.32 and -.41 for apparel and carpet wool, respectively. Both of these estimates are somewhat lower than ours. They estimated the corresponding income elasticities of demand to be +.34 and +.86, our estimate lying below these two values. Attempting to explain quarterly mill consumption of apparel wool in the United States, Ferguson and Polasek in another study obtained an estimated price elasticity of .5574.[22] Short-run elasticities being smaller in absolute value than long-run elasticities, this estimate does not contradict the one we have obtained.

The estimates of the long-run or equilibrium elasticities of net demand to price and income implied by the short-run elasticity estimates and the estimated adjustment coefficient are -7.700 and +.965, respectively, which are high. Because the adjustment process is slow relative to the rate of change of the explanatory variables, it is the short-run estimates that are most relevant to year-to-year movements in the market. However, it is not correct to reason from estimates of the short-run price inelasticity of demand that a rise in wool prices that continued over a number of years would have little effect on long-run demand for wool, for our results show that the effect would be considerable.

Looking at some other implications of equation (6.5), we see that the net consumption of synthetic fibers has had the expected negative effect on the net consumption of wool, a certeris paribus increase in consumption of one million pounds of synthetic fibers

[22] C. E. Ferguson and Metodey Polasek, "The Elasticity of Import Demand for Raw Materials in the United States," Econometrica, Vol. XXX (October, 1962), p. 677.

implying a decrease in net wool consumption of 210 thousand pounds. The fact that the estimated decrease in wool consumption is less than half the increase in synthetics consumption shows that some of the increase in synthetic consumption has not been at the expense of wool consumption, probably because some of these fibers have been used as inputs that are complements to wool in blends (for example, nylon is used to strengthen wool textiles) and because some of these fibers have displaced fibers other than wool (for example, cotton and rayon). This estimate underestimates the effect of synthetics on wool consumption because more wool fiber is lost in processing, about 5 percent, than is the case for synthetic fibers, about 4 percent; and hence one pound of synthetics can substitute for more than one pound of wool. Further difficulties of interpretation are caused by the incomparability of the net trade factors. The large value of the Korean War dummy variable's coefficient in (6.5) is an indication of the distortion of the United States market caused by the speculative boom of 1951. The positive sign and the statistical significance of the coefficient of the change in disposable income suggests that, in times of rising income, consumers replace wool products faster and increase their stocks of these products. Similarly, in times of falling income, consumers tend to live off their stocks and delay their purchases of new items. This implied significant short-run adjustment of consumer stocks is contrary to the permanent income hypothesis that states the consumption decisions are based on long-run expected normal or permanent income and are not influenced by short-run "transitory" variations in income.[23]

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[23]Milton Friedman, A Theory of the Consumption Function, National Bureau of Economic Research (Princeton, New Jersey: Princeton University Press, 1957).

B. The United Kingdom

Equation (6.6) for the United Kingdom's net consumption of wool is not satisfactory, the wool price variable having the "wrong" sign, most variables having little explanatory power and the Durbin Watson statistic being rather high. The coefficient of adjustment is not statistically different from 1.000 and implies that the adjustment process is just about completed in a year. In an attempt to get a better equation for the United Kingdom, the coefficient of adjustment was constrained to be 1.000 (that is, lagged consumption was dropped from the equation) and wool price lagged one year was substituted for current wool price. The resulting equation is

$$(6.14)\quad Cuk_t = \underset{(.173)}{-.649}\ Pw_{t-1} + \underset{(.560)}{9.109}\ Yuk_t \underset{(.954)}{-1.896}\ \Delta Yuk_t \underset{(.106)}{-.878}\ NSuk_t \underset{(16.935)}{-40.910}\ KWD_t$$

$$R^2 = .77,\ D.W. = 1.87,\ F = 9.009,\ \delta \equiv 1.000 \quad .$$

Equation (6.14) is considerably better than (6.6) in just about all respects. The estimated elasticities of net demand to lagged price and to income are -.250 and +1.515, respectively. The coefficient of the change-in-income variable has a negative sign which is difficult to interpret. Perhaps short-run or transitory changes in income are spent on other products to the detriment of wool products.Clearly there is no active consumer stock adjustment as was implied by the United States equation. The synthetics fiber consumption variable is considerably larger than that for the United States and indicates that most of the increased use of synthetic fibers in the United Kingdom has been at the expense of wool consumption. The Korean War dummy is highly significant.

C. Japan

The Japanese net consumption demand equation, (6.7), is quite good except that the coefficient of adjustment is not statistically different from 1.000. Thus the Japanese equation was re-estimated with the coefficient of adjustment constrained to be equal to 1.000, yielding

$$(6.15)\quad Cj_t = \underset{(.231)}{-.198}\, Pw_t + \underset{(1.807)}{8.374}\, Yj_t + \underset{(4.008)}{11.424}\, \Delta Yj_t \underset{(.130)}{-.335}\, NSj_t$$

$$R^2 = .91,\ D.W. = 2.30,\ F = 41.954,\ \delta \equiv 1.000 \quad .$$

The signs of all coefficients in (6.15) correspond to our <u>a priori</u> expectations, but the wool price variable is not very significant. Substituting lagged wool price for the current price did not yield any better results. The estimated price elasticity of demand obtained from (6.15) is -.126, indicating that wool prices have not been a significant factor in determining net Japanese consumption in the postwar period. It is the growth in Japanese income that has been the major determinant, for the estimated income elasticity of demand is a high +1.296. The positive coefficient of the change-in-income variable suggests short-run consumer stock adjustment behavior similar to that of the United States. The consumption of synthetics has had some significant negative effect on wool consumption, but apparently much of the increased use of synthetics has been either at the expense of other fibers or as a complementary product with wool in products made of blends of the two fibers.

D. France

Equation (6.8) for the French net wool demand is rather unsatisfactory with "wrong" signs for many of the variables. The consumption-of-synthetics variable has little significance, indicating that the introduction of synthetic fibers has not been an important factor in France. This result corresponds with the estimated elasticity of net demand to lagged price derived from (6.16) is -.159, indicating that price changes also have little importance. Actually, except for the years 1951, 1956 and 1957 when the French market was affected by unusual forces, demand has been fairly constant.

E. Italy

The equation explaining net Italian wool consumption, (6.9), is unsatisfactory in that the standard errors of most coefficients are high. Also, we did not expect the coefficient of the income variable to have a negative sign. The insignificance of the synthetic fiber consumption variable is not surprising in light of the results obtained by Polasek and Powell discussed earlier.[26] Equation (6.9) was re-estimated with the change in income-in-income and the net consumption of synthetics variables dropped, but the results were worse than (6.9). Then, in an attempt to get at the more dynamic aspects of the Italian market, the change in the current wool price over that of last year, ΔPw_t, was substituted for Pw_t, and the resulting equation, equation (6.17) below, was the best of the Italian demand equations that were estimated.

$$(6.17) \quad Ci_t = \underset{(.102)}{.793}\, Ci_{t-1} \underset{(.125)}{-.403}\, \Delta Pw_t + \underset{(.399)}{.696}\, Yi_t$$

$$R^2 = .57,\ D.W. = 1.84,\ F = 8.711,\ \delta = .208.$$

Equation (6.17) (and all other Italian equations that were estimated) indicates that the adjustment process in Italy is significantly slower than a year, the estimated coefficient of adjustment being .208. Polasek and Powell indicate that relative fiber prices have been quite an important factor in the Italian fiber market.[27] Unfortunately, there are no available data on

[26] *Ibid.*, pp. 56-57.

[27] *Ibid.*

relative prices over the observation period; but equation (6.16) indicates that year-to-year changes in wool prices have had a significant negative effect on net wool consumption, with the estimated short-run elasticity of demand with respect to changes in wool prices being -.477. Income enters (6.17) with a positive sign, and the estimated short-run and equilibrium income elasticities of demand are +.179 and +.858. The difficulties in estimating a net consumption equation for Italy are probably due to the omission, due to a lack of data, of the effects of relative fiber prices, of the consumption of non-virgin wool and of the changing of apparel fashions. These three factors are apparently more important for Italy than for the other countries studied here.

F. Germany

The German net consumption equation (6.10) is fairly good except for the fact that the estimated value of the coefficient of adjustment is not statistically different from 1.000. This equation was re-estimated with this coefficient constrained to be equal to 1.000, and the resulting equation is

$$(6.18) \quad Cg_t = \underset{(51.313)}{86.400} \; \underset{(.251)}{-.300}\, Pw_t + \underset{(1.070)}{6.067}\, Yg_t \; \underset{(2.744)}{-6.058}\, \Delta Yg_t \; \underset{(.237)}{-.832}\, NSg_t$$

$$R^2 = .92, \; D.W. = 2.48, \; F = 33.093, \; \delta \equiv 1.000.$$

All coefficients in (6.18) have the expected signs except for the coefficient of ΔYg_t, which like that for the United Kingdom, is negative. The estimated price elasticity of net demand is very small, -.136. The income variable is fairly important for Germany, with the estimated income elasticity of net demand being + 1.110. The postwar growth in consumption of synthetic fibers in Germany has been, for the most part, at the expense of consumption of wool, an increase of synthetic fiber consumption of one million pounds being associated with a decrease in wool consumption of 832 thousand pounds.

G. Belgium

Equation (6.11) explaining the net consumption of wool in Belgium is not very satisfactory; for the standard errors for most coefficients are quite high, the sign of the income and the change-in-income variable coefficients are unexpectedly negative, and the estimated coefficient of adjustment is not statistically different from 1.000. This equation was re-estimated with the coefficient of adjustment constrained to be 1.000 and without the change-in-income variable. The resulting equation is

$$(6.19) \quad Cb_t = \underset{(31.035)}{77.093} \; \underset{(.110)}{-.133} \, Pw_t \; \underset{(3.283)}{-2.535} \, Yb_t \; \underset{(.460)}{-.674} \, NSb_t$$

$$R^2 = .73, \; D.W. = 1.89, \; F = 10.744, \; \delta \equiv 1.000 \quad .$$

Equation (6.19) indicates that the price elasticity of net demand in Belgium is -.386. The income elasticity of demand, contradicting our *a priori* expectations, is estimated from (6.19) to be negative, -.570. However, the income coefficient is not statistically significant. It is difficult to explain why wool products would have negative income effects, but there definitely has been a steady decline in Belgium wool consumption during the past seventeen years in the face of a fairly steady growth in income. The consumption of synthetic fibers, as is indicated by equation (6.19), has accounted for some of this decline. The unquantifiable factor, changes in fashion or taste, may be another explanation of this decline.

H. Netherlands

The Netherlands' net consumption equation, (6.12), has many coefficients with large standard errors, and the positive sign of the price variable does not coincide with our a priori expectations. The insignificance of the synthetic-fiber-consumption variable indicates that the introduction of synthetic fibers into the Netherlands market has not had much effect, as measured here, on wool consumption. Equation (6.12) was re-estimated without variables ΔYn_t and NSn_t and with Pw_{t-1} substituted for Pw_t. The resulting equation is

$$(6.20) \quad Cn_t = \underset{(20.286)}{38.546} + \underset{(.226)}{.742}\, Cn_{t-1} - \underset{(.096)}{.122}\, Pw_{t-1} - \underset{(.958)}{1.237}\, Yn_t - \underset{(10.019)}{38.058}\, KWD_t$$

$$R^2 = .64, \text{ D.W.} = 2.11, F = 4.982, \delta = .258 .$$

Equation (6.20), while being generally better, statistically, than (6.12), includes income with a negative and again not highly significant coefficient. The estimated short-run and equilibrium income elasticities of demand are -.171 and -.661. The remarks made in respect to similar results for France and Belgium apply here also. The estimated coefficient of adjustment of .258 indicates that wool consumption in the Netherlands is slow to adjust to changes in factors affecting equilibrium consumption. Finally, the estimated short-run and equilibrium elasticities of demand to lagged price are quite low, -.235 and -.912, respectively.

I. The "Rest-of-the-World" Sector

The net consumption equation for the final, highly aggregated "Rest-of-the-World" sector, equation (6.13), is fairly good in respect to all coefficients having the expected signs, with the possible exception of the negative sign of the change-in-income coefficient. However, the standard errors of these coefficients are uniformly too high. In an attempt to get a more satisfactory equation for this sector, (6.13) was reestimated with the lagged wool price substituted for the current price. The resulting equation is

$$(6.21) \quad Crw_t = \underset{(.161)}{.882}\, Crw_{t-1} - \underset{(.480)}{1.294}\, Pw_{t-1} + \underset{(2.588)}{4.290}\, Yrw_t - \underset{(2.998)}{3.016}\, \Delta Yrw_t - \underset{(.196)}{.446}\, NSrw_t$$

$$R^2 = .96, \ D.W. = 1.79, \ F = 85.143, \ \delta = .118$$

Equation (6.21) is considerably better than (6.13) and indicates that adjustment of consumption to changing factors in this aggregate sector is truly a slow process. This result is implied by the small estimated value of δ, the negative sign of ΔYrw_t and the improvement of the equation resulting from the substitution of Pw_{t-1} for Pw_t. The estimated short-run and equilibrium elasticities of demand with respect to lagged wool prices are -.097 and -.823, which are very low. The most important factor in explaining demand in this sector appears to be income, with the estimated short-run and equilibrium income elasticities being + .326 and + .2.756, respectively. Since many of the countries in this sector are undergoing development plans which should lead to considerable growth in their incomes in the next few decades, the above results suggest that these countries will provide significant new markets for wool products. Synthetic fibers have displaced wool to a small but significant extent in this sector, and the process of the market adjusting to these new fibers is considerably less completed than is the case for the eight major consuming countries considered here.

5. Conclusions

We have found that the determination of the net consumption of wool varies significantly in the eight major consuming countries and a "Rest-of-the-World" sector with respect to the importance and direction of the effects of the wool price, income, change-in-income and net-consumption-of-synthetics variables and to the speed of adjustment of actual consumption towards desired consumption. The net wool consumptions of the United States, the United Kingdom, Japan, West Germany and the "Rest-of-the-World" sector are affected much more strongly by levels and/or changes in income than by wool prices. However, the income effect is much weaker, and in some cases negative, for France, Italy, Belgium and the Netherlands. The price elasticities of wool demand are low for most countries considered, an exception being the United States. The introduction of synthetic fibers has had a significant negative effect on wool consumption in all countries considered except France, Italy and the Netherlands; but the size of this effect varies considerably among the countries in which it is significant. The estimated one-year adjustment coefficients vary from a low of .118 for the "Rest-of-the-World" sector to a high of 1.000 for the United Kingdom, Japan, France, West Germany and Belgium.

The heterogeneous nature of the demand side of the world wool market that was revealed by this study indicates the difficulties facing the attainment of any international agreement on wool similar to that for cotton and the differential impacts such an agreement would have on wool consumption in the different countries considered. This hetrogeneity is in direct contrast to homogeneous and concentrated nature of the supply side of the market. Thus it would be difficult to maintain the principle of equal representation of consumers and producers in such an agreement that is advocated by the United Nations.[28]

Another implication of these results is that the aggregation of these countries into the "world demand" for wool really covers up the most interesting aspects of world demand, and disaggregation at least by countries is preferable whenever possible. Let us now turn to a consideration of the complete world model and some of its implications.

[28] See J. W. Rowe, Primary Commodities in International Trade (London: The Cambridge University Press, 1965), especially Chapter 14.

CHAPTER 7

THE COMPLETE WORLD WOOL MARKET MODEL

1. Introduction

In this chapter we draw together from the previous three chapters a complete model of the world wool market consisting of twenty-four structural equations; a market clearing identity and three definitional identities. In section 2 the final estimates of the model are given and some of the model's statistical properties are reviewed. In section 3 the reduced form of the model is derived and analyzed. In section 4 dynamic multipliers of impulse and sustained exogenous changes are derived from the model and discussed. Next, in section 5 the more general inherent response characteristics of the model are studied in order to determine the implied stability of the market. Finally, in section 6 the predictive ability of the model is tested by generating predictions for one year after and for one year within the observation period used in estimating the model.

2. Final Equation Summary

Equations (7.1) through (7.24) are the final forms of the wool production, stocks, price and consumption equations in the world wool market model. Equation (7.1) is the equation for wool price obtained by re-estimating the New Zealand producer wool stocks equation after normalizing the equation on wool prices as discussed in Chapter 5. Equation (7.25) is the market clearing identity which defines New Zealand producer wool stocks. Equations (7.26), (7.27) and (7.28) are the identities defining the relationship between mill consumption and net consumption of wool in the United States, United Kingdom and Japan. Equations (7.4), (7.5), (7.15), (7.19), (7.23) and (7.24) were estimated by ordinary least squares since they contain no explanatory endogenous variables. Equations (7.2), (7.3), (7.6) and (7.8) were estimated by an iterative approximation to generalized least squares as was described in Chapter 4. These equations also are recursive to the rest of the model. Equations (7.9), (7.10), (7.11), (7.12), (7.13), (7.14), (7.16), (7.17), (7.18), (7.20), (7.21) and (7.22) were estimated simultaneously by the method of two-stage least squares with principal components of all predetermined variables used as instrumental variables as was described in Chapter 5. The identities were not estimated. The estimated standard errors of all coefficients are given beneath the coefficients and the estimated values of the multiple correlation coefficients, R^2, the Durbin-Watson statistics, D.W., and the F-test statistics, F, are given for each estimated equation. A list of the variables used in the model is given in the appendix to this chapter. The only variables not previously used in Chapters 4,5 and 6 are the variables ΔSNC_t in (7.25), the change in world non-commerical wool stocks (these stocks were defined in Chapter 5), and the variables $NIus_t$, $NIuk_t$ and NIj_t, in (7.26), (7.27) and (7.28) which are the annual net imports of semi-finished and finished wool products, in terms of their wool content, into the United States, the United Kingdom and Japan, respectively.

(7.1) $$Pw_t = \underset{(15.899)}{33.676} + \underset{(.165)}{1.333}\, Snz_t - \underset{(.308)}{.976}\, Snz_{t-1} + \underset{(.195)}{.605}\, Pw_{t-1}$$

$$R^2 = .88,\ D.W. = 1.82,\ F = 29.69$$

(7.2) $$Wau_t = \underset{(.141)}{.695}\, Wau_{t-1} + \underset{(.399)}{.660}\, Pw_{t-2} - \underset{(1.360)}{1.749}\, Pwhau_{t-3} + \underset{(.208)}{.381}\, Fau_{t-1} + \underset{(.387)}{.569}\, Rau_t$$

$$R^2 = .96,\ D.W. = 2.40,\ F = 88.00$$

$$(7.3) \quad Wnz_t = \underset{(.020)}{.961}\, Wnz_{t-1} + \underset{(.057)}{.155}\, RP_{t-1} + \underset{(.090)}{.296}\, Plnz_{t-2}$$

$$R^2 = .99, \; D.W. = 1.86, \; F = 594.00$$

$$(7.4) \quad Wsa_t = \underset{(.047)}{.900}\, Wsa_{t-1} + \underset{(.062)}{.108}\, Pw_{t-2} - \underset{(.068)}{.079}\, Pwhsa_{t-2} + \underset{(.074)}{.141}\, Rsa_{t-1}$$

$$R^2 = .92, \; D.W. = 2.20, \; F = 49.83$$

$$(7.5) \quad Wag_t = \underset{(.178)}{.791}\, Wag_{t-1} + \underset{(.168)}{.101}\, Pw_{t-1} - \underset{(20.490)}{11.974}\, Pwhag_{t-1} + \underset{(1.883)}{1.769}\, Pbag_{t-1} + \underset{(.227)}{.305}\, Rag_t$$

$$R^2 = .62, \; D.W. = 1.51, \; F = 4.50$$

$$(7.6) \quad Wur_t = \underset{(.123)}{.561}\, Wur_{t-1} + \underset{(.109)}{.251}\, Pw_{t-1} + \underset{(.093)}{.103}\, Pbur_{t-1} + \underset{(.087)}{.194}\, Phur_{t-1}$$

$$R^2 = .66, \; D.W. = 1.86, \; F = 7.77$$

$$(7.7) \quad Wus_t = \underset{(77.348)}{83.592} + \underset{(.309)}{.606}\, Wus_{t-1} + \underset{(.180)}{.294}\, Pwus_{t-2} - \underset{(.168)}{.211}\, Pwhus_{t-2} - \underset{(.768)}{.695}\, Pbus_{t-2} + \underset{(1.327)}{.297}\, Plus_{t-2}$$

$$R^2 = .67, \; D.W. = 1.54, \; F = 4.87$$

(7.8) $$Wrw_t = \underset{(.023)}{.950}\, Wrw_{t-1} + \underset{(.253)}{.550}\, Pw_{t-2} - \underset{(.091)}{.156}\, Pwhus_{t-2} + \underset{(.859)}{1.127}\, Plnz_{t-2}$$

$R^2 = .99$, D.W. = 2.15, F = 396.00

(7.9) $$Sau_t = \underset{(.132)}{.978}\, Sau_{t-1} + \underset{(.047)}{.075}\, Pw_t - \underset{(.048)}{.054}\, Pw_{t-1}$$

$R^2 = .72$, D.W. = 1.92, F = 16.34

(7.10) $$Ssa_t = \underset{(.261)}{.594}\, Ssa_{t-1} + \underset{(.004)}{.029}\, Pw_t - \underset{(.007)}{.023}\, Pw_{t-1}$$

$R^2 = .77$, D.W. = 1.46, F = 21.44

(7.11) $$Sag_t = \underset{(19.905)}{-53.700} + \underset{(.196)}{.927}\, Pw_t - \underset{(.172)}{.475}\, (Pw_t - Pw_{t-1}) + \underset{(11.146)}{98.479}\, Dag_t$$

$R^2 = .95$, D.W. = 2.10, F = 70.59

(7.12) $$Sur_t = \underset{(.028)}{.131}\, Pw_t - \underset{(.080)}{.206}\, (Pw_t - Pw_{t-1}) + \underset{(5.601)}{22.342}\, Dur_t$$

$R^2 = .73$, D.W. = 1.95, F = 17.65

(7.13) $$Cus_t = \underset{(388.944)}{419.931} + \underset{(.228)}{.897}\, Cus_{t-1} - \underset{(1.176)}{4.250}\, Pw_t + \underset{(1.105)}{.167}\, Yus_t + \underset{(1.716)}{9.298}\, \Delta Yus_t - \underset{(.150)}{.210}\, NSns_t + \underset{(94.401)}{266.329}\, KWD_t$$

$R^2 = .85$, D.W. = 2.12, F = 8.29

(7.14) $$SCus_t = \underset{(.010)}{.334}\ MCus_t - \underset{(.053)}{.162}\ (MCus_t - MCus_{t-1})$$

$$R^2 = .63,\ D.W. = 1.76,\ F = 24.07$$

(7.15) $$Cuk_t = -\underset{(.173)}{.649}\ Pw_{t-1} + \underset{(.560)}{9.109}\ Yuk_t - \underset{(.954)}{1.896}\ \Delta Yuk_t - \underset{(.106)}{.878}\ NSuk_t - \underset{(16.935)}{40.910}\ KWD_t$$

$$R^2 = .77,\ D.W. = 1.87,\ F = 9.01$$

(7.16) $$SCuk_t = \underset{(.171)}{.186}\ SCuk_{t-1} + \underset{(.065)}{.300}\ MCuk_t + \underset{(.119)}{.074}\ (MCuk_t - MCuk_{t-1})$$

$$R^2 = .59,\ D.W. = 1.93,\ F = 9.43$$

(7.17) $$Cj_t = -\underset{(.231)}{.198}\ Pw_t + \underset{(1.807)}{8.374}\ Yj_t + \underset{(4.008)}{11.424}\ \Delta Yj_t - \underset{(.130)}{.335}\ NSj_t$$

$$R^2 = .91,\ D.W. = 2.30,\ F = 41.95$$

(7.18) $$SCj_t = \underset{(.096)}{.812}\ SCj_{t-1} + \underset{(.090)}{.176}\ (MCj_t - MCj_{t-1}) + \underset{(.031)}{.034}\ Pw_t$$

$$R^2 = .73,\ D.W. = 1.93,\ F = 17.47$$

(7.19) $$Cf_t = \underset{(32.160)}{224.250} - \underset{(.137)}{.235}\ Pw_{t-1} - \underset{(.515)}{1.135}\ Yf_t + \underset{(9.044)}{40.688}\ Df_t - \underset{(13.112)}{40.641}\ KWD_t$$

$$R^2 = .75,\ D.W. = 2.23,\ F = 8.01$$

$$(7.20)\quad Ci_t = \underset{(.102)}{.793}\, Ci_{t-1} - \underset{(.125)}{.403}\, (Pw_t - Pw_{t-1}) + \underset{(.399)}{.696}\, Yi_t$$

$R^2 = .57$, D.W. $= 1.84$, $F = 8.71$

$$(7.21)\quad Cg_t = \underset{(51.313)}{86.400} - \underset{(.251)}{.300}\, Pw_t + \underset{(1.070)}{6.067}\, Yg_t - \underset{(2.744)}{6.058}\, \Delta Yg_t - \underset{(.237)}{.832}\, Nsg_t$$

$R^2 = .92$, D.W. $= 2.48$, $F = 33.09$

$$(7.22)\quad Cb_t = \underset{(3.100)}{7.709} - \underset{(.110)}{.133}\, Pw_t - \underset{(3.283)}{2.535}\, Yb_t - \underset{(.460)}{.674}\, NSb_t$$

$R^2 = .73$, D.W. $= 1.89$, $F = 10.74$

$$(7.23)\quad Cn_t = \underset{(20.286)}{38.546} + \underset{(.226)}{.742}\, Cn_{t-1} - \underset{(.096)}{.122}\, Pw_{t-1} - \underset{(.958)}{1.237}\, Yn_t - \underset{(10.019)}{38.058}\, KWD_t$$

$R^2 = .64$, D.W. $= 2.11$, $F = 4.98$

$$(7.24)\quad Crw_t = \underset{(.161)}{.882}\, Crw_{t-1} - \underset{(.48)}{1.294}\, Pw_{t-1} + \underset{(2.588)}{4.290}\, Yrw_t - \underset{(2.998)}{3.016}\, \Delta Yrw_t - \underset{(.196)}{.446}\, NSrw_t$$

$R^2 = .96$, D.W. $= 1.79$, $F = 85.143$

$$(7.25)\quad Snz_t = Wau_t + Wnz_t + Wsa_t + Wag_t + Wur_t + Wus_t + Wrw_t - Sau_t - Ssa_t - Sag_t - Sur_t + Sau_{t-1} + Snz_{t-1} + Ssa_{t-1} + Sag_{t-1} + Sur_{t-1} - Cus_t - Cuk_t - Cj_t - Cf_t - Ci_t - Cg_t - Cb_t - Cn_t - Crw_t - SCus_t - SCuk_t - SCj_t + SCus_{t-1} + SCuk_{t-1} + SCj_{t-1} - \Delta SNC_t - \Delta SCrw_t$$

$$(7.26)\quad MCus_t = Cus_t - NIus_t$$

$$(7.27)\quad MCuk_t = Cuk_t - NIuk_t$$

$$(7.28)\quad MCj_t = Cj_t - NIj_t$$

The statistical properties of the twenty-four estimated equations vary quite widely, with R^2 values ranging from a low of .57 to a high of .99 and Durbin-Watson statistics ranging from 1.46 to 2.48. The F-test statistics are significant at the five percent level for all equations and at the one percent level for all but the equations for Argentine and United States wool production and Netherlands wool consumption. However, as was pointed out in Chapter 5, the standard t, F and Durbin-Watson tests are not valid for structural estimates of simultaneous equation models, especially in cases where lagged values of the dependent variable are used as explanatory variables. Yet these statistics were included as a systematic means of evaluating the estimated equations. Goldfeld and Quandt, in examining the samll sample properties of two-stage least squares estimates, obtained results suggesting that this method tends to underestimate the significance of the parameter estimates.[1] Because of this failure of the standard tests, greater emphasis had to be placed on the a priori specifications of the model; and the model is quite reasonable in this respect.

The resulting system of equations describes the world wool market as a highly damped system in which the main simultaneous link is the world wool price variable. The elasticities of the wool production and consumption variables with respect to the wool price are uniformly low, with wide variations in stocks and prices serving as the main means of clearing the market. While this highly simplified model is only a rough approximation of the actual market, the analysis of this model in the remaining sections of this chapter yields some interesting insights into the way by which the market functions over time.

3. The Reduced Form

The structural equations given in the previous section describe the endogenous variables in the world wool market as being functions of predetermined (exogenous and lagged endogenous) variables, disturbance terms and, in many cases, of jointly determined endogenous variables.

The reduced form version of the model expresses the endogenous variables as functions of predetermined variables and disturbance terms only, and it is the reduced-form version which is most useful for prediction and many other analytical purposes. If the structural form of the model is written as

$$\Gamma y_t + Bz_t = u_t \tag{7.29}$$

[1]Stephen M. Goldfeld and Richard E. Quandt, Nonlinear Simultaneous Equations: Estimation and Prediction, Research Memorandum No. 79, Econometric Research Program, Princeton University (October 21, 1965).

where y_t is the vector of current endogenous variables, z_t is the vector of predetermined variables, Γ and B are the matrices of the structural coefficients, and u_t is the vector of structural disturbance terms, then the reduced-form version of the model is

$$(7.30) \qquad y_t = -\Gamma^{-1} B z_t + \Gamma^{-1} u_t = \Pi z_t + v_t$$

where Π is the matrix of reduced-form coefficients and v_t ($= \Gamma^{-1} u_t$) is the vector of reduced-form disturbance terms. Each reduced-form coefficient, π_{ij}, indicates the immediate (that is, within the same year) direct and <u>indirect</u> effects of a unit change in the j^{th} predetermined variable on the i^{th} endogenous variable with all other predetermined variables held constant; that is, $\pi_{ij} = \Delta y_i / \Delta z_j$, while the structural coefficients, b_{ij}, give only the direct effects. Because these effects are those occurring in the first year, the coefficients of the reduced form have been called "impact multipliers."[2]

The estimates of the reduced-form coefficients obtained from the estimates of the structural equations coincide with the estimates obtained by applying ordinary least squares directly to the system

$$(7.31) \qquad y_t = \Pi z_t + v_t$$

only in the case where all equations are exactly identified.[3]

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[2]Arthur S. Goldberger, <u>Impact Multipliers and Dynamic Properties of the Klein-Goldberger Model</u> (Amsterdam: North-Holland Publishing Company, 1966), p. 16.

[3]Arthur S. Goldberger, <u>Econometric Theory</u> (New York: John Wiley and Sons, Inc., 1964), p. 365.

However, all equations are overidentified in the world wool market model. The reduced-form estimates derived from the structural estimates are asymptotically more efficient than direct estimates, for they incorporate all a priori information that was used in obtaining the estimates of the structural equations. Also, since there are more predetermined variables than observations, for our model direct estimation by ordinary least squares would be impossible. Thus the reduced-form version of the world wool market was calculated from the estimates of the structural equations, and part of the reduced form is given in tables (7.1), (7.2) and (7.3). Identities (7.26), (7.27) and (7.28) were omitted by substitution. The reduced-form equations for the wool production variables are not given; for, since these variables are recursive to the rest of the model, these equations are the same as the structural equations. Table (7.1) contains the reduced-form coefficients for the lagged endogenous variables and the constant term. Table (7.2) contains the reduced-form coefficients for the exogenous variables contained in the wool production equations (agricultural prices, rainfall, etc.), the four dummy variables and the exogenous stocks variables. Table (7.3) contains the coefficients of variables that enter the demand (consumption and commercial stocks) equations.

Because the wool price variable is the main simultaneous link in the model, the signs of most reduced-form coefficients are predictable. For example, since higher wool production leads to lower wool prices, all variables which have positive signs in the production equations have negative signs in the reduced-form equation for wool prices. A decrease in the Australian rainfall index, Rau_t, of 10 points[4] implies (from Table 7.2) an increase in the

[4]All changes in values of predetermined variables given in this section are certeris paribus changes.

TABLE 7.1

REDUCED-FORM COEFFICIENTS (LAGGED ENDOGENOUS AND CONSTANT)

Endogenous Variable	Predetermined Variables												
	Pw_{t-1}	Pw_{t-2}	Wau_{t-1}	Wnz_{t-1}	Wsa_{t-1}	Wag_{t-1}	Wur_{t-1}	Wus_{t-1}	Wrw_{t-1}	Sau_{t-1}	Snz_{t-1}	Ssa_{t-1}	Sag_{t-1}
Pw_t	- .4895	-.2754	-.1454	-.2010	-.1881	-.1653	-.1172	-.1267	-.1987	-.0046	-.0560	-.0850	-.2091
Sau_t	- .0908	-.0205	-.0108	-.0150	-.0140	-.0123	-.0087	-.0094	-.0148	-.9776	-.0042	-.0063	-.0156
Snz_t	- .8215	-.2066	-.1091	-.1509	-.1412	-.1241	-.0880	-.0951	-.1491	-.0035	-.6901	-.0638	-.1569
Ssa_t	- .3370	-.0081	-.0043	-.0059	-.0055	-.0048	-.0034	-.0037	-.0058	-.0001	-.0016	.5911	-.1161
Sag_t	.2533	-.1246	-.0658	-.0910	-.0851	-.0748	-.0531	-.0573	-.0899	-.0021	-.0253	.0385	-.0946
Sur_t	.2431	.0207	.0109	.0151	.0141	.0124	.0088	.0095	.0149	.0003	.0042	.0064	.0157
Cus_t	2.0805	1.1706	.6180	.8545	.7996	.7028	.4984	.5386	.8446	.0196	.2381	.3612	.8888
$SCus_t$	.3564	.2005	.1059	.1464	.1370	.1204	.0854	.0923	.1447	.0034	.0408	.0619	.1523
Cuk_t	- .6494	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
$SCuk_t$	- .2424	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
Cj_t	.0968	.0545	.0288	.0398	.0372	.0327	.0232	.0251	.0393	.0009	.0111	.0168	.0414
SCj_t	.0005	.0003	.0002	.0002	.0002	.0002	.0001	.0001	.0002	.0000	.0001	.0001	.0002
Cf_t	- .2346	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
Ci_t	.6006	.1110	.0586	.0811	.0758	.0667	.0473	.0511	.0801	.0019	.0226	.0343	.0843
Cg_t	.1471	.0828	.0437	.0604	.0565	.0497	.0352	.0381	.0597	.0014	.0168	.0255	.0629
Cb_t	.0649	.0365	.0193	.0266	.0249	.0219	.0155	.0168	.0263	.0006	.0074	.0113	.0277
Cn_t	- .1224	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
Crw_t	-1.2936	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

TABLE 7.1 (Cont.)

Endogenous Variable	Predetermined Variables										
	Sur_{t-1}	Cus_{t-1}	$SCus_{t-1}$	Cuk_{t-1}	$SCuk_{t-1}$	Cj_{t-1}	SCj_{t-1}	Ci_{t-1}	Cn_{t-1}	Crw_{t-1}	Constant
Pw_t	-.2091	.2491	-.2091	-.0154	-.1703	-.0368	-.0394	.1657	.1552	.1844	158.0041
Sau_t	-.0156	.0186	-.0156	-.0011	-.0127	-.0027	-.0029	.0123	.0116	.0137	11.7713
Snz_t	-.1569	.1869	-.1569	-.0115	-.1278	-.0276	-.0295	.1243	.1165	.1383	93.2905
Ssa_t	-.0061	.0073	-.0061	-.0005	-.0050	-.0011	-.0012	.0049	.0045	.0054	4.6295
Sag_t	-.0946	.1127	-.0946	-.0070	-.0771	-.0167	-.0178	.0750	.0702	.0834	17.7966
Sur_t	.0157	-.0187	.0157	.0012	.0128	.0028	.0030	-.0124	-.0117	-.0138	- 11.8661
Cus_t	.8888	-.1799	.8888	.0654	.7239	.1564	.1673	-.7044	-.6597	-.7837	-251.6447
$SCus_t$	.1523	.1310	.1523	.0112	.1240	.0268	.0287	-.1207	-.1130	-.1342	- 43.1067
Cuk_t	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
$SCuk_t$	.0000	.0000	.0000	-.0736	.1855	.0000	.0000	.0000	.0000	.0000	.0000
Cj_t	.0414	-.0493	.0414	.0030	.0337	.0073	.0078	-.0328	-.0307	-.0365	- 31.2532
SCj_t	.0002	-.0003	.0002	.0000	.0002	-.1760	.8818	-.0002	-.0002	-.0002	- .1758
Cf_t	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	224.2504
Ci_t	.0843	-.1004	.0843	.0062	.0687	.0148	.0159	.7257	-.0626	-.0743	- 63.7073
Cg_t	.0629	-.0749	.0629	.0046	.0512	.0111	.0118	-.0498	-.0467	-.0554	38.9042
Cb_t	.0277	-.0330	.0277	.0020	.0226	.0049	.0052	-.0220	-.0206	-.0244	56.1572
Cn_t	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.7422	.0000	38.5463
Crw_t	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.8817	.0000

TABLE 7.2

REDUCED-FORM COEFFICIENTS
(AGRICULTURAL, DUMMY, AND EXOGENOUS STOCKS VARIABLES)

Endogenous Variable	Predetermined Variables: Rau_t	Fau_{t-1}	$Pwhau_{t-2}$	RP_{t-1}	Pln_{t-2}	$Pwhsa_{t-2}$	Rsa_{t-1}	$Pwhag_{t-1}$	$Pbag_{t-1}$	Rag_t	$Pbur_{t-1}$	$Phur_{t-1}$	$Pwus_{t-2}$
Pw_t	-.1190	-.0797	.3657	-.0323	-.2581	.0166	-.0294	2.5039	-.3700	-.0638	-.0216	-.0405	-.0614
Sau_t	-.0089	-.0059	.0272	-.0024	-.0192	.0012	-.0022	.1865	-.0276	-.0048	-.0016	-.0030	-.0046
Snz_t	-.0893	-.0598	.2744	-.0242	-.1937	.0124	-.0221	1.8788	-.2776	-.0479	-.0162	-.0304	-.0461
Ssa_t	-.0035	-.0023	.0107	-.0009	-.0076	.0005	-.0009	.0734	-.0108	-.0019	-.0006	-.0012	-.0018
Sag_t	-.0539	-.0361	.1655	-.0146	-.1168	.0075	-.0133	1.1330	-.1674	-.0289	-.0098	-.0183	-.0278
Sur_t	.0089	.0060	- .0275	.0024	.0194	.0012	.0022	-.1880	.0278	.0048	.0016	.0030	.0046
Cus_t	.5059	.3386	-1.5544	.1373	1.0971	-.0705	.1250	-10.6426	1.5727	.2711	.0919	.1721	.2610
$SCus_t$	.0867	.0580	- .2663	.0235	.1879	-.0121	.0214	-1.8231	.2694	.0464	.0157	.0295	.0447
Cuk_t	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
$SCuk_t$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
Cj_t	.0235	.0158	- .0723	.0064	.0511	-.0033	.0058	- .4953	.0732	.0126	.0043	.0080	.0121
SCj_t	.0001	.0001	- .0004	.0000	.0003	.0000	.0000	- .0028	.0004	.0001	.0000	.0000	.0001
Cf_t	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
Ci_t	.0480	.0321	- .1475	.0130	.1041	-.0067	.0119	-1.0096	.1492	.0257	.0087	.0163	.0248
Cg_t	.3058	.0239	- .1099	.0097	.0776	-.0050	.0088	- .7527	.1112	.0192	.0065	.0122	.0185
Cb_t	.0158	.0106	- .0485	.0043	.0342	-.0022	.0039	- .3318	.0490	.0085	.0029	.0054	.0081
Cn_t	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
Crw_t	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

TABLE 7.2 (Cont.)

Endogenous Variable	Predetermined Variables: $Pwhus_{t-2}$	$Pbus_{t-2}$	$Plus_{t-2}$	Dag_t	Dur_t	KWD_t	Df_t	ΔSNC_t	$\Delta SCrw_t$
Pw_t	7.6919	.1454	-.0622	20.8021	4.6719	60.5236	8.5084	.2091	.2091
Sau_t	.5730	.0108	-.0046	1.5498	.3481	4.5090	.6339	.0156	.0156
Snz_t	5.7717	.1091	-.0466	15.6090	3.5056	45.4143	6.3843	.1569	.1569
Ssa_t	.2254	.0043	-.0018	.6095	.1369	1.7733	.2493	.0061	.0061
Sag_t	3.4806	.0658	-.0281	108.8919	2.1140	27.3869	3.8500	.0946	.0946
Sur_t	- .5777	-.0109	.0047	- 1.5622	21.9909	- 4.5453	- .6390	-.0157	-.0157
Cus_t	-32.6938	-.6181	.2642	-88.4174	-19.8575	9.0789	-36.1640	-.8888	-.8888
$SCus_t$	- 5.6005	-.1059	.0453	-15.1459	- 3.4016	1.5552	- 6.1949	-.1523	-.1523
Cuk_t	.0000	.0000	.0000	.0000	.0000	40.9103	.0000	.0000	.0000
$SCuk_t$	.0000	.0000	.0000	.0000	.0000	15.2718	.0000	.0000	.0000
Cj_t	- 1.5215	-.0288	.0123	- 4.1147	- .9241	-11.9716	- 1.6830	-.0414	-.0414
SCj_t	- .0086	-.0002	.0001	- .0231	- .0052	- .0674	- .0095	-.0002	-.0002
Cf_t	.0000	.0000	.0000	.0000	.0000	40.6414	40.6883	.0000	.0000
Ci_t	- 3.1014	-.0586	.0251	- 8.3874	- 1.8837	-24.4031	- 3.4306	-.0843	-.0843
Cg_t	- 2.3122	-.0437	.0187	- 6.2531	- 1.4044	-18.1934	- 2.5576	-.0629	-.0629
Cb_t	- 1.0192	-.0193	.0082	- 2.7563	- .6190	- 8.0194	- 1.1274	-.0277	-.0277
Cn_t	.0000	.0000	.0000	.0000	.0000	-38.0583	.0000	.0000	.0000
Crw_t	.000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

TABLE 7.3

REDUCED-FORM COEFFICIENTS (DEMAND SECTOR VARIABLES)

Endogenous Variable	Predetermined Variables												
	Yus_t	ΔYus_t	$NSus_t$	$NIus_t$	$NIus_{t-1}$	Yuk_t	ΔYuk_t	$NSuk_t$	$NIuk_t$	$NIuk_{t-1}$	Yj_t	ΔYj_t	NSj_t
Pw_t	.0409	2.2773	-.0514	.0358	-.0338	2.6160	-.5446	-.2521	-.0781	.0154	2.0594	2.8094	-.0824
Sau_t	.0030	.1697	-.0038	.0027	-.0025	.1949	-.0406	-.0188	-.0058	.0011	.1534	.2093	-.0061
Snz_t	.0307	1.7088	-.0386	.0269	-.0254	1.9629	-.4086	-.1891	-.0586	.0115	1.5453	2.1081	-.0619
Ssa_t	.0012	.0067	-.0015	.0010	-.0010	.0766	-.0160	-.0074	-.0023	.0005	.0603	.0823	-.0024
Sag_t	.0185	1.0305	-.0233	.0162	-.0153	1.1837	-.2464	-.1141	-.0353	.0070	.9319	1.2713	-.0373
Sur_t	-.0031	-.1710	.0039	-.0027	.0025	-.1965	.0409	.0189	.0059	-.0012	-.1547	-.2110	.0062
Cus_t	-.0068	-.3817	.0086	-.1523	.1438	-11.1189	2.3146	1.0714	.3318	-.0654	-8.7531	-11.9411	.3504
$SCus_t$	-.0012	-.0654	.0015	.1452	-.1372	-1.9047	.3965	.1835	.0568	-.0112	-1.4994	-2.0455	.0600
Cuk_t	.0000	.0000	.0000	.0000	.0000	9.1094	-1.8963	-.8778	.0000	.0000	.0000	.0000	.0000
$SCuk_t$	.0000	.0000	.0000	.0000	.0000	3.4005	-.7079	-.3277	-.3733	.0736	.0000	.0000	.0000
Cj_t	-.0081	-.4504	.0102	-.0071	.0067	-.5174	.1077	.0499	.0154	-.0030	7.9670	10.8686	-.3189
SCj_t	.0000	-.0025	.0001	.0000	.0000	-.0029	.0006	.0003	.0001	.0000	1.4716	2.0076	-.0589
Cf_t	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
Ci_t	-.0165	-.9182	.0207	-.0144	.0136	-1.0548	.2196	.1016	.0315	-.0062	-.8303	-1.1328	.0332
Cg_t	-.0123	-.6845	.0155	-.0108	.0102	-.7864	.1637	.0758	.0235	-.0046	-.6190	-.8445	.0248
Cb_t	-.0054	-.3017	.0068	-.0047	.0045	-.3466	.0722	.0334	.0103	-.0020	-.2729	-.3722	.0109
Cn_t	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
Crw_t	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

TABLE 7.3 (Cont.)

Endogenous Variable	Predetermined Variables												
	NIj_t	NIj_{t-1}	Yf_t	Yi_t	Yg_t	ΔYg_t	NSg_t	Yb_t	NSb_t	Yn_t	Yrw_t	ΔYrw_t	$NSrw_t$
Pw_t	-.0368	.0368	-.2373	.1455	1.2688	-1.2668	-.1740	-.5301	-.1410	-.2586	.8970	-.6306	-.0932
Sau_t	-.0027	.0027	-.0177	.0108	.0945	-.0944	-.0130	-.0395	-.0105	-.0193	.0668	-.0470	-.0069
Snz_t	-.0276	.0276	-.1781	.1092	.9520	-.9506	-.1305	-.3977	-.1058	-.1940	.6731	-.4732	-.0700
Ssa_t	-.0011	.0011	-.0070	.0043	.0372	-.0371	-.0051	-.0155	-.0041	-.0076	.0263	-.0185	-.0027
Sag_t	-.0167	.0167	-.1074	.0658	.5741	-.5732	-.0787	-.2398	-.0638	-.1170	.4059	-.2854	-.0422
Sur_t	.0028	-.0028	.0178	-.0109	-.0953	.0951	.0131	.0398	.0106	.0194	-.0674	.0474	.0070
Cus_t	.1564	-.1564	1.0086	-.6184	-5.3927	5.3846	.7395	2.2529	.5991	1.0991	-3.8127	2.6805	.3963
$SCus_t$	.0268	-.0268	.1728	-.1059	-.9238	.9224	.1267	.3859	.1026	.1883	-.6531	.4592	.0679
Cuk_t	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
$SCuk_t$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
Cj_t	.0073	-.0073	.0469	-.0288	-.2510	.2506	.0344	.1048	.0279	.0511	-.1774	.1247	.0184
SCj_t	-.1760	.1760	.0003	-.0002	-.0014	.0014	.0002	.0006	.0002	.0003	-.0010	.0007	.0001
Cf_t	.0000	.0000	-1.1348	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
Ci_t	.0148	-.0148	.0957	.6371	-.5116	.5108	.0701	.2137	.0568	.1043	-.3617	.2543	.0376
Cg_t	.0111	-.0111	.0713	-.0437	5.6860	-5.6774	-.7797	.1593	.0424	.0777	-.2696	.1896	.0280
Cb_t	.0049	-.0049	.0314	-.0193	-.1681	.1679	.0231	-2.4646	-.6554	.0343	-.1189	.0836	.0124
Cn_t	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	-1.2366	.0000	.0000	.0000
Crw_t	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	4.2897	-3.0158	-.4459

world wool price of 1.19 cents. Similarly, an increase in the New Zealand lamb price, $Plnz_{t-2}$, of 10 cents in the first year of season t-3, t-2, implies a decrease in the world wool price in season t-1, t of 2.581 cents. This decrease is due to the increased wool production which is a by-product of the increased investment in sheep encouraged by the higher lamb prices.

The endogenous variables which are negatively affected by price, namely, the wool consumption variables, are negatively affected by factors which affect price positively. Hence, the decrease in the Australian rainfall index variable of 10 points discussed above would imply a decrease in United States' net wool consumption of 5.059 million pounds, in Japan's net wool consumption of .235 million pounds, and similarly for other consuming countries. In some cases, when the indirect effects of contemporaneous feedbacks are added to the direct effect of a change in a predetermined variable, the net effect, given by the reduced-form coefficient, is quite different from the direct effect alone given by the corresponding structural coefficient. In the structural equation for United States wool consumption, the direct effect of an increase in real disposable income of ten billion dollars would lead to an increase in consumption of 1.668 million pounds. However, this increased demand would lead to higher wool prices which would force demand back down, this effect being the "indirect" effect. The reduced-form coefficient in Table 7.3 states that the net effect in the first year of this change would be -.068 million pounds, which is considerably smaller and, in fact, negative. In the cases of the reduced-form equations for net consumption in other countries that have positive income elasticities and contain current wool prices in the structural equations (Japan, Italy, and Germany), the net effects of an increase in income are in the same direction but are somewhat smaller than the direct effects. For example, the coefficient of income in the Japanese structural consumption equation is 8.3743, which is only slightly larger than the corresponding reduced-form coefficient of 7.9670. The indirect effects are smaller in these countries because demand in these countries is more income elastic and less price elastic.

There are a few policy-controlled variables in the system, the New Zealand Reserve Price for wool, RP_{t-1}, the United States support price for wool, $Pwus_{t-2}$, the dummy variables for export policy in Argentina and Uruguay, Dag_t, Dur_t, and the change in non-commercial wool stocks, ΔSNC_t. The reduced-form coefficients of these variables give the quantitative effects throughout the wool market of different policy actions. Table 7.4, taken from Tables 7.1, 7.2 and 7.3, gives the impact multipliers for changes in these variables for a representative subset of the endogenous variables.

The New Zealand reserve price and the United States support price have only weak effects on the endogenous variables given in Table 7.4. These weak effects are due to the initial weak effects of these variables on wool production and the low price elasticity of most of the other variables. Thus the use of these variables to affect significantly the world wool market is quite limited. In contrast, the effect of export policies in the two South American countries is quite strong. The model implies that a season in which the government policy in Argentina is adverse to wool exports following a non-adverse season will lead to an increase in the wool price of 20.802 cents, a decrease in United States consumption and stock demand of 88.417 and 15.146 million pounds, respectively, and a decrease in Japanese consumption and stock demand of 4.115 and .023 million pounds, respectively. Adverse export policy in Uruguay has similar but weaker effects. Thus it appears that a major source of variation in wool prices, stocks and, to a lesser degree, consumption is the variations in export policies of these South American countries.

TABLE 7.4

IMPACT MULTIPLIERS FOR POLICY-CONTROLLED VARIABLES

Endogenous Variables	Policy-Controlled Variables RP_{t-1}	$Pwus_{t-2}$	Dag_t	Dur_t	ΔSNC_t
Pw_t	-.0323	-.0614	20.8021	4.6719	.2091
Wnz_t	.1545	.0000	.0000	.0000	.0000
Wus_t	.0000	.2936	.0000	.0000	.0000
Snz_t	-.0242	-.0461	15.6090	3.5056	.1569
Sag_t	-.0146	-.0278	108.8919	2.1140	.0946
Sur_t	.0024	.0046	- 1.5622	21.9909	-.0157
Cus_t	.1373	.2610	-88.4174	-19.8575	-.8888
$SCus_t$	.0235	.0447	15.1459	- 3.4016	-.1523
Cj_t	.0064	.0121	- 4.1147	- .9241	-.0414
SCj_t	.0000	.0001	- .0231	- .0052	-.0002

The impact multipliers for the change in non-commericial stocks variable, these stocks including stocks held by the Reserve Boards of New Zealand and South Africa, are significant when considered with the values of this variable that occurred in the early part of the observation period (for example, the change in this variable equalled +64 for the season 1952-1953) but are less significant with respect to the very small changes that have occurred in recent years. There is a considerable amount of literature on the possibility of stabilizing wool prices by varying non-commercial wool stocks.[5] It is interesting to consider the implications of the world wool market model for the feasibility of such a stabilization scheme.

The reduced-form coefficient of ΔSNC_t in the price equation, .2091, suggests that the prevention of the 19.2 cents fall in wool prices from 99.4 cents in the 1963-64 season to 80.2 cents in the 1964-65 season would have required an increase in world non-commerical stocks of 92.822 million pounds over the previous season's increase of one million pounds, raising the level of these stocks to 99.822 million pounds at the end of the 1964-65 season. This increase is comparable in size to the United Kingdom's strategic stockpile in the middle 1950's and thus certainly would be feasible. However, this analysis is of the effects of such a purchase in the same year only. Also, the decision of one or a group of governments to attempt to stabilize prices in this way would probably cause some structural changes in the market, and the resulting policy requirements for price

[5]See, for example, E. L. Jenkins, An Assessment of Costs and Capital of a Reserve-Price Scheme for Australian Wool, Wool Economic Research Report Number 7, Bureau of Agricultural Economics (Canberra, Australia, December, 1964); and M. Weisser, "Stabilization of Wool Prices," in The Simple Fleece, ed. Alan Barnard (Parkville, Victoria, Australia: Melbourne University Press, 1962), pp. 507-520.

stabilization in the season 1964-65 might have been considerably different from that indicated by the reduced form. It is also important to note that the purchase of 92.822 million pounds of wool stocks is a policy derived when the values of all other predetermined variables were known. The need to forecast these variables accurately is one of the major drawbacks of such a stabilization scheme.

The above discussion suggests some of the limitations of using the reduced form of a model for analysis.[6] First, the impact multipliers give the first period response only of an endogenous variable to a change in a predetermined variable. With a model containing variables lagged one and two periods, the final response may be considerably different from that occurring in the first time period as is shown in the next two sections in which the longer-run responses of the endogenous variables are studied. Second, the relative sizes of the reduced-form coefficients do not alone indicate the relative importance of the corresponding predetermined variables. It is the relative variation in these variables together with these coefficients that must be considered. Third, these coefficients give the initial responses only under the assumption that all other predetermined variables remain constant. This assumption is never true in practice, and hence the partial nature of this analysis must be kept in mind.

4. Dynamic Multipliers

In the preceding section the matrix, Π, of reduced-form coefficients or impact multipliers was derived. These coefficients take account of the simultaneous feedbacks among the endogenous variables in the system. However, the world wool market model

[6]These limitations are pointed out by Stephen M. Goldfeld in Commercial Bank Behavior and Economic Activity (Amsterdam: North-Holland Publishing Company, 1966), p. 176.

contains many variables that are lagged one and two years, and the response of an endogenous variable to a change in an exogenous variable after the lagged feedbacks are taken into account may be quite different from the response occurring in the initial year. In order to study these cross-temporal feedbacks in the model and their effects on the time paths of the endogenous variables, longer-run dynamic multipliers were computed.[7]

The reduced-form of the model, system (7.31), that was derived in the previous section, is a second-order system of difference equations in twenty-five endogenous variables, where the only endogenous variable lagged two time periods is the world wool price. As is shown in the next section, this system can be converted to a first order system of twenty-six equations in twenty-six variables by defining a new variable, $Pw^*_t = Pw_{t-1}$, substituting Pw^*_{t-1} for Pw_{t-2} in all equations, and adding the equation defining Pw^*_t to the system. If we write this first-order system as

$$(7.31) \qquad y_t = \Pi z_t + v_t \quad ,$$

then the reduced form matrix, Π, can be partitioned into two matrices A and B; and the system can be rewritten as

$$(7.32) \qquad y_t = Ay_{t-1} + Bx_t + v_t$$

[7]The analysis used in this section is that used by Arthur S. Goldberger in <u>Econometric Theory</u>, <u>op. cit</u>., pp. 373-375, and <u>Impact Multipliers and Dynamic Properties of the Klein-Goldberger Model</u>, <u>op. cit</u>., Chapter 3.

where y_t is the 26 x 1 vector of current endogenous variables

y_{t-1} is the 26 x 1 vector of lagged endogenous variables

x_t is the 49 x 1 vector of exogenous variables

v_t is the 26 x 1 vector of reduced-form disturbances

A is the 26 x 26 matrix of reduced-form coefficients of the lagged endogenous variables

B is the 26 x 49 matrix of reduced-form coefficients of the exogenous variables.

If system (7.32) is lagged times, each time substituting the result back into (7.32), the resulting system is

$$(7.33)\quad y_t = A^{s+1}y_{t-s-1} + \sum_{\tau=0}^{s} C_\tau x_{t-\tau} + \sum_{\tau=0}^{s} A^\tau v_{t-\tau}$$

where

$$(7.34)\quad C_\tau = A^\tau B \cdot$$

If we let s go to infinity and assume $\lim_{\tau\to\infty} A^\tau = 0$, we get the <u>final form</u> of the model

$$(7.35)\quad y_t = \sum_{\tau=0}^{\infty} C_\tau x_{t-\tau} + \sum_{\tau=0}^{\infty} A^\tau v_{t-\tau} \quad .$$

The assumption about A above will be met if all the roots of A have modulus less than unity, that is, if the system is stable; and the results given in the next section indicate that this assumption is justified for the world wool market model.

For $\tau = 0$, $C_\tau = A^0B = B$, the matrix of impact multipliers of the exogenous variables. For $\tau>0$, $C_\tau = A^\tau B$ is the matrix of τ^{th} period <u>delay multipliers</u>, which give the delayed responses τ years after an impulse exogenous change. As Goldberger notes about the elements of the matrices C_0, C_1, C_2..., "they answer the questions 'If an exogenous variable is raised by one unit in a period and then restored to its original level, what will happen to the current and future values of an endogenous variable.'"[8]

We may also be interested in the response to a sustained unit exogenous change, and these responses are given by the matrices of the cumulative multipliers,

$$(7.36) \quad D_{\tau} = \sum_{v=0}^{\tau} C_{v} = \sum_{v=0}^{\tau} A^{v}B$$

$$= (I + A + \ldots + A^{\tau})B \qquad (\tau = 1,\ldots.) \quad .$$

These multipliers answer the question, "If an exogenous variable is raised by one unit in a period and then sustained at its new level, what will happen to the current and future values of an endogenous variable."[9]

The matrices of the delay and cumulative multipliers of the world wool market model were computed for years $\tau = 0, 1, 2, 3, \ldots 8$. However, since each matrix contains 26 x 49 coefficients, only a small subset of these coefficients can be given here. Tables (7.5a), (7.6a), (7.7a), (7.8a) and (7.9a) give, for a representative subset of the endogenous variables, the delay multipliers for the Australian rainfall index, the Australian wheat price, the change in United States disposable income, the net United Kingdom consumption of synthetics fibers and the change in non-commercial stocks variables. Table (7.5b), (7.6b), (7.7b), (7.8b) and (7.9b) give the corresponding cumulative multipliers. The first columns of these tables are simply the reduced-form coefficients or impact multipliers that were given in the previous section. As was the case with the reduced-form coefficients, these coefficients indicate the time path of the

[8] Arthur S. Goldberger, Econometric Theory, op. cit., p. 375.
[9] Ibid.

TABLE 7.5a

DELAY MULTIPLIERS: AUSTRALIAN RAINFALL

Endogenous Variable	Time Period 0	1	2	3	4	5	6	7	8
Pw_t	-.1190	-.1652	-.1601	-.1310	-.1031	-.0746	-.0491	-.0259	-.0152
Wau_t	.5692	.3757	.2479	.2045	.1548	.0958	.0485	.0653	.0472
Wsa_t	.0000	.0612	.0296	.0095	.0220	+.0498	.0061	-.0039	.0004
Cus_t	.5059	.7783	.8100	.6998	.5666	.4233	.2895	.1668	.0988
Cuk_t	.0000	.0773	.1073	.1040	.0851	.0669	.0485	.0319	.0168
Cj_t	.0235	.0327	.0317	.0260	.0204	.0148	.0097	.0051	.0030
Crw_t	.0000	.1679	.2330	.2258	.1847	.1454	.1052	.0692	.0366

TABLE 7.5b

CUMULATIVE MULTIPLIERS: AUSTRALIAN RAINFALL

Endogenous Variable	Time Period 0	1	2	3	4	5	6	7	8
Pw_t	-.1190	-.2842	-.4443	-.5752	-.6783	-.7529	-.8020	-.8279	-.8431
Wau_t	.5692	.9449	1.1928	1.3974	1.5522	1.6479	1.6965	1.7618	1.8089
Wsa_t	.0000	.0612	.0908	.0813	.0593	.1090	.1151	.1112	.1116
Cus_t	.5059	1.2842	2.0942	2.7940	3.3606	3.7839	4.0734	4.2402	4.3390
Cuk_t	.0000	.0773	.1845	.2885	.3736	.4405	.4889	.5208	.5376
Cj_t	.0235	.0562	.0879	.1139	.1343	.1491	.1588	.1640	.1670
Crw_t	.0000	.1679	.4008	.6266	.8113	.9567	1.0619	1.1311	1.1677

response of the endogenous variables to a unit change in an exogenous variable under the assumption that all other exogenous variables remain the same. However, as Goldberger notes, because of the "superposition theorem of mathematical dynamics," it is possible to construct in a linear system the time paths of the responses to complex exogenous shocks by adding together the responses to unit changes.[10]

Tables (7.5a) and (7.5b) give the responses of the world wool price, Australian and South African wool productions, and the United States', United Kingdom's, Japanese and the "Rest-of-the-World" sector's wool consumptions to a "one shot" change and a sustained unit change, respectively, in the Australian rainfall index. A drought would correspond to a negative change in this variable of 10 to 20 points. As the tables indicate, the effect of even a one year drought on most of these variables is strong for at least five years afterwards. Wool prices would be driven up more in the first, second and third year after such a drought than in the initial year; and wool consumption would decrease more in those years, the consumption of the United Kingdom and the "Rest-of-the-World" sector not being affected at all in the initial year due to the delayed response of these variables to price.

Tables (7.6a) and (7.6b) indicate how the same endogenous variables would respond to a "one shot" unit change and a sustained unit change, respectively, in the Australian wheat price, this price being measured in dollars per ten bushels. It should

[10]Arthur S. Goldberger, Impact Multipliers and Dynamic Properties of the Klein-Goldberger Model, op. cit., p. 83; Paul Anthony Samuelson, Foundations of Economic Analysis, Harvard Economic Studies Vol. 8 (Cambridge, Massachusetts: Harvard University Press, 1947), p. 352.

TABLE 7.6a

DELAY MULTIPLIERS: AUSTRALIAN WHEAT PRICE

Endogenous Variable	Time Period 0	1	2	3	4	5	6	7	8
Pw_t	.3657	.5076	.4919	.4025	.3167	.2293	.1507	.0796	.0466
Wau_t	-1.7489	-1.1543	-.7618	-.6285	-.4756	-.2943	-.1491	-.2006	-.1449
Wsa_t	.0000	-.1880	-.0910	.0293	.0676	-.1529	-.0187	.0121	-.0014
Ccu_t	-1.5544	-2.3918	-2.4889	-2.1501	-1.7411	-1.3007	-.8894	-.5126	-.3035
Cuk_t	.0000	-.2375	-.0100	-.3194	-.2614	-.2057	-.1489	-.0979	-.0517
Cj_t	-.0723	-.1005	-.0975	-.0798	-.0628	-.0454	-.0299	-.0158	-.0092
Crw_t	.0000	-.5158	-.7160	-.6937	-.5676	-.4466	-.3233	-.2126	-.1123

TABLE 7.6b

CUMULATIVE MULTIPLIERS: AUSTRALIAN WHEAT PRICE

Endogenous Variable	Time Period 0	1	2	3	4	5	6	7	8
Pw_t	.3657	.8733	1.3652	1.7677	2.0844	2.3136	2.4643	2.5400	2.5906
Wau_t	-1.7489	-2.9032	-3.6650	-4.2935	-4.7691	-5.0634	-5.2124	-5.4130	-5.5580
Wsa_t	.0000	-.1880	-.2790	-.2496	-.1821	-.3350	-.3537	-.3416	-.3430
Cus_t	-1.5544	-3.9462	-6.4351	-8.5852	-10.3263	-11.6270	-12.5164	-13.0290	-13.3325
Cuk_t	.0000	-.2375	-.2207	-.8866	-1.1479	-1.3536	-1.5025	-1.6003	-1.6520
Cj_t	-.0723	-.1728	-.2703	-.3501	-.4128	-.4582	-.4881	-.5039	-.5132
Crw_t	.0000	-.5158	-1.2318	-1.9255	-2.4931	-2.9398	-3.2631	-3.4757	-3.5800

be noted that wheat was found in Chapter 4 to be a substitute crop for wool production. These tables indicate that sustained increases in Australian wheat prices could have a significant depressing effect on activity in the world wool market in general as well as on Australian wool production, and considerable increases in such food prices are not unlikely given the world's current and expected future problems in feeding an expanding population. Table (7.6b) indicates that an increase in this price of ten dollars (that is, to the level of this price in the early 1950's) sustained for the following eight years would lead in the eighth year to a decrease in Australian wool production of some 55.6 million pounds (clean basis), to an increase in the wool price of 25.9 cents and to a decrease in United States' net wool consumption of 130.3 million pounds.

In Tables (7.7a) and (7.7b), the delay and cumulative multipliers for a unit change in United States' disposable income are given. The delay multipliers are especially interesting, for they demonstrate some of the cyclical behavior of the model that is discovered in the analysis of the next section. The initial response of United States' consumption to this change is negative because of the contemporaneous effect on price. However, in the years 1 through 7, the effect is positive on United States' consumption and negative on wool price. Wool production begins to increase and then to decrease in response to the first rising and then falling prices.

Similar cyclical response patterns are found in Tables (7.8a) and (7.8b) which give the delay and response multipliers for a unit change in the United Kingdom's consumption of synthetic fibers variable. While, in the initial year in which an impulse change occurs, an increase in synthetics consumption causes a decrease in wool consumption and prices, in the first year after the change, the lagged effect of the wool price dominates and wool consumption increases, although not back to the original level. Changes in price caused by changed United Kingdom wool consumption

TABLE 7.7a

DELAY MULTIPLIERS: CHANGE IN U.S. DISPOSABLE INCOME

Endogenous Variable	Period 0	1	2	3	4	5	6	7	8
Pw_t	2.2773	-1.3856	-.4022	-.0745	-.1076	-.1389	-.0415	.0051	.0286
Wau_t	.0000	.0000	.0000	.0000	.1379	.2787	-.0057	-.0203	.2130
Wsa_t	.0000	.0000	.2063	.2807	-.2836	-.0247	.3386	-.4769	.2130
Cus_t	-.3817	5.8317	2.5790	.8460	.6707	.7258	.3078	.0459	-.1039
Cuk_t	.0000	-1.4789	.8998	.2612	.0484	.0699	.0902	.0270	-.0033
Cj_t	-.4504	.2740	.0798	.0149	.0213	.0275	.0083	-.0010	-.0057
Crw_t	.0000	-3.2119	1.9544	.5673	.1050	.1517	.1960	.0586	-.0073

TABLE 7.7b

CUMULATIVE MULTIPLIERS: CHANGE IN U.S. DISPOSABLE INCOME

Endogenous Variable	Period 0	1	2	3	4	5	6	7	8
Pw_t	2.2773	.8917	.4895	.4149	.3073	.1684	.1269	.1320	.1606
Wau_t	.0000	.0000	.0000	.0000	.1379	.4166	.4109	.3907	.6037
Wsa_t	.0000	.0000	.2063	.4870	.2034	.1787	.5173	.0404	.1724
Cus_t	-.3817	5.4500	8.0290	8.8750	9.5457	10.2715	10.5793	10.6252	10.5213
Cuk_t	.0000	1.4789	- .5791	-.3179	-.2695	-.1996	-.1094	-.0824	-.0857
Cj_t	-.4504	- .1764	- .0966	-.0817	-.0604	-.0329	-.0246	-.0256	-.0313
Crw_t	.0000	-3.2119	-1.2575	-.6903	-.5852	-.4335	-.2375	-.1789	-.1862

TABLE 7.8a

DELAY MULTIPLIERS: U.K. NET SYNTHETICS CONSUMPTION

Endogenous Variable	Time Period 0	1	2	3	4	5	6	7	8
Pw_t	-.2521	.1707	.0267	.0001	.0100	.0146	.0041	.0003	-.0018
Wau_t	.0000	.0000	.0000	.0000	-.0153	-.298	.0023	.0007	-.0254
Wsa_t	.0000	.0000	-.0228	-.0295	.0329	-.0012	-.0387	.0549	-.0196
Cus_t	1.0714	-.5642	-.1724	-.0361	-.0537	-.0718	-.0300	-.0077	-.0054
Cuk_t	-.8778	.1637	-.1108	-.0173	-.0001	-.0065	-.0095	-.0027	-.0002
Cj_t	.0499	-.0337	-.0053	-.0001	-.0020	-.0029	-.0008	-.0001	.0004
Crw_t	.0000	-.2051	-.2408	-.0376	-.0002	-.0141	-.0205	-.0058	-.0004

TABLE 7.8b

CUMULATIVE MULTIPLIERS: U.K. NET SYNTHETICS CONSUMPTION

Endogenous Variable	Time Period 0	1	2	3	4	5	6	7	8
Pw_t	-.2521	-.0814	-.0547	-.0546	-.0446	-.0300	-.0259	-.0256	-.0274
Wau_t	.0000	.0000	.0000	.0000	-.0153	-.0451	-.0428	-.0420	-.0674
Wsa_t	.0000	.0000	-.0228	-.523	0.0195	-.0207	-.0593	-.0044	-.0240
Cus_t	1.0714	.5072	.3348	.2987	.2450	.1732	.1432	.1355	.1410
Cuk_t	-.8778	-.7141	-.8249	-.8243	-.8424	-.8489	-.8583	-.8610	-.8612
Cj_t	.0499	.0162	.0109	.0108	.0088	.0060	.0051	.0050	.0054
Crw_t	.0000	.3556	.1148	.0772	.0770	.0629	.0423	.0365	.0361

lead to changes in consumption in other countries and in wool production.

In Tables (7.9a) and (7.9b), the delay and cumulative multipliers of a unit change in the change of world non-commercial stocks variable are given. These multipliers show that the initial increase in price caused by a positive one-shot increase in this stocks variable will lead to increases in wool production and decreases in consumption, but after eight years these compensating changes in supply and demand return the price only half-way to its former level. These delayed responses occurring after the initial year of the change would have to be considered by those running a price stabilization scheme based on variation of non-commercial stocks.

The few dynamic multipliers considered in this section demonstrate the need to go beyond the initial responses when analyzing the effects of changes in exogenous variables in markets in which the relationships are of a highly lagged nature. For example, if only the impact multipliers were considered, the significance of a change in Australian rainfall or in the Australian wheat price would be underestimated; and the ultimate qualitative nature of the effects of a change in the rate of growth of United States' disposable income would be misjudged.

These dynamic multipliers give the truncated time paths of the responses of the endogenous variables to particular sequences of changes in exogenous variables. Let us turn now to a consideration of the general inherent response characteristics of the model.

5. Qualitative Analysis of the Model

Important but frequently neglected aspects of a dynamic econometric model are the model's qualitative stability properties.[11] By considering the stability properties of the

[11]In this section, the approach followed is that of Arthur S. Goldberger, ibid., Chapter 4.

TABLE 7.9a

DELAY MULTIPLIERS: CHANGE IN WORLD NON-COMMERCIAL STOCKS

Endogenous Variable	Period 0	1	2	3	4	5	6	7	8
Pw_t	.2091	.0149	-.0113	-.0086	-.0147	-.0231	-.0207	-.157	-.0102
Wau_t	.0000	.0000	.0000	.0000	.0127	.0342	.0237	.0170	.0063
Wsa_t	.0000	.0000	.0189	.0386	.0016	.0021	.0337	-.0204	.0009
Cus_t	-.8888	-.1970	-.0031	.0278	.0653	.1083	.1059	.0854	.0592
Cuk_t	.0000	-.1358	-.0096	.0074	.0056	.0096	.0150	.0134	.0102
Cj_t	-.0414	-.0030	.0022	.0017	.0029	.0046	.0041	.0031	.0020
Crw_t	.0000	-.2949	-.0209	.0160	.0121	.0207	.0325	.0292	.0221

TABLE 7.9b

CUMULATIVE MULTIPLIERS: CHANGE IN WORLD NON-COMMERCIAL STOCKS

Endogenous Variable	Period 0	1	2	3	4	5	6	7	8
Pw_t	.2091	.2240	.2126	.2040	.1893	.1662	.1456	.1299	.1197
Wau_t	.0000	.0000	.0000	.0000	.0127	.0469	.0705	.0875	.1213
Wsa_t	.0000	.0000	.0189	.0576	.0592	.0614	.0951	.0747	.0756
Cus_t	-.8888	-1.0858	-1.0890	-1.0612	-.9959	-.8875	-.7817	-.6963	-.6370
Cuk_t	.0000	- .1358	- .1454	- .1381	-.1325	-.1229	-.1080	-.0945	-.0844
Cj_t	-.0414	- .0444	- .0421	- .0404	-.0375	-.0330	-.0289	-.0258	-.0237
Crw_t	.0000	- .2949	- .3158	- .2998	-.2877	-.2670	-.2344	-.2053	-.1832

model, we are studying the implied long-run time paths of the endogenous variables. Stability implies that, as time goes on, these variables get arbitrarily close to their equilibrium values or the particular solution of the system determined by the exogenous variables and the stochastic terms. An analysis of the stability of the model will also serve as a test of the reasonableness of the estimated model. A stable model would imply that the estimated equations have captured a significant amount of the systematic, non-random structure of the market.

The reduced form of the world wool market model is a second-order difference equation system which can be transformed easily into a first-order system. The only endogenous variable lagged two periods is the wool price. This system may be written as

$$
\begin{aligned}
P_t &= a_{1,1}P_{t-1} + a_{1,2}P_{t-2} + a_{1,3}y_{1_{t-1}} + \dots + a_{1,26}\, y_{24_{t-1}} + z_{1_t} \\
y_{1_t} &= a_{2,1}P_{t-1} + a_{2,2}P_{t-2} + a_{2,3}y_{1_{t-1}} + \dots + a_{2,26}\, y_{24_{t-1}} + z_{2_t} \\
&\vdots \\
y_{24_t} &= a_{25,1}P_{t-1} + a_{25,2}\, P_{t-2} + a_{25,3}y_{1_{t-1}} + \dots + a_{25,26}y_{24_{t-1}} \\
&\qquad + z_{25_t}
\end{aligned} \tag{7.37}
$$

where P_t is the wool price, $y_{1_{t-1}} \dots y_{24,t-1}$, are the 24 other endogenous variables in the system and z_{1_t} , ... z_{25_t} are the summed effects of the exogenous variables and the stochastic term in each reduced-form equation. System (7.37) can be transformed into a first-order system by defining a new variable $P^*_t = P_{t-1}$. We then have system (7.38) of 26 equations in 26 endogenous variables

$$P_t = a_{1,1} P_{t-1} + a_{1,2} P^*_{t-1} + a_{1,3} y1_{t-1} + \ldots\ldots + a_{1,26} y24_{t-1} + z1_t$$

(7.38)

$$y1_t = a_{2,1} P_{t-1} + a_{2,2} P^*_{t-1} + a_{2,3} y1_{t-1} + \ldots\ldots + a_{2,26} y24_{t-1} + z2_t$$

$$\vdots \qquad\qquad \vdots$$

$$y24 = a_{25,1} P_{t-1} + a_{25,2} P^*_{t-1} + a_{25,3} y1_{t-1} + \ldots\ldots + a_{25,26} y24_{t-1} + z25_t$$

$$P^*_t = P_{t-1}$$

By bringing the right-hand side of the equations in (7.38) over to the left, the system can be re-written as

$$- a_{1,1} P_{t-1} + P_t - a_{1,2} P^*_{t-1} - a_{1,3} y1_{t-1} \ldots - a_{1,26} y24_{t-1} + z1_t = 0$$

$$- P_{t-1} + P^*_t = 0$$

(7.39)

$$- a_{2,1} P_{t-1} - a_{2,2} P^*_{t-1} - a_{2,3} y1_{t-1} + y1_t \ldots - a_{2,26} y24_{t-1} + z2_t = 0$$

$$\vdots \qquad\qquad \vdots$$

$$- a_{25,1} P_{t-1} - a_{25,2} P^*_{t-1} - a_{25,3} y1_{t-1} \ldots - a_{25,26} y24_{t-1} + y24_t + z25_t = 0$$

where the equation defining P^*_t has been inserted just after the equation for P_t. Using the lag operator E, where $Ey_t = y_{t-1}$, the system can be rewritten in matrix notation as

$$(7.40) \qquad [\,I - A\,(E)\,] \begin{bmatrix} P_t \\ P_t^* \\ y_{1_t} \\ \vdots \\ y_{24_t} \end{bmatrix} + [\,Z_t\,] = 0$$

Stability of this system requires that the roots of the characteristic matrix, A, have modulus less than unity. The estimated roots of the characteristic matrix for the wool market model are given in Table (7.10).[12] These estimated roots imply that the model is quite stable. The characteristic equation of the system is common to all of the endogenous variables of the model, and hence each endogenous variable has the same characteristic roots and corresponding stability or instability properties. Thus in the wool market model, the basic characteristic component of the solutions of the endogenous variables has monotonic components corresponding to the two positive real roots, λ_1, and λ_6, sawtooth components, which are positive in even years and negative in odd years, corresponding to the three negative real roots, λ_{11}, λ_{12}, λ_{13}, and oscillatory components corresponding to the eight pairs of complex roots, λ_2, λ_3, λ_4, λ_5, λ_7, λ_8, λ_9, λ_{10}, λ_{14}, λ_{15}, λ_{16}, λ_{17}, λ_{18}, λ_{19}, λ_{20}, λ_{21}. The oscillatory components corresponding to these eight pairs of roots have periods of 33.1431 years, 11.8861 years, 2.2088 years, 4.2208 years, 2.3583 years, 2.4372 years, 3.7167 years and 8.6076 years with corresponding damping factors of $(.7035)^t$, $(.2026)^t$, $(.0001)^t$, $(.0001)^t$, $(.3212)^t$, $(.6000)^t$, $(.7256)^t$ and $(.7114)^t$.[13] Such oscillatory behavior was

[12] These roots were obtained by first reducing the matrix to Hessenberg form. The roots were then found by LaGuerre's method using the Hessenberg form to evaluate the polynomial and derivatives.

[13] The oscillatory component contributed by the complex roots, $\lambda = \alpha + \beta i$, $\lambda = \alpha - \beta i$, has period equal to $360/\theta$, where $\theta = \arctan(\beta/\alpha)$, and with damping factor, ρ^t, where $\rho = (\alpha^2+\beta^2)^{\frac{1}{2}}$, that is, the modulus.

TABLE 7.10

ROOTS OF THE CHARACTERISTIC MATRIX OF THE WOOL MARKET MODEL

	Real Part	Imaginary Part
λ_1	.759027	0.0
λ_2	.690883	.132568
λ_3	.690883	-.132568
λ_4	.174906	.102156
λ_5	.174906	-.102156
λ_6	.064163	0.0
λ_7	-.000108	.000044
λ_8	-.000108	-.000044
λ_9	.000007	.000085
λ_{10}	.000007	-.000085
λ_{11}	-.054098	0.0
λ_{12}	-.075425	0.0
λ_{13}	-.137134	0.0
λ_{14}	-.285267	.147556
λ_{15}	-.285267	-.147556
λ_{16}	-.507158	.320481
λ_{17}	-.507158	-.320481
λ_{18}	-.056671	.720387
λ_{19}	-.056671	-.720387
λ_{20}	.530164	.474414
λ_{21}	.530164	-.474414
λ_{22}	0.0	0.0
λ_{23}	0.0	0.0
λ_{24}	0.0	0.0
λ_{25}	0.0	0.0
λ_{26}	0.0	0.0

found in the dynamic multipliers derived in the previous section. One of the zero valued roots is probably a very small positive real root, for the program iterated down to the value .45205037E-7 and then set the value of the root equal to zero. The four other zero valued roots result from the reduced-form equations for consumption in the United Kingdom, France, Germany and Belgium and for P_t^* which have zero coefficients for the diagonal terms.

These roots indicate that much of the oscillatory component of the inherent response of the system consists of components with long periods. Also, the frequency range corresponding to periods of two to four years is significant. These results are substantiated by the spectral analysis of Australian wool production and Merino wool prices for the years 1863 to 1962 that is reported in Chapter 8. In this analysis significant peaks were found in the spectra of both series in the low frequency range corresponding to periods of 8 or more years and in the spectrum of wool production at frequencies corresponding to periods of 2.2, 3.1 and 4.4 years. A wide peak was found in the spectrum of wool prices in the frequency range corresponding to periods of 2.35 to 4 years. Such peaks indicate that oscillatory components with these periods are relatively more important than those of other periods. A more detailed account of this analysis and the techniques used is given in Chapter 8.

These roots characterize the inherent response characteristics of the system or the basic characteristic component of the complete solution of the system. The complete solution also contains a particular component, which depends on the time path of the exogenous variables and the stochastic or error terms, and a component which depends on the initial conditions of the system. Goldberger points out that the particular and initial solution components of the solution of a system of first-order difference equations can substantially alter the qualitative nature of the complete solution that is suggested by an analysis of the system's initial response characteristics.[14] In particular, fluctuating exogenous variables such as income and weather and components of the stochastic terms such as changing tastes and expectations (much of which has not been included in the structural equations) could lead to a higher degree of instability in the market than the above analysis suggests.[15]

6. Prediction

In this section we give some predictions by means of the model for the year following the period for which the model was fitted and for a year within the observation period. Such predictions are one means by which the reasonableness of the model can be evaluated. Three types of predictions are given in Table (7.11) for the season 1964-65 in the case of the wool price, wool production and end-of-season producers' stocks variables and for the calendar year 1965 for the consumption and consumer stocks variables. The first type of predictions, "partial predictions"[16] are obtained by inserting the observed values of all explanatory variables, including endogenous variables, into the structural equations and then solving for the dependent variables. This method of prediction suppresses the simultaneity in the system but serves as a test of the individual equations.

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[14] Arthur S. Goldberger, Impact Multipliers and Dynamic Properties of the Klein-Goldberger Model, op. cit., p. 119.

[15] For a discussion of the importance of the stochastic terms in determining the qualitative nature of the model, see E. P. Howrey, Dynamic Properties of Linear Stochastic Models, Princeton University, mimeographed (1967).

[16] Arthur S. Goldberger, Impact Multipliers and Dynamic Properties of the Klein-Goldberger Model, op. cit., p. 49.

The second type of predictions, reduced-form predictions, are obtained by inserting the observed values of all predetermined variables into the reduced-form equations of the model, which were derived in section 3 of this chapter, and solving for the endogenous variables. This method does take account of the simultaneity in the model and serves as a test of the model as a whole. However, if one of the structural equations is faulty, the errors in this equation may cause significant errors in the reduced-form equations for other endogenous variables which are determined simultaneously. In the cases of the endogenous variables whose structural equations contain no explanatory current endogenous variables, these first two types of predictions coincide.

The third type of predictions, termed generalized-least-squares predictions, were made for the wool production variables whose structural equations were estimated by an approximate form of generalized least squares, that is, for the wool productions of Australia, New Zealand, Uruguay and the "Rest-of-the-World" sector. As was described in Chapter 4, these structural estimates were obtained by transforming the dependent variable, y_t, and the independent variables, $x_{1t}, x_{2t}, \ldots\ldots, x_{n_t}$, by the estimated auto-correlation coefficient of the residuals,[17] $\hat{\rho}_1$, to $y_t - \hat{\rho}_1 y_{t-1}$, $x_{1_t} - \hat{\rho}_1 x_{1_{t-1}}$, $x_{2_t} - \hat{\rho}_1 x_{2_{t-1}}, \ldots, x_{n_t} - \hat{\rho}_1 x_{n_{t-1}}$. The structural coefficients, β_j, were then estimated by applying ordinary least squares to

(7.41)

$$y_t - \hat{\rho}_1 y_{t-1} = \beta_1 (x_{1_t} - \hat{\rho}_1 x_{1_{t-1}}) + \beta_2 (x_{2_t} - \hat{\rho}_1 x_{2_{t-1}}) + \ldots + \beta_n (x_{n_t} - \hat{\rho}_1 x_{n_{t-1}}) .$$

[17]For purposes of exposition, the first-order case is considered here. For some equations, the second-order case was used.

TABLE 7.11

PREDICTIONS FOR THE SEASON 1964-65 AND THE CALENDAR YEAR 1965[a]

Variables	Actual Values	Partial Predictions	Reduced-Form Predictions	Generalized Least Squares Predictions
1 Pw_t	80.2	110.573	46.164	..
2 Wau_t	1025.8	1076.949	1076.949	1001.440
3 Wnz_t	439.2	443.877	443.877	442.390
4 Wsa_t	153.9	170.483	169.035	..
5 Wag_t	230.5	234.618	233.459	..
6 Wur_t	117.8	124.435	124.435	121.510
7 Wus_t	125.4	123.863	123.863	..
8 Wrw_t	1177.2	1207.763	1207.763	1213.638
9 Sau_t	49.0	36.760	34.224	..
10 Snz_t	26.0	4.059[c]	-23.330	..
11 Ssa_t	3.0	1.218	.283	..
12 Sag_t	47.0	29.759	113.863	..
13 Sur_t	24.0	28.9030	39.381	..
14 Cus_t	444.9[b]	348.561	492.071	..
15 $SCus_t$	103.0	123.359	150.474	..
16 Cuk_t	240.0[b]	190.938	190.938	..
17 $SCuk_t$	174.0	150.839	135.206	..
18 Cj_t	294.6[b]	408.648	415.332	..
19 SCj_t	33.0	29.873	48.954	..
20 Cf_t	134.8[b]	133.978	133.978	..
21 Ci_t	93.8[b]	93.012	122.218	..
22 Cg_t	287.1[b]	241.914	252.145	..
23 Cb_t	11.3[b]	6.555	11.065	..
24 Cn_t	57.0[b]	53.129	53.129	..
25 Crw_t	1695.0[b]	1646.449	1646.449	..

a. Pw_t is in United States cents per pound, clean basis. All other variables are in millions of pounds, clean basis.

b. These values were estimated from mill consumption data.

c. This estimate is from the New Zealand stock equation (5.6) in Chapter 5 which is not in the final system. Clearly, the partial estimate from identity (7.25) would be exact.

Johnston shows that, when such estimates are obtained, the prediction of y_{t+1} obtained from transforming the variables in the manner used above, that is, predicting y_{t+1} by the generalized least squared method,

$$(7.42) \quad y_{t+1} = \hat{\rho}_1 y_t + \beta_1 (x_{1_{t+1}} - \hat{\rho}_1 x_{1_t}) + \beta_2 (x_{2_{t+1}} - \hat{\rho}_1 x_{2_t}) + \ldots + \beta_n (x_{n_{t+1}} - \hat{\rho}_1 x_{n_t})$$

is more efficient than predicting by

$$(7.43) \quad y_{t+1} = \beta_1 x1_{t+1} + \beta_2 x2_{t+1} + \ldots + \beta_n x_{n_{t+1}}$$

because the latter takes no account of recent disturbance terms.[18]

As Table (7.11) indicates, all of the "actual" values for net consumption in 1965 are estimates obtained from preliminary mill consumption figures and the relationship between net and mill consumption figures that existed in 1963. Many of the exogenous variables used in obtaining the predictions also had to be estimated. The South American export policy dummy variables were given values of 1.0 in 1965 due to the adverse conditions that existed. The predictions for wool production in the 1964-65 season are not really predictions outside of the sample period, for the wool production equations were fitted to data which included initial estimates of 1964-65 data. Therefore, estimates for the season 1965-66 are given in Table (7.12) for the wool production variables. It was not possible to estimate the other endogenous variables for 1966, for practically no data was available at the time.

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[18] J. Johnston, Econometric Methods (New York: McGraw-Hill Book Company, Inc., 1963), pp. 196-197.

Comparing the 1965 predictions in Table (7.11), 11 of the partial predictions are better than the reduced-form predictions, some significantly so. Only three of the reduced-form predictions are better than the partial predictions. This result is to be expected because partial predictions are made on the basis of more information. While the partial prediction of the world wool price is some four cents closer to the actual wool price, the reduced-form prediction did forecast correctly that the wool price would fall significantly while the partial prediction forecast that the price would continue to rise. Thus, in a very important sense, the reduced-form price prediction, which takes into account all the simultaneity in the model, is superior. The negative reduced-form prediction for New Zealand stocks results from defining these stocks by a market clearing identity which adds together the errors made in forecasting the other variables. One surprisingly bad forecast is that for Japanese consumption, considering the fairly good statistical fit of the corresponding equation to the data of the observation period. This high forecast resulted mainly from a very high preliminary estimate of deflated national income in 1965 of 64.0 billion dollars,[19] an increase of 9.6 billion dollars over that of 1964. Estimated net consumption went up only slightly, suggesting that the phenomenal growth of the textile market in Japan may be slowing down perhaps due to increases in the consumer's stocks of clothing and/or a change in consumers' tastes. This conclusion is substantiated by the fact that net consumption of synthetic fibers actually declined in the same period after growing at a very fast rate in previous years. Thus the estimated income elasticity of 1.2955 for Japanese

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[19]This preliminary estimate from the United Nations, Department of Economics and Social Affairs, Statistical Office of the United Nations, Statistical Yearbook (New York, 1966), was converted to U.S. dollars at the average 1965 exchange rate and deflated by the 1965 wholesale price index.

TABLE 7.12

WOOL PRODUCTION PREDICTIONS 1965-66
(Millions of Pounds, Clean Basis)

Variables	Actual Values	Reduced-Form Predictions	Generalized Least Squares Predictions
Wau_t	941.8	1057.755	1078.381
Wnz_t	490.0	449.411	458.355
Wsa_t	169.0	153.839	..
Wag_t	218.4	233.672	..
Wur_t	115.3	121.149	119.367
Wus_t	120.2	129.7922	..
Wrw_t	1197.2	1181.9930	1215.066

demand may be too high for the coming years. However, early reports on 1966 activity in the Japanese wool textile industry stating a strong increase in activity over that for 1965 suggest that the income effect may have just been delayed. This delay is probably due to the fact that major portion of the increase in income in 1965 occurred in the last two quarters.

The 1964-65 reduced-form predictions of wool production are inferior in all but one case to the generalized least squares predictions. For the predictions for 1965-66 given in Table (7.12), there are two cases for which the generalized least squares estimates are superior. Both types of prediction failed to predict the 8 percent drop in the 1965-66 season in wool production in Australia caused by the continued draught which was longer and more severe than any that occurred in the period for which the Australian equation was estimated. This failure indicates that further research needs to be done on this aspect of the

Australian production equation.

As the data used in the above predictions are preliminary and thus subject to considerable revision, predictions were also generated for the season 1954-55 and the calendar year 1955 with the more reliable data that exists for that period. These predictions, which are given in Table (7.13), are better than those for 1965 and the seasons 1964-65, as should be expected; for they are within the sample period used in estimating the model.

TABLE 7.13

PREDICTIONS FOR THE SEASON 1954-55 AND THE CALENDAR YEAR 1955[a]

Variables	Actual Values	Partial Predictions	Reduced-Form Predictions	Generalized Least Squares Predictions
1 Pw_t	101.5	104.47	113.03	..
2 Wau_t	723.9	750.82	750.82	765.874
3 Wnz_t	309.9	304.67	304.67	312.541
4 Wsa_t	150.0	149.25	149.25	..
5 Wag_t	212.1	228.17	228.17	..
6 Wur_t	126.2	128.66	128.66	127.341
7 Wus_t	122.9	121.89	121.89	..
8 Wrw_t	980.0	1022.12	1022.12	997.485
9 Sau_t	10.0	9.24	10.10	..
10 Snz_t	12.0	10.78[b]	18.43	..
11 Ssa_t	1.0	1.59	1.93	..
12 Sag_t	55.0	45.93	51.15	..
13 Sur_t	40.0	38.06	37.19	..
14 Cus_t	453.5	489.75	441.37	..
15 $SCus_t$	138.0	133.07	144.50	..
16 Cuk_t	281.50	279.19	279.19	..
17 $SCuk_t$	145.0	174.31	183.07	..
18 Cj_t	115.1	140.67	138.38	..
19 SCj_t	25.0	26.70	31.19	..
20 Cf_t	143.1	145.86	145.86	..
21 Ci_t	43.7	74.2	69.57	..
22 Cg_t	235.0	217.95	214.43	..
23 Cb_t	32.6	40.68	39.15	..
24 Cn_t	53.1	53.33	53.33	..
25 Crw_t	1303.0	1308.74	1308.74	..

a. Pw_t is in United States cents per pound, clean basis. All other variables are in millions of pounds, clean basis.

b. This estimate is from the New Zealand stock equation in Chapter 5 which is not in the final system. Clearly, the partial estimate from identity (7.25) would be exact.

APPENDIX TO CHAPTER 7

The endogenous variables determined by the world wool market model are:

1. Pw_t = Deflated world wool price, season t-1, t
2. Wau_t = Australian wool production, season t-1, t
3. Wnz_t = New Zealand wool production, season t-1, t
4. Wsa_t = South African wool production, season t-1, t
5. Wag_t = Argentine wool production, season t-1, t
6. Wur_t = Uruguayan wool production, season t-1, t
7. Wus_t = United States wool production, season t-1, t
8. Wrw_t = "Rest-of-the-World" wool production, season t-1, t
9. Sau_t = Australian producer stocks, end of season t-1, t
10. Snz_t = New Zealand producer stocks, end of season t-1, t
11. Ssa_t = South African producer stocks, end of season t-1, t
12. Sag_t = Argentine producer stocks, end of season t-1, t
13. Sur_t = Uruguayan producer stocks, end of season t-1, t
14. Cus_t = United States net wool consumption, year t
15. $SCus_t$ = United States commercial wool stocks, year t
16. Cuk_t = United Kingdom net wool consumption, year t
17. $SCuk_t$ = United Kingdom commercial wool stocks, year t
18. Cj_t = Japanese net wool consumption, year t
19. SCj_t = Japanese commercial wool stocks, year t
20. Cf_t = French net wool consumption, year t
21. Ci_t = Italian net wool consumption, year t
22. Cg_t = German net wool consumption, year t

23. Cb_t = Belgian net wool consumption, year t

24. Cn_t = Netherlands net wool consumption, year t

25. Crw_t = "Rest-of-the-World" net wool consumption, year t

26. $MCus_t$ = United States mill consumption of wool, year t

27. $MCur_t$ = United Kingdom mill consumption of wool, year t

28. MCj_t = Japanese mill consumption of wool, year t

The exogenous variables in the world wool market model are, in order of their appearance in the model,

(1) $Pwhau_{t-2}$ = Australian deflated wheat price, first year of season t-3, t-2

(2) Fau_{t-1} = Australian use of super-phosphate fertilizers, season t-2, t-1

(3) Rau_t = Australian rainfall index, season t-1, t

(4) RP_{t-1} = New Zealand deflated reserve price for wool, season t-2, t-1

(5) $Plnz_{t-2}$ = New Zealand deflated lamb price, first year of season t-3, t-2

(6) $Pwhsa_{t-2}$ = South African deflated wheat price, first year of season t-3, t-2

(7) Rsa_{t-1} = South African rainfall index, season t-2, t-1

(8) $Pwhag_{t-1}$ = Argentine deflated wheat price, first year of season t-2, t-1

(9) $Pbag_{t-1}$ = Argentine deflated beef price, first year of season t-2, t-1

(10) Rag_t = Argentine rainfall index, season t-1, t

(11) $Pbur_{t-1}$ = Uruguayan deflated beef price index, second year of season t-2, t-1

(12) $Phur_{t-1}$ = Uruguayan deflated hide index, second year of season t-2, t-1

(13) $Pwus_{t-2}$ = United States deflated wool support price, year t-2

(14) $Pwhus_{t-2}$ = United States deflated wheat price, year t-2

(15) $Pbus_{t-2}$ = United States deflated beef price, year t-2

(16) $Plus_{t-2}$ = United States deflated lamb price, year t-2

(17) Dag_t = Argentine export policy dummy variable, year t

(18) Dur_t = Uruguay export policy dummy variable, year t

(19) Yus_t = United States deflated disposable income, year t

(20) ΔYus_t = $Yus_t - Yus_{t-1}$

(21) $NSus_t$ = United States net consumption of synthetic fibers, year t

(22) KWD_t = Korean War dummy variable

(23) Yuk_t = United Kingdom deflated disposable income, year t

(24) ΔYuk_t = $Yuk_t - Yuk_{t-1}$

(25) $NSuk_t$ = United Kingdom net consumption of synthetic fibers, year t

(26) Yj_t = Japanese deflated national income, year t

(27) ΔYj_t = $Yj_t - Yj_{t-1}$

(28) NSj_t = Japanese net consumption of synthetic fibers, year t

(29) Yf_t = French deflated national income, year t

(30) Df_t = French Algerian war dummy variable

(31) Yi_t = Italian deflated national income, year t

(32) Yg_t = German deflated national income, year t

(33) ΔYg_t = $Yg_t - Yg_{t-1}$

(34) NSg_t = German net consumption of synthetic fibers, year t

(35) Yb_t = Belgian deflated national income, year t

(36) NSb_t = Belgian net consumption of synthetic fibers, year t

(37) Yn_t = Netherlands deflated national income, year t

(38) Yrw_t = Index of deflated world income, year t

(39) ΔYrw_t = $Yrw_t - Yrw_{t-1}$

(40) $NSrw_t$ = "Rest-of-the-World" net consumption of synthetic fibers, year t

(41) ΔSNC_t = Change in world non-commercial stocks, end-of-season t-1, t

(42) $\Delta SCrw_t$ = Change in world residual stocks, end-of-season t-1, t

(43) $NIus_t$ = United States net imports of wool products, year t

(44) $NIuk_t$ = United Kingdom net imports of wool products, year t

(45) NIj_t = Japanese net imports of wool products, year t

For a fuller description of these variables, see Chapters 3,4,5 and 6 in which these variables are introduced.

CHAPTER 8

SHORT-RUN MOVEMENTS IN WOOL PRICES AND RELATED TIME SERIES

1. Introduction

The approach of the earlier chapters was to study annual movements of wool prices, production, consumption and stocks from a structural point of view by specifying, estimating and analyzing a simultaneous equation model of the world wool market. In this chapter we turn to a study of monthly time series, mainly different wool price series, from a point of view which ignores most of the simultaneous interactions in the market and concentrates on the description of the stochastic processes which, given many simplifying assumptions, may be thought to generate these time series. A basic hypothesis of this study is that most segments of the wool market are closely related and that prices in different auction centers and for different quality wools move together. One purpose of this chapter is to examine this hypothesis as it relates to monthly wool prices. Ideally, one would wish to take account of the simultaneous relationships that exist in movements at all frequencies in the time series. However, the high serial correlation of the monthly data prohibited the structural approach from being followed. What is lost by omission of many of the simultaneous relationships is offset, to some degree, by the powerful methods of spectral and cross-spectral analysis. In Section 2 of this chapter, the techniques of spectral analysis are outlined and are applied in Section 3 to the various monthly wool price series. In Section 4 a simple model of monthly wool price determination is developed. In Section 5 the techniques of cross-spectral analysis are outlined and in Section 6 are applied to a comparison of monthly prices of different qualities of wool and of wool sold at different selling centers. In Section 7 results of spectral and cross-spectral analysis of United

States monthly mill consumption, wool prices and a general index of industrial activity are given. In Section 8 the techniques of spectral and cross-spectral analysis are applied to long-run annual data on wool prices and Australian wool production. Finally, in the Appendix to this chapter, the possibility of developing simple methods of forecasting monthly wool prices is studied.

2. Spectral Analysis of Economic Time Series

Although the techniques of spectral analysis were introduced by Bartlett and Tukey around 1950, until very recently these techniques had not been used widely or even understood by most econometricians because the methods are highly mathematical and still rapidly evolving with many problems still not resolved in a satisfactory manner and also because economists were unaccustomed to considering economic time series in terms of their frequency components. In this chapter the techniques are only briefly outlined, and the reader should consult some of the references for a more complete description of the theory of spectral analysis and the many subtle problems that arise in applying these techniques to economic time series.[1]

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[1]Useful references on spectral and cross-spectral analysis are C.W.J. Granger and M. Hatanaka, Spectral Analysis of Economic Time Series (Princeton, New Jersey: Princeton University Press, 1964); G. M. Jenkins, "General Considerations in the Analysis of Spectra," Technometrics, Vol. 3 (May, 1961), pp. 133-166; G. M. Jenkins, "Some Examples of and Comments on Spectral Analysis," in Proceedings of the IBM Scientific Computing Symposium on Statistics, October 21-23, 1963 (White Plains, New York: International Business Machines Corporation, 1965); Marc Nerlove, "Spectral Analysis of Seasonal Adjustment Procedures," Econometrica, Vol. XXXII (July, 1964), pp. 241-286; and Emanuel Parzen, "Mathematical Considerations in the Estimation of Spectra," Technometrics, Vol. III (May, 1961), pp. 167-190.

Consider a time series $\{x_t\}$, $t=\ldots, -2, -1, 0, 1, 2,\ldots$. It is composed of fluctuations of varying lengths of time and varying regularity. Spectral analysis is concerned with examining the relative importance of these fluctuations. The time series is assumed to be generated by a stochastic process defined by a collection of random variables, $\{x_t\}$, and characterized by a joint probability distribution of these random variables. The data are considered to be a sample drawn from the population, that is, a realization of the stochastic process drawn from the collection of all possible realizations, the ensemble.

The stochastic process may be described by its moments defined over the ensemble which are called ensemble moments. However, since in the the analysis of economic data usually only one realization of the process is available, estimation must be based on averages over time, that is, averages down the realization. Thus, in order to be able to make statistical inferences, the stochastic process being studied must be a weakly stationary ergodic process.[2] This condition requires that the mean, variance and the autocovariances of the series be independent of time; that is,

$$E\,(x_t) = u \qquad \text{(independent of } t\text{)}$$

$$E[(x_t-u)\,(x_{t+s}-u)] = \gamma(s), \qquad (s=0,1,\ldots;\ \text{independent of } t)$$

This condition, also known as "covariance stationarity," "stationarity in the wide sense " or "second-order stationarity," is a condition of statistical equilibrium in the stochastic process to ensure equivalence between time averages and ensemble

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[2]For the application of spectrum techniques to non-stationary processes see Michio Hatanaka and Mitsuo Suzuki, A Theory of the Pseudo Spectrum and its Application to Non-Stationary Dynamic Econometric Models, Research Memorandum No. 52, Econometric Research Program, Princeton University (January, 1963).

averages. This condition means that attention must be restricted to situations where temporary shifts in economic phenomena (for example, variations in weather) are dominant over permanent changes in the economic structure. It is difficult to meet this condition in studying raw economic time series; but some of the simpler forms of nonstationarity, such as a linear trend in the mean, may be corrected for by a simple transformation of the data, such as linear detrending or taking first differences. In this study it is assumed that by removing a linear trend in the mean the stationarity condition is approximately satisfied. This assumption appears to be valid for all of the series analyzed.

If the stochastic process is not only weakly stationary but also Gaussian, then this stochastic process is entirely described by its autocovariance functions, $\gamma(s)$. We may normalize the autocovariances, $\gamma(s)$, by dividing each by the variance, $\gamma(0)$, obtaining the autocorrelation coefficients of the process. A plot of the autocorrelation coefficients as a function of the time lag, s, is called the correlogram of the time series and can be used to analyze the time series in the time domain. However, since neighboring autocorrelations in a sample autocorrelation function tend to be highly correlated and thus make the estimation of the correlogram very difficult, it is preferable to avoid this problem by analyzing the time series in the frequency domain.

When the stationarity condition is met, the power spectral density function of the time series, $f(\omega)$, where ω=frequency, is the Fourier transform of the autocovariance function, $\gamma(s)$; that is, the autocovariance function and the power spectral density function are a Fourier transform pair, two different representations of the same information; and one might consider one as well as the other.

The power spectral density function is given by

(8.1) $$f(\omega) = \frac{1}{2\pi} \sum_{s=-\infty}^{\infty} e^{-is\omega} \gamma(s) \quad , \qquad (0 \leq \omega \leq \pi)$$

and the autocovariance function is given by

$$(8.2) \qquad \gamma(s) = \int_{-\pi}^{\pi} f(\omega)e^{i\omega s}d\omega \ , \qquad (-\infty \leq s \leq -\infty)$$

which for a real process can be shown equivalent to

$$(8.3) \qquad = \int_{-\pi}^{\pi} \cos \omega s \ f(\omega) \ d(\omega) \ . \qquad (-\infty \leq s \leq -\infty)$$

For the case of s=0, $\gamma(0)$ is the variance of the time series; and

$$(8.4) \qquad \gamma(0) = \int_{-\pi}^{\pi} \cos (0) \ f(\omega) \ d(\omega) = \int_{-\pi}^{\pi} f(\omega)d\omega \ ,$$

which demonstrates that the power spectral density function is a measure of the contribution to the total variance of the series from an infinitesimal frequency interval about ω. "Thus the spectrum of a time series may be thought of as a decomposition of the variance at different frequencies,"[3] and the above expression "expresses the variance of $\{x_t\}$ as the sum of variances at different frequencies."[4] By looking at the power spectral density function of a series, the relative importance of the different frequency components (fluctuations of different periods) in shaping the overall process can be determined; for if a particular frequency band contributes a large proportion of the total variance, it may be considered to be more important than a frequency band which contributes a smaller amount to the

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[3]Marc Nerlove, op. cit., p. 248.

[4]Ibid.

variance. In practice such discrimination proves to be difficult due to the estimation problems involved.

The discrete analogue of equation (8.1) is

$$(8.5) \quad f(\omega) = \frac{1}{\pi} [\gamma(0) + 2\sum_{s=1}^{M} \cos 2\pi\omega s \gamma(s)] \quad , \left(0 \leq \omega \leq \pi\right)$$

where M is the maximum number of lags taken in estimating the autocovariances. It is necessary to estimate the power spectral density function at each frequency by taking weighted averages across a small interval around each frequency in order to obtain statistically consistent estimates. Taking weighted averages across a small band in the frequency range corresponds to weighting the estimated autocovariances before making the estimates of the power spectral density function. A weighting scheme for the autocovariances is called a <u>spectral window</u>, and there is considerable discussion in the literature about the properties of alternative windows.[5] The window used in this study is one recommended by Parzen which has the desirable property that it yields spectral estimates which are everywhere positive.[6] The weighted autocovariances, c (s), substituted in (8.5) for the raw autocovariances, γ (s), are computed by

$$(8.6) \quad c(s) = \sum_{k=1}^{M} W(k) \gamma(k)$$

[5]R. B. Blackman and J. W. Tukey, <u>The Measurement of Power Spectra</u> (New York: Dover Publications, Inc., 1958), G. M. Jenkins, "General Considerations in the Analysis of Spectra," <u>op. cit.</u>, and Emanuel Parzen, <u>op. cit</u>.

[6]Emanuel Parzen, <u>op. cit</u>., p. 176.

where the weights, $W(k)$, are given by

$$(8.7) \quad W(k) = \begin{cases} 1-6\frac{k^2}{M^2}\left(1-\frac{k}{M}\right), & \left(0 \leq k \leq \frac{M}{2}\right) \\ 2\left(1-\frac{k}{M}\right)^3, & \left(\frac{M}{2} \leq k \leq M\right) \\ 0, & (M < k) \end{cases}$$

and where M is the maximal lag. This window emphasizes the frequencies near ω on which it is centered and suppresses the frequencies distant from this frequency. However, since not all the weight is concentrated on the frequency on which the window is centered, the existence of very high power at some frequency is likely to distort the spectral estimates at other frequencies, this distortion being known as "leakage."

The degree to which an estimate of the power spectral density function is distorted by leakage is a function not only of the type of window but also of the maximal lag which regulates the band width of the window. In the time domain, the maximal lag corresponds to the number of autocovariance functions we choose to estimate. The more we estimate, the smaller the number of degrees of freedom we have for the estimation of each autocovariance and hence the greater the variance of the estimates. In the frequency domain, however, the greater the maximal lag, the smaller the band width of the window and hence the greater the discrimination between spectral estimates at neighboring frequencies. In this study, the problem of achieving the best trade off between higher resolution and less variance of the estimates was met by estimating the spectra with increasingly small windows until the estimates appeared to become "unstable." The length of the time series varies from 100 to 156 observations and the corresponding maximal lags used varied from 36 to 48.

Let us now turn to the application of spectral analysis to time series generated in the world wool market. The spectral estimates given in the rest of this chapter are of the <u>normalized</u>

power spectral density function; that is, we estimate

(8.8) $$\frac{\pi f(\omega)}{\gamma(0)} \qquad (0 \leq \omega \leq \pi)$$

where $f(\omega)$ is estimate of $f(\omega)$ and $\gamma(0)$ is the estimated variance. This function is referred to in the rest of this chapter as the <u>spectral density function</u> or, in some cases, simply the <u>spectrum</u> of the series and is such that the theoretical spectral density of a purely random series (or "white noise") is 0.5 for all frequencies.[7]

3. Spectral Analysis of Monthly Wool Prices

The Dominion wool price series, which are averages of wool prices in the London, Australian, New Zealand and South African auctions, are considered in this study to represent "world wool prices;" for it is in these markets that the major amount of the world's wool production is sold. Through the use of the techniques described in the preceeding section, the movements in the Dominion price series for different qualities of wool can be analyzed with respect to the relative importance of fluctuations of different lengths of time or frequencies. This information should yield insights into the types of stochastic processes that are imbedded in the world wool market.

Estimates of the spectral density functions of monthly Dominion wool prices in U.S. cents per pound for 70s, 64s, 56s 46s quality wools for the years 1952-64 are given in Figures 8.1, 8.2, 8.3 and 8.4.[8] A linear trend has been estimated by

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[7]Computations were performed at the Princeton University Computer Center with a program written by M. D. Godfrey and modified by E. P. Howrey. This same program was used to obtain the cross-spectral estimates given in the last three sections of this chapter.

[8]These series are from United States Department of Agriculture, <u>Wool Statistics and Related Data: 1920-1964</u>, Statistical Bulletin No. 363 (Washington, D.C.: U.S. Government Printing Office, July, 1965). Since in some years no price was reported for the month of August, the "gaps" in the data were filled by linear interpolation.

regression and removed from these series. These figures give plots of the values of the estimated spectral density functions, which are measured on the logarithmic scale of the vertical axis, for frequencies between 0.0 and π, which are measured on the horizontal axis. Since the period of a cycle equals $\frac{2\pi}{\omega}$, the period in months corresponding to any frequency on the horizontal axis can be obtained. As reference values, the frequency 1.0π corresponds to 2 month fluctuations, .6π corresponds to 3.3 month fluctuations, .2π corresponds to 10 month fluctuations, .167π corresponds to 12 month fluctuations and .1π corresponds to 20 month fluctuations. Thus the spectral estimates for fluctuations with a period of a year or greater are given at the far left of each figure.

These estimates of the spectral density functions of the Dominion wool price series are quite similar, with a lot of power (over 90 percent) in the frequency range corresponding to fluctuations of periods greater than one year, even though a linear trend has been removed. Thus short-run changes in wool prices of less than a year are relatively less important in shaping the over price process than are longer-run changes. Such long-run cycles were detected also in the analysis of the annual world wool market in Chapter 7. All four spectra have small peaks at the 12 month frequency, .167π, at the 6 month frequency, .33π, and at the 3 month frequency, .67π. The estimates for 70s and 64s prices have peaks at 4 month frequency, .5π; and the estimates for the 56s and 46s prices have peaks at the 2.4 month frequency, .83π. All of these peaks are quite small, indicating that the relative importance of these frequencies is not much greater than that of the other frequencies. The frequencies at which these peaks were found correspond to the "seasonal frequencies" at which peaks would be found if there were an annual seasonal component in the time series; that is, they are the harmonics of an annual component.[9] Such an annual component would be expected given the

[9]Marc Nerlove, op. cit., pp. 259-260.

Figure 8.1. Dominion Wool Prices, 70s, Monthly, 1952-64.

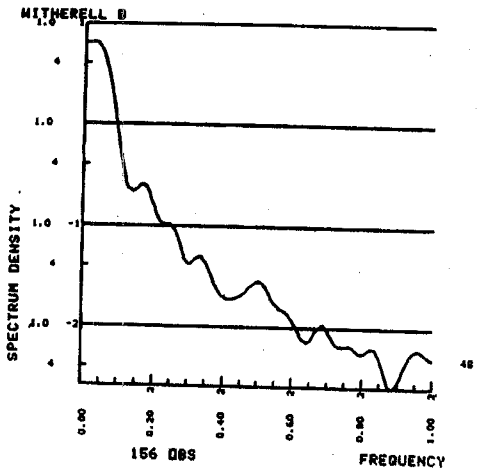


Figure 8.2. Dominion Wool Prices, 64s, Monthly, 1952-64.

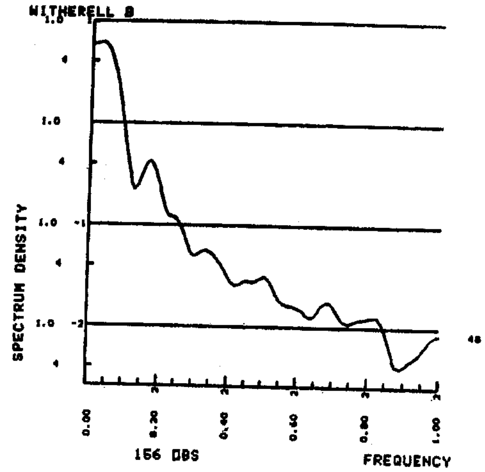


Figure 8.3. Dominion Wool Prices, 56s, Monthly, 1952-64.

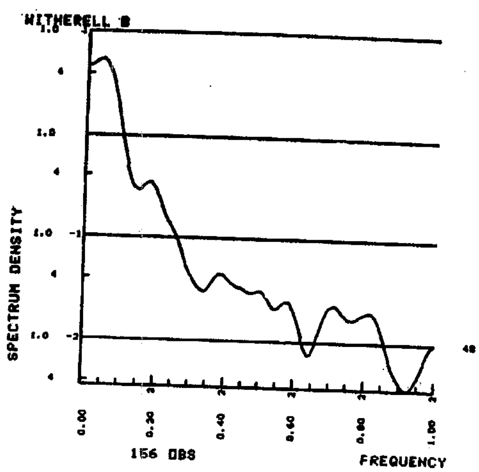
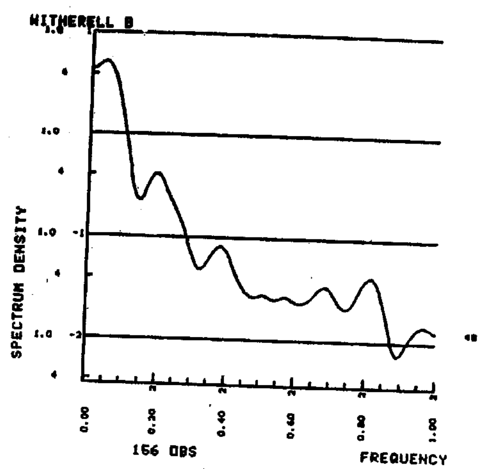


Figure 8.4. Dominion Wool Prices, 46s, Monthly, 1952-64.



seasonal nature of wool supply; and the surprising result is that these peaks are so small. The spectra of the 56s and 46s price series also have peaks at the non-seasonal frequency, $.4\pi$, which corresponds to fluctuations with periods of 5 months.

The slightly flatter nature of the spectra for the lower quality wools, 56s and 46s, in the high frequency range suggests that short-run fluctuations are relatively more important for these quality wools. This result contradicts that of Rainnie, who found that, during the period 1946-47 to 1955-56, merino (high quality wool) prices fluctuated more than crossbred (low quality wool) prices.[10] This greater variation may be caused by substitution of low for high quality wools in times of high wool prices, and high for low in times of low wool prices. Further discussion of this question is given in Section 5 where more conclusive results of cross-spectral analyses of different quality wools are reported.

Figures 8.5, 8.6, 8.7, 8.8 and 8.9 are estimates of the spectral density functions of representative wool prices in London, Australia, United States, Argentina and Uruguay.[11] All were estimated using 48 lags, and a linear trend was removed from each series. The London series is for the period 1952-62, and the Australian series is for the period 1952-63. All other series are for the period 1952-64.

Figure 8.5 gives the estimate of the spectral density function of monthly London Auction prices for 64s/70s good medium fleece wools, clean basis, for the period 1952-62. This estimated spectral density function is, except for the large hole centered

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[10]G. F. Rainnie, "Raw Materials and Markets," in The Woolen and Worsted Industry: An Economic Analysis, ed. G. F. Rainnie (Oxford, England: Clarendon, Press, 1965), p. 11.

[11]All price series used in this section are in U.S. cents per pound, clean, and are from the U.S. Department of Agriculture, op. cit.

Figure 8.5. London Auction Wool Prices, 64s/70s, good medium fleeces, Monthly, 1952-62.

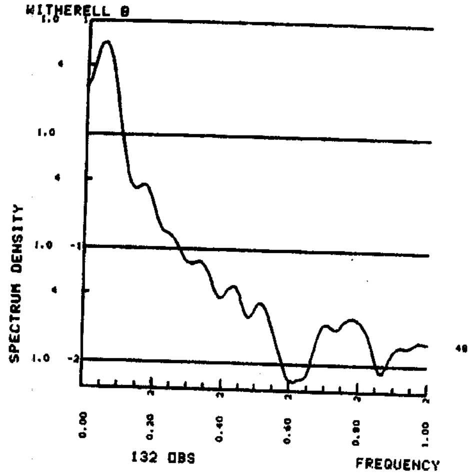


Figure 8.6. Australian Auction Wool Prices, good combing, Monthly, 1952-63.

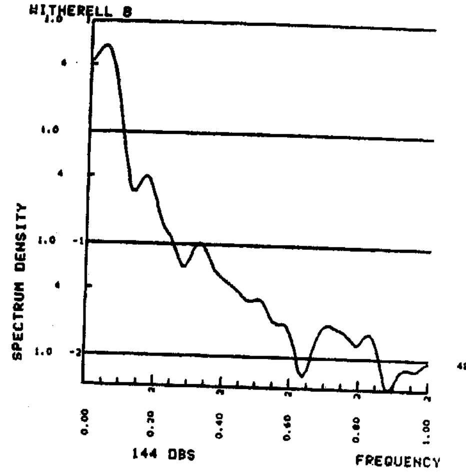


Figure 8.7. U.S. Wool Prices, Fine, Good French Combing and Staple, Monthly, 1952-64.

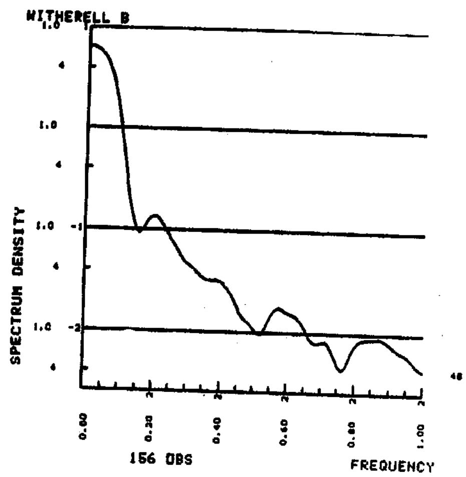


Figure 8.8. Argentine (Buenos Aires) Wool Prices, 5s (40s), at Boston (in bond), Monthly, 1952-64.

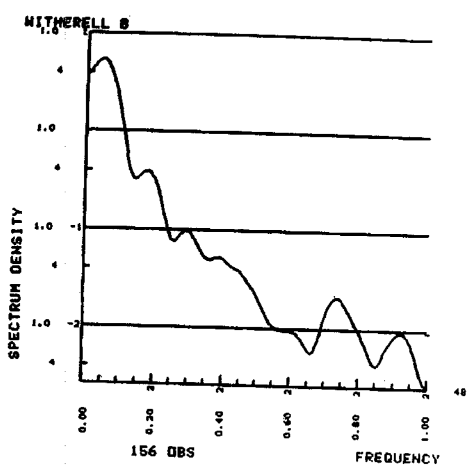
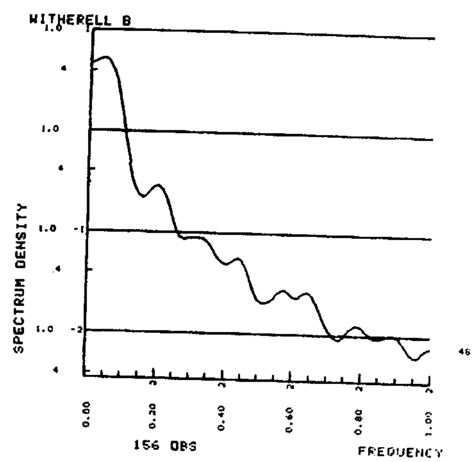


Figure 8.9. Uruguayan (Montevideo) Wool Prices, 1s (56s), at Boston (duty paid), Monthly, 1952-64.



on the 3.3 month frequency, $.6\pi$, very similar to the corresponding functions for Dominion wools, as given in Figures 8.1 and 8.2, and contains similar seasonal peaks. Since London auction prices enter the Dominion price series, the similarity is not surprising.

The estimated spectral density function of monthly Australian good combing wool prices, clean scoured basis, at the Australian auctions for the period 1952-63 is given in Figure 8.6. These prices are a major component of the Dominion price series, and the estimated spectral density function is almost identical to that of Dominion 64s prices given in Figure 8.2 with peaks at the seasonal frequencies.

In Figure 8.7 the estimated spectral density function of the monthly prices of United States Territory French combing and staple fine and good quality wool, clean basis, for the period 1952-64 is given. This function is smoother than that of the corresponding Dominion 70s price series given in Figure 8.1 with a similar seasonal peak at the annual frequency, $.167\pi$, and at the 2.4 month frequency, $.83\pi$. Also, the United States estimate has a peak at the $.58\pi$ frequency, which corresponds to fluctuations of 3.4 months. The underlying process that generates long-run Dominion and United States wool prices may be similar, but the short-run processes appear to be different. The results of cross-spectral analyses of United States and Dominion prices given in Section 5 support this hypothesis. The difference is probably in part due to government protection of the domestic wool industry and the fact that almost all United States wool is sold by private treaty and used in the United States. Thus, the United States market is not fully integrated with the rest of the world wool market, at least with respect to short-run fluctuations.

Estimates of the spectral density functions of monthly Argentine (Buenos Aires) 5s (40s) wool prices, at Boston, in bond; and Uruguayan (Montevideo) 1s (56s) wool prices at Boston, duty paid, for the period 1952-64 are given in Figures 8.8 and 8.9. Both spectra have most of their power in the low frequencies and have small peaks at the seasonal 12 month frequency, $.167\pi$, and in these respects are similar to those of the corresponding Dominion prices series (for 46s and 56s wools). The spectral density function of the Dominion 46s wool price series is considerably flatter than that of the Argentine 5s (40s) series for frequencies higher than $.4\pi$, which correspond to fluctuations with periods less than 5 months.

The estimated spectra of both South American series lack significant peaks at the seasonal harmonics suggesting that the seasonal components of these series are relatively less important than those of the Dominion price series.

All Argentine wool and most Uruguayan wool is sold by private treaty, and the differences between the short-run movements of the prices in these countries and those in the Dominion markets are probably partially due to the insufficient information about world market conditions that is possessed by sellers in such markets. Another cause may be the changing economic policies and unstable political structure of these countries.

In order to compare more systematically fluctuations in the different price series, the methods of cross-spectral analysis are used in Section 6. But first, let us turn to a simple theoretical model of monthly wool price formation.

4. A Model of Short-Run Price Formation

Fishman has described a number of simple theoretical market models which would produce price series with spectra similar to those found for the Dominion wool price series.[12] While over-simplifying the many complex factors that are working in the market, (for example, no account is taken of the seasonal effect),

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[12] G. S. Fishman, "Price Behavior Under Alternative Forms of Price Expectations," Quarterly Journal of Economics, Vol. LXXVIII (May, 1964), pp. 281-298.

one model does appear to give a reasonable explanation to the most important structural aspects of the auction market that is generating these monthly price series. The model developed here is not an alternative to the annual model developed in the previous chapters but, instead, is an attempt to describe the shorter-run movements in the auction markets, that is, fluctuations with periods of two to twelve months. This model is formed by assuming simple demand and supply relationships which are linear in terms of prices and assuming that price expectations are "rational" in the sense that they are the same as those suggested by economic theory.[13] More specifically, we assume the auction market demand curve to be

$$(8.9) \qquad D_t = -a \; P_t$$

and the supply curve to be

$$(8.10) \qquad S_t = b \; P_t^e + (1-\alpha) \sum_{\tau=0}^{\infty} \alpha^\tau \; \varepsilon_{t-\tau} \; ,$$

where all variables are deviation from their equilibrium values. P_t is the actual price in period t, and P_t^e is the price expected by the sellers to prevail in period t. These expectations are formed at the time sellers decide to offer their wool for sale. The assumption that, after their decision is made to offer the wool, the sellers will accept the highest bid prices instead of withdrawing the wool from sale if not satisfied with the prices is quite reasonable for the Dominion wool markets, especially for Australia where sellers are exhorted by brokers to "meet the market" and "sell and repent, but sell."[14] This assumption is

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[13] John F. Muth, Rational Expectations and the Theory of Price Movements, O.N.R. Research Memorandum No. 65, Carnegie Institute of Technology, (1959), pp. 2-4.

[14] Alan Barnard, "A Century and a Half of Wool Marketing," in The Simple Fleece, ed. Alan Barnard (Parkville, Victoria, Australia: Melbourne University Press, 1962), p. 480.

less realistic for the United States and South American markets where sale is by private treaty and especially in the South American markets where the sellers frequently refuse to accept the current demand prices. Supply is assumed to be affected by a geometric weighting of the disturbances which have occurred in the past. The disturbance process $\{\varepsilon_t\}$ is assumed to be a discrete stationary stochastic process with mean and variance $(0,\sigma^2)$. The parameter of the geometric weighting scheme is α. The condition of market clearing implies

(8.11) $$P_t + \frac{b}{a} P_t^e = - \frac{(1-\alpha)}{a} \sum_{\tau=0}^{\infty} \alpha^\tau \varepsilon_{t-\tau} .$$

We next make the assumption that the actual price is a weighted linear combination of the disturbances affecting supply and that, since expectations are rational, expected price also is a weighted linear combination of supply disturbances up to the period in which expectations are formed, t-1, the weights being the same as those determining actual price. That is,

(8.12) $$P_t = \sum_{\tau=0}^{\infty} W_\tau \varepsilon_{t-\tau}$$

(8.13) $$P_t^e = \sum_{\tau=1}^{\infty} W_\tau \varepsilon_{t-\tau} ,$$

As Nerlove has pointed out, the assumption of rational expectations is not that sellers in the market are skilled econometricians that have formulated complete and correct models of the market but, instead, is the assumption that they "... behave as if (they) had made predictions on the basis of the same econometric model used by the economist to analyze industry behavior."[15] The assumption is that, in some undefined way,

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[15]Marc Nerlove, "Time-Series Analysis of the Supply of Agricultural Products" in Agricultural Supply Functions, eds. Earl O. Heady, et. al. (Ames, Iowa: Iowa State University Press, 1961), p. 48.

sellers, in attempting to maximize their profits, are able, on the average, to predict prices at least as well as the model economists develop to predict their behavior.

Substituting (8.12) and (8.13) into (8.11) yields

$$(8.14)\quad W_o\varepsilon_t + \left(1+\frac{b}{a}\right)\sum_{\tau=1}^{\infty} W_\tau \varepsilon_{t-\tau} = -\left(\frac{1-\alpha}{a}\right)\sum_{\tau=0}^{\infty} \alpha^\tau \varepsilon_{t-\tau} .$$

Equation (8.14) is an identity in the ε_t's; and, therefore, the coefficients of the corresponding ε_t's must be equal. Thus the weights, W_τ, must be[16]

$$(8.15a)\quad W_o = -\frac{(1-\alpha)}{a}$$

$$(8.15b)\quad W_\tau = -\frac{(1-\alpha)\alpha^\tau}{a+b} .$$

The equation for price is, therefore,

$$(8.16)\quad P_t = -\frac{(1-\alpha)}{a}\varepsilon_t - \frac{(1-\alpha)}{a+b}\sum_{\tau=1}^{\infty} \alpha^\tau \varepsilon_{t-\tau} .$$

---

[16]The weight, $W_{\hat{\tau}}$, for any value of τ, $\hat{\tau}$, is derived easily by setting $\varepsilon_{t-\tau}=0$ for all $\tau \neq \hat{\tau}$. Since (8.14) must hold for all values of the ε_t,

$$\frac{a+b}{a} W_{\hat{\tau}}\varepsilon_{t-\hat{\tau}} = -\frac{(1-\alpha)}{a}\alpha^{\hat{\tau}}\varepsilon_{t-\hat{\tau}}$$

or

$$W_{\hat{\tau}} = \left(\frac{a}{a+b}\right)\left(-\frac{(1-\alpha)}{a}\right)\alpha^{\hat{\tau}} = -\frac{(1-\alpha)\alpha^{\hat{\tau}}}{a+b} .$$

Fishman has computed the power spectral density function of this price process to be[17]

$$(8.17)\quad f(\omega) = \frac{(1-\alpha)^2\sigma^2[(a+b)^2-2(a+b)\ b\alpha\cos\omega + b^2\alpha^2]}{\pi a^2\ (a+b)^2\ \ (1-2\alpha\cos\omega+\alpha^2)} .$$

$$(\omega \le \omega \le \pi)$$

This theoretical power spectral density function is plotted against frequency in Figure 8.10.[18]

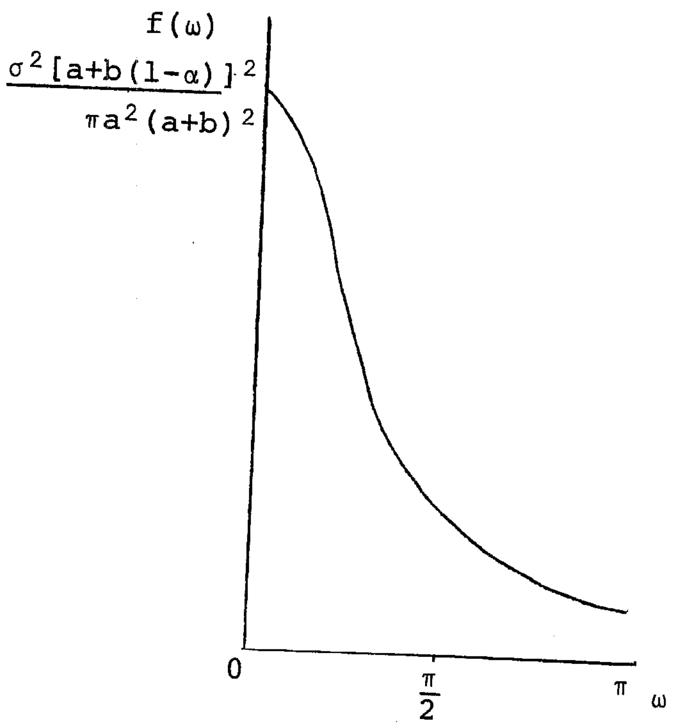

Figure 8.10. Power Spectral Density Function of the Rational Expectations Model.

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[17] G. S. Fishman, op. cit., p. 296.

[18] Ibid., from Figure VII.

The assumption of rational expectations in the presence of serially correlated disturbances in this model implies a price process in which price changes in successive periods are small as compared to long-term changes, and clearly the price processes represented in Figures 8.1 to 8.4 also have this characteristic. However, Fishman shows that other assumptions about price expectations in the presence of serially correlated disturbances, such as adaptive expectations, will also yield power spectral density functions that have this property; and we can not reject the hypothesis that one of these other assumptions is the correct one. We can reject the hypothesis of a monthly cobweb model or a monthly adaptive expectations model in which the monthly disturbances are assumed to be serially uncorrelated; for, as Fishman shows, the power spectral density functions of the price processes corresponding to these models would be as in Figure 8.11,[19] both

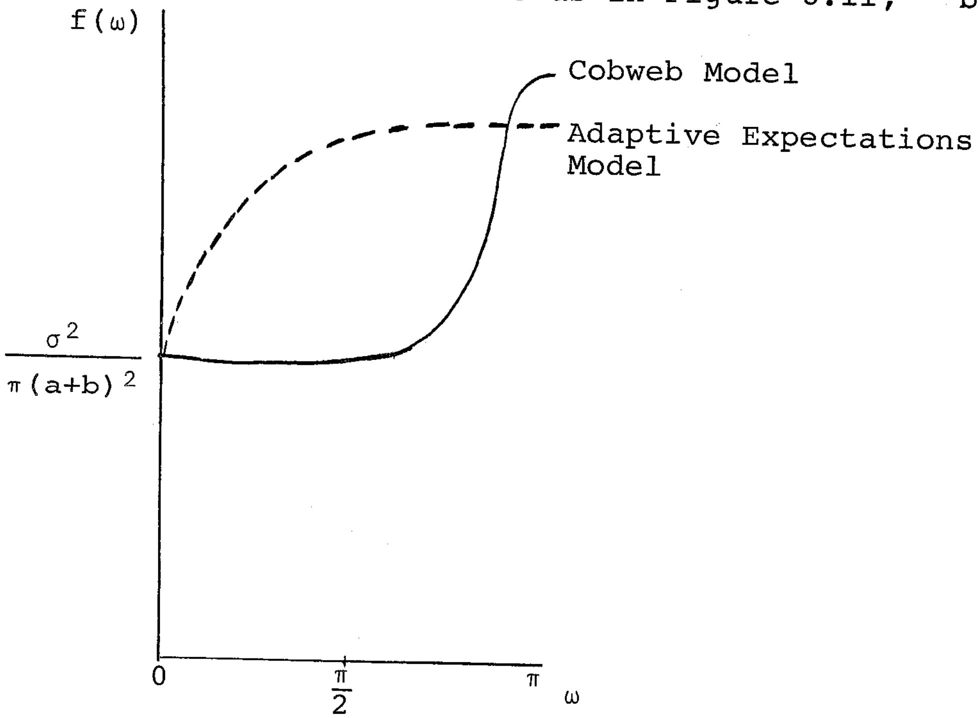

Figure 8.11. Power Spectral Density Function of the Cobweb and Adaptive Expectations Models.

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[19] *Ibid.*, pp. 289-290, from Figures III and V. Note again, however, that these results were obtained using the simple two equation model given in (8.9) and (8.10).

of which show power concentrated in the higher frequencies. In the Appendix to this chapter, model (8.16) is used to generate forecasts of Dominion 70s wool prices; and the results obtained suggest that the model is not a bad approximation of the monthly Dominion wool market.

5. Cross-Spectral Analysis of Economic Time Series

Cross-spectral analysis is a generalization of spectral analysis to the study of relationships between two time series. Again only a few of the more important concepts will be outlined and described intuitively here and the interested reader should consult the sources listed in footnote 1 of Section 2 for a more complete understanding of this method.

A basic assumption in cross-spectral analysis is that, for a bivariate stochastic process in $\{y_t\}$ and $\{x_t\}$, the stationarity assumption be extended to require that the two series be jointly stationary in the weak sense, that is that the cross-covariances,

(8.18a) $$E[(y_t)\ (x_{t+s})] = \gamma_{yx}(s)\ , \qquad (s=0,1,2,\ldots)$$

(8.18b) $$E[(x_t)\ (y_{t+s})] = \gamma_{xy}(s)\ , \qquad (s=0,1,2,\ldots)$$

be functions of the lag, s, only and invariant with respect to time, t. The cross-spectral density function, $f_{yx}(\omega)$, of such a process is defined as the Fourier transform of the cross-covariance function, that is,

(8.19) $$f_{yw}(\omega) = \frac{1}{2\pi} \sum_{s=-\infty}^{\infty} \gamma_{yx}(s) e^{-is\omega}. \qquad (0 \leq \omega \leq \pi)$$

Thus since

(8.20) $$\gamma_{yx}(s) = \int_{-\pi}^{\pi} f_{yx}(\omega)\ e^{i\omega s} d\omega\ , \qquad (-\infty \leq s \leq +\infty)$$

the cross-spectral density function and the cross-covariance function are a Fourier transform pair, one describing the relationship between the two series in the frequency domain, the other, in the time domain.

Unlike the spectral density function for a single series, the cross-spectral density function is complex valued and hence is difficult to interpret. A number of statistics which make use of the cross-spectral density functions and which describe some aspects of the relationship between the two series under study have been derived, and three of these statistics are used in this study.

The first statistic is the coherence, $C_{yx}(\omega)$, of the relationship, which is given by

$$(8.21) \qquad C_{yx}(\omega) = \frac{|f_{yx}(\omega)|^2}{f_{yy}(\omega) f_{xx}(\omega)}, \qquad (0 \leq \omega \leq \pi)$$

where $f_{yy}(\omega)$ and $f_{xx}(\omega)$ are the power spectral density functions of series $\{y_t\}$ and $\{x_t\}$. The coherence of a series is analogous to the squared correlation coefficient and has values lying between 0.0 and 1.0. It measures the extent to which the two series are correlated at each frequency, ω, or, more specifically, the extent to which the two series are related by a linear time invariant relation around ω.

The second statistic used is the phase angle, $\phi_{yx}(\omega)$, of the relationship between the two series, which is measured by

$$(8.22) \qquad \phi_{yx}(\omega) = \text{ARCTAN}\left(\frac{q_{yx}(\omega)}{c_{yx}(\omega)}\right) \qquad (0 \leq \omega \leq \pi)$$

where $q_{yx}(\omega)$, the quadrature spectral density function, is the imaginary part of the cross-spectral density function and $c_{yx}(\omega)$, the co-spectral density function, is the real part. The phase angle is a measure of the phase lag relationship between the series $\{x_t\}$ and the series $\{y_t\}$ at each frequency. A positive phase angle indicates series $\{y_t\}$ lags series $\{x_t\}$ at that frequency. Using the relationship

$$(8.23) \qquad \text{Lag} = \frac{\phi_{yx}(\omega)}{\omega} ,$$

we can see how the lead-lag relationship between the series varies for fluctuations of different periods. For example, for monthly data, if $\phi_{yx}(.5\pi) = 1.0$, four month fluctuations in series y lag four month fluctuations in series x by $\frac{1.0}{.5} = 2$ months.

The third statistic used is the <u>gain</u>, $G_{yx}(\omega)$, of series $\{y_t\}$ on series $\{x_t\}$ and is measured by

$$(8.24) \qquad G_{yx}(\omega) = \frac{|f_{yx}(\omega)|}{f_{xx}(\omega)} \qquad (0 \leq \omega \leq \pi)$$

The values of the gain may be interpreted as the regression coefficients of the series $\{y_t\}$ on the series $\{x_t\}$ at each frequency, ω. The phase angle and gain statistics are best understood as being characteristics of a <u>frequency response function</u> between the input series $\{x_t\}$ and the output series $\{y_t\}$, where this function is a linear, time invariant relationship. The coherence is somewhat free from this interpretation and can be considered to be simply a measure of the correlation at each frequency of the stochastic increments of the two time series.

6. Cross-Spectral Analysis of Wool Prices

The first use of cross-spectral analysis in this study was the examination of the coherence, gain, and phase functions of the relationships between the Dominion wool price series for different qualities of wool. Figures 8.12 through 8.19 give the estimates of these functions for the following pairs of wool quality groups: 70s and 64s, 64s and 56s, 56s and 46s, and 70s and 46s. The second price in each pair was taken as the "input series." Linear trends were estimated and removed from all of these series.

Looking first at the coherence estimates, we see that the coherences between the prices of the two finer quality wools, the 70s and 64s wools, and between the coarser quality wools, the 56s and the 46s wools, are very high at most frequencies, especially at the seasonal frequencies. The coherence between prices of the 64s and 56s quality wools is slightly lower, especially in higher frequency range; and the coherence between the wool prices for 70s and 46s quality wools is significantly lower. Thus the fluctuations of prices of wools that are close technical substitutes in the wool textile industry and that are grown on the same type of sheep are more closely related at all frequencies than are the fluctuations of prices of wools that are not as close substitutes and that are grown on different types of sheep.[20]

Most of the peaks in the coherence estimates are at the seasonal frequencies. The coherence estimates for all but the first pair of price series also have relative peaks at the non-seasonal 5 month frequency, $.4\pi$, which was found to be important in the spectra of the 56s and 46s series.

The phase angle estimates are very close to zero at all but the highest frequencies, indicating an absence of any important lag relationships between the fluctuations of these price series. For all of these estimates for pairs of price series, the second price series is assumed to be the input series and the first the output

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[20]Generally, 70s and 64s wools are grown on Merino sheep and 56s and 46s are grown on crossbred sheep. Crossbred sheep are more suited to lamb production and are raised mainly in New Zealand.

Figure 8.12. Dominion Wool Prices, 70s and 64s, Monthly, 1952-64.

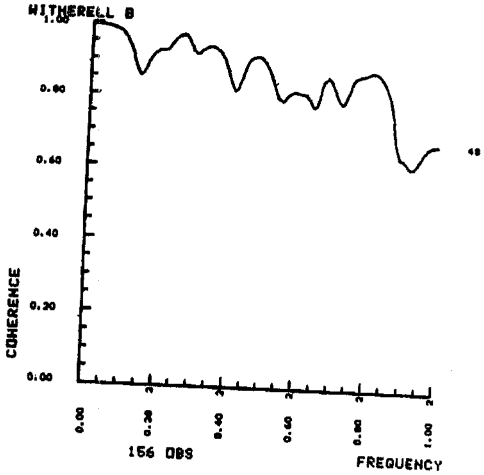


Figure 8.13. Dominion Wool Prices, 70s and 64s, Monthly, 1952-64.

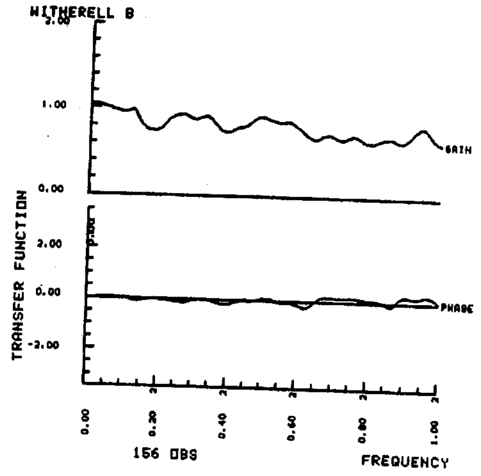


Figure 8.14. Dominion Wool Prices, 64s and 56s, Monthly, 1952-64.

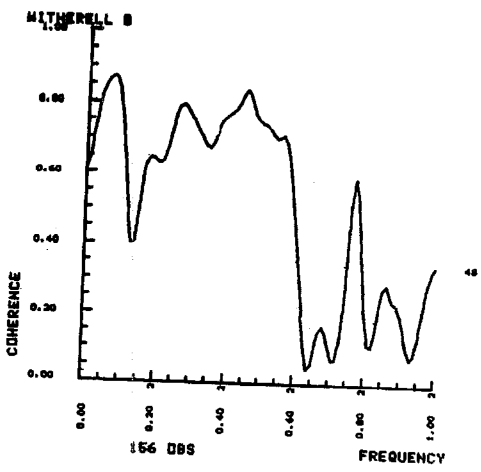


Figure 8.15. Dominion Wool Prices, 64s and 56s, Monthly, 1952-64.

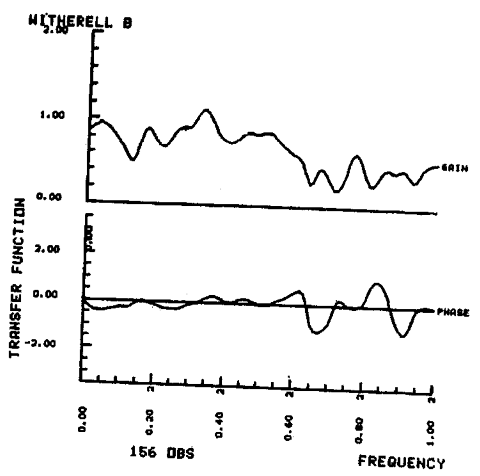


Figure 8.16. Dominion Wool Prices, 56s and 46s, Monthly, 1952-64.

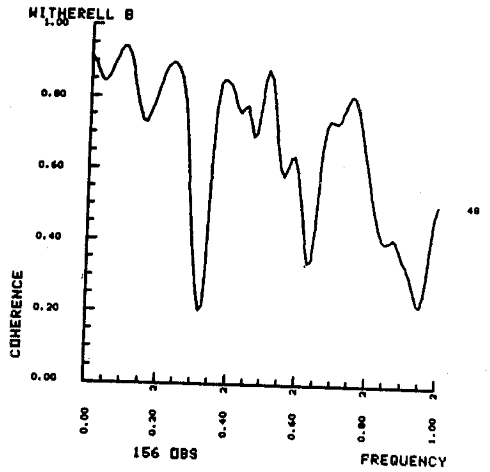


Figure 8.17. Dominion Wool Prices, 56s and 46s, Monthly, 1952-64.

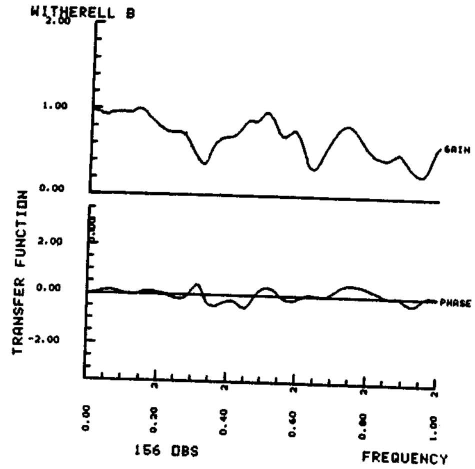


Figure 8.18. Dominion Wool Prices, 70s and 46s, Monthly, 1952-64.

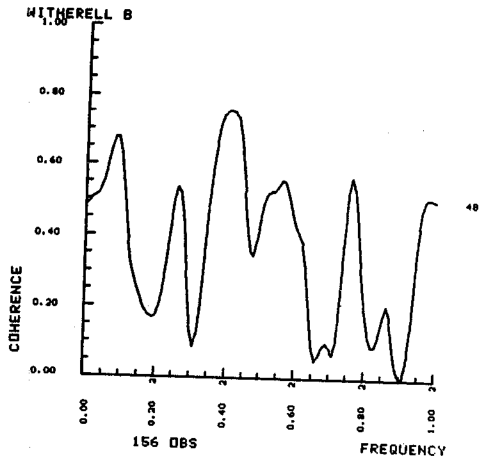
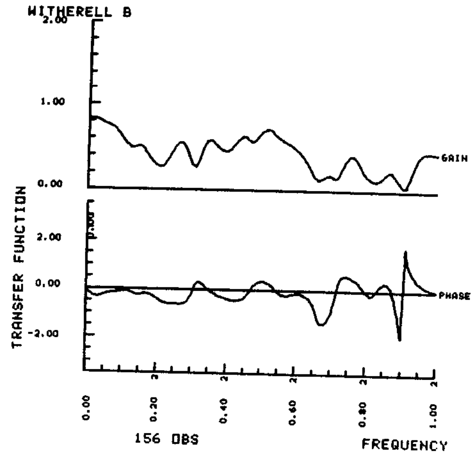


Figure 8.19. Dominion Wool Prices, 70s and 46s, Monthly.



series. Thus positive phase estimates indicate the first series lags the second series. When interpreting phase and gain estimates, the estimates of coherence should also be considered because the confidence intervals around the phase and gain estimates are a positive function of the coherence at the same frequencies; that is, the higher the coherence in a frequency range, the smaller the confidence interval around these estimates in the same range. For example, while the phase angle between 70s and 46s wool prices is about -2.0π radians at the $.9\pi$ frequency, indicating that 2.2 month fluctuations in 46s prices lag the corresponding fluctuations in 70s prices by $\frac{2.0}{.9} = 2.22$ months, the very low coherence between the two series indicates that this lag is not very significant. However, the correct interpretation of these results must remain inconclusive because estimates of coherence are not reliable for frequencies in which the phase angle is rapidly changing as is the case here.

Since normalized spectral and cross-spectral density function estimates were used in estimating the gain (as well as the coherence and phase), the estimated value of the gain at a frequency is analogous to the regression coefficient of the standardized values of the series $\{y_t\}$ on $\{x_t\}$. In Figures 8.13, 8.15, 8.17 and 8.19, the estimated gain of the prices of higher quality wool on the prices of lower quality wool is close to one in the very low frequencies and tends to decrease in the higher frequencies. This tendency is greatest in Figure 8.19, for which the quality difference is the greatest. Thus, in the higher frequency range (fluctuations with periods less than 12 months), the prices of the coarser quality wools have higher relative variation, suggesting that an important substitution effect exists between wools of different qualities. This short-run substitution may be carried out by both textile producers and by consumers. However, this relatively higher variation of prices of coarser quality wools may also be caused by varying exogenous factors that affect only the

Figure 8.34. U.S. Mill Consumption of Apparel Wool, Dominion 64s Wool Prices, Monthly, 1952-64.

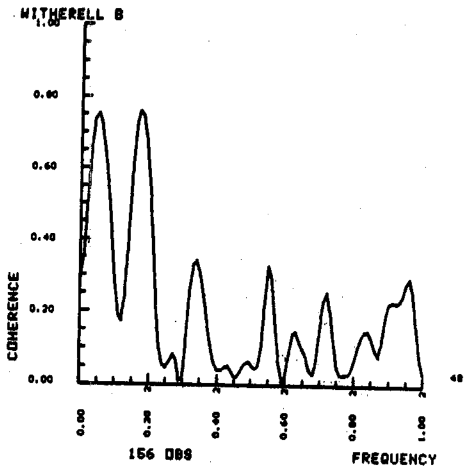


Figure 8.35. U.S. Mill Consumption of Apparel Wool, Dominion 64s Wool Prices, Monthly, 1952-64.

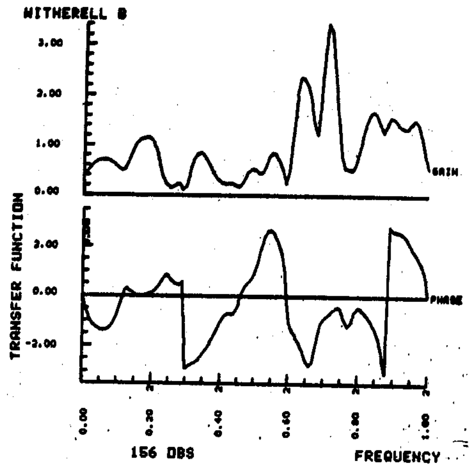


Figure 8.36. U.S. Mill Consumption of Apparel Wool and U.S. Index of Industrial Production, Monthly, 1952-64.

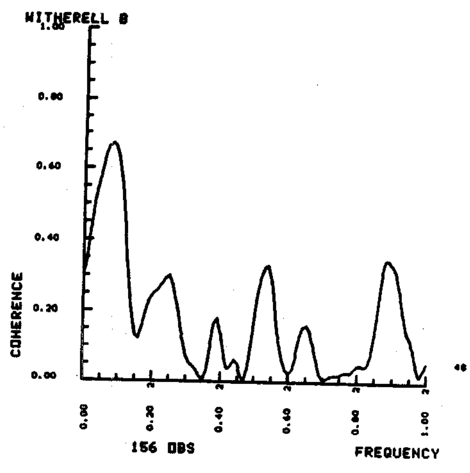
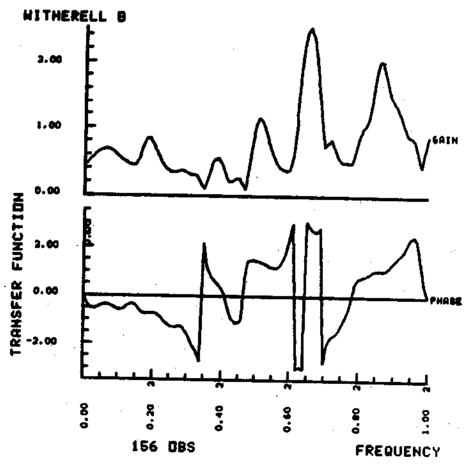


Figure 8.37. U.S. Mill Consumption of Apparel Wool and U.S. Index of Industrial Production, Monthly, 1952-64.



trend was estimated and removed from the series. This spectrum is considerably flatter than those of the wool price series, which indicates that short-run fluctuations are more important for mill consumption than for wool prices. The spectral density function has peaks at the very low frequencies (.0π to .05π), at the annual frequency, .167π, at the six month frequency, .33π, at the four month frequency, .5π, at the three month frequency, .67π, at the 2.4 month frequency, .83π, and at the two month frequency, π. Since all but the first of these frequencies are the "seasonal frequencies," that is, the harmonics of an annual component, monthly United States mill consumption appears to be dominated by a strong annual seasonal component and a long-run component, which is probably determined by income, long-run price movements and competition by synthetic fibers. The strong seasonal pattern, which is caused mainly by the scheduling of production to the highly seasonal demand for wool products and which is characterized by low points in July and December, has been noted by many observers of the United States textile industry.[22]

Figures 8.32 and 8.34 give estimates of the coherence, gain and phase of the United States mill consumption series and a representative monthly wool price series, that of United States Territory French combing and staple, fine and good quality wool, clean basis. The estimated spectral density function for this wool price series was given in Figure 8.7. Wool prices were assumed to be the "input series" for these estimates. The coherence between these two series is very low at all frequencies, rising to a high of .57 at the 40 month frequency, .05π, and to a little over .30 in the 12 to 10 month frequency range, .17π to .20π. Because of these low values of the coherence, the estimates

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[22] See, for example, Frank Lowenstein, Changes in Textile Cycles, Agricultural Marketing Service, U.S. Department of Agriculture (Washington, D.C.: U.S. Government Printing Office, 1960), p. 4.

in the South American countries when the sellers are unwilling to accept the price levels prevailing in the Dominion selling centers are further evidence of the central role of these Dominion wool prices. With respect to prices of different quality wools, it was found that they also move together in the long-run probably because of substitution in the wool textile industry and in the raising of different breeds of sheep. Yet, since such substitutions are difficult for widely different qualities of wool, the series do not move as closely together in the short-run; and disaggregation into at least two broad quality groups would be advisable for short-run studies. Moreover, since the coherence between 70s and 40s wools is not very high at even the low frequencies (see Figure 8.18), this disaggregation would probably improve the results of an annual or longer-run study such as that given in the preceeding chapters. The major problems facing the suggested disaggregations are the lack of the relevant data and the manageability of the resulting models.

7. Spectral and Cross-Spectral Analysis of United States Monthly Mill Consumption of Wool

In the annual model described in the previous chapters, annual net wool consumption was found to be related to the annual world wool prices. The price elasticity of net United States wool consumption was estimated to be - .932. In this section, the results of a spectral and cross-spectral analysis of United States monthly mill consumption of wool are given. These analyses were carried out to study the strength and timing of the relationship between monthly movements in mill consumption and wool prices. Figure 8.30 is an estimate of the spectral density function for monthly mill consumption of apparel wool, scoured basis, in the United States for the period 1952-1964.[21] A linear

[21] This series is from the U.S. Department of Agriculture, *op. cit.*, Table 84, p. 88.

Since Australian auction prices are the most important component of the Dominion wool price series, it is not surprising to find that at all frequencies, the coherence is very high, the gain is very close to 1.0 and the phase angle is very close to 0.0.

Next, cross-spectral analyses of the relationships between wool prices not contained in the Dominion wool price series and Dominion wool prices were carried out. Figures 8.24 and 8.25, which give the cross-spectral estimates of coherence, gain and phase between Dominion 70s and United States Territory French combing and staple wool prices, detrended, indicate that United States wool prices move with Dominion wool prices, for the most part, only in the long-run. The coherence does rise above .6 in the frequency range of $.50\pi$ to $.44\pi$, which corresponds to fluctuations of 4 to 4.5 months. The gain of United States wool prices on Dominion prices is about .5 in this frequency range with the phase angle close to 0.00. At other frequencies where the coherence is low, the gain rises close to one, and the phase angle is positive, indicating Dominion wool prices lead United States prices except at the very high frequencies. It appears that the United States wool market, being thirty percent self-sufficient and sheltered by heavy duties on imports of all but carpet wools and on all wool products, is protected, in the short-run, from the full effect of movements in the rest of the world wool market, although the damped effects of 4 to 4.4 month fluctuations in Dominion prices are important. The fact that almost all United States wool is sold by private treaty also probably contributes to this partial insulation of the United States market in the short-run because in this type of market the producers are liable to be less informed about world market conditions. In respect to longer-run (greater than 12 months) fluctuations, the United States market is more closely integrated with the rest of the world wool market; for the trade barriers are only partial; and the textile industry does import some seventy percent of the raw wool it uses.

Figure 8.20. London Auction Wool Prices, 64s/70s, and Dominion 70s Wool Prices, Monthly, 1952-62.

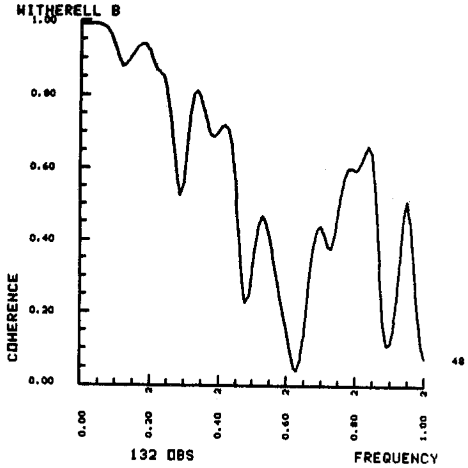


Figure 8.21. London Auction Wool Prices, 64s/70s, and Dominion 70s Wool Prices, Monthly, 1952-62.

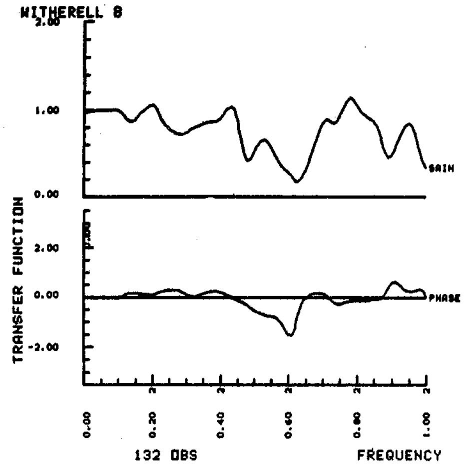


Figure 8.22. Australian Auction Wool Prices, good combing, and Dominion 64s Wool Prices, Monthly, 1952-63.

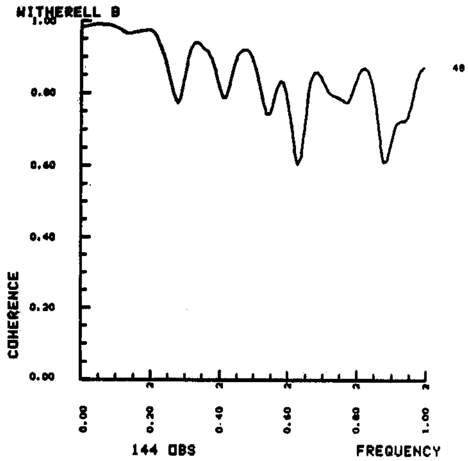


Figure 8.23. Australian Auction Wool Prices, good combing, and Dominion 64s Wool Prices, Monthly, 1952-63.

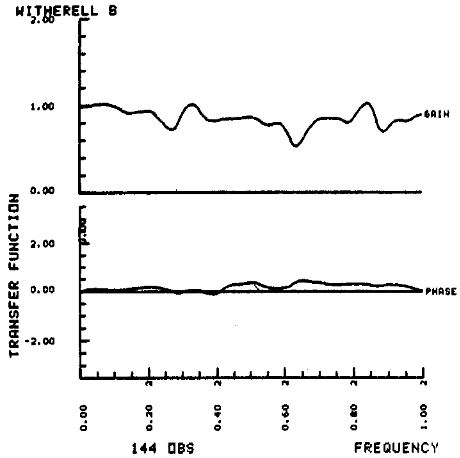


Figure 8.24. U.S. Wool Prices, Fine, Good French Combing and Staple, and Dominion 70s Wool Prices, Monthly, 1952-64.

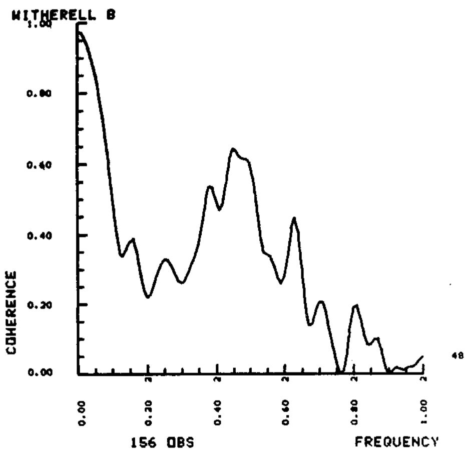


Figure 8.25. U.S. Wool Prices, Fine, Good French Combing, and Dominion 70s Wool Prices, Monthly, 1952-64.

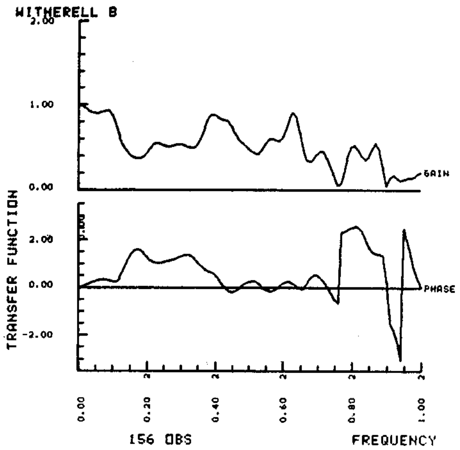


Figure 8.34. U.S. Mill Consumption of Apparel Wool, Dominion 64s Wool Prices, Monthly, 1952-64.

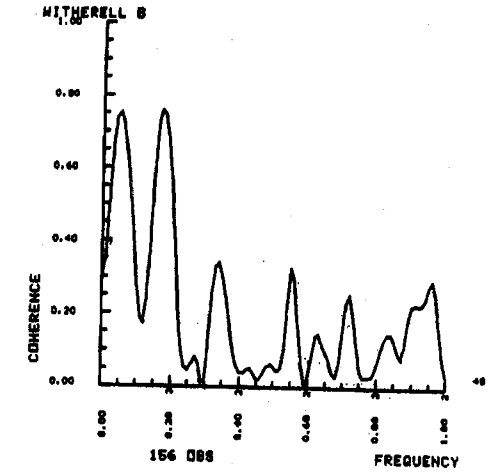


Figure 8.35. U.S. Mill Consumption of Apparel Wool, Dominion 64s Wool Prices, Monthly, 1952-64.

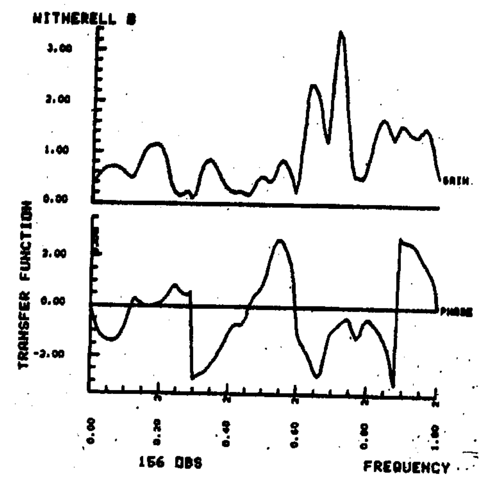


Figure 8.36. U.S. Mill Consumption of Apparel Wool and U.S. Index of Industrial Production, Monthly, 1952-64.

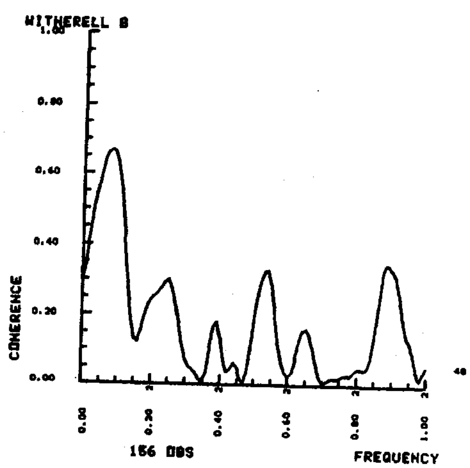
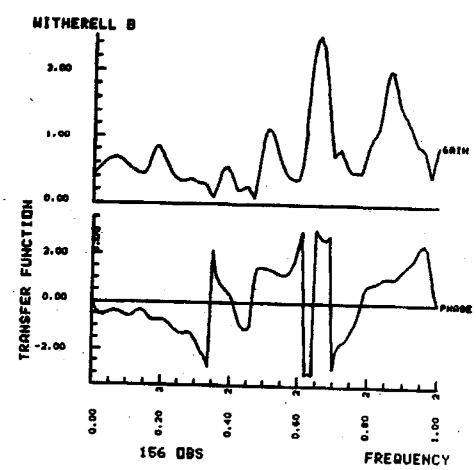


Figure 8.37. U.S. Mill Consumption of Apparel Wool and U.S. Index of Industrial Production, Monthly, 1952-64.



Since fluctuations of less than a year's duration in United States mill consumption of apparel wool were found to be not at all closely related to wool prices, a cross-spectral analysis of this mill consumption series and the monthly Federal Reserve Board's index of total industrial production in the United States,[25] detrended, for the period 1952-64 was carried out in order to examine how closely short-run movements in the wool textile industry correspond to general movements in the United States economy. The estimated spectral density function of the index of industrial production given in Figure 8.27 is less flat than that of mill consumption, having considerably less power in higher frequencies, is smoother and has peaks at the 9.5 month frequency, $.21\pi$, and at the 3.6 month frequency, $.56\pi$. There appears to be no important seasonal component in this series.

The cross-spectral estimates of coherence, gain and phase of these two series, where the industrial index was assumed to be the "input series," are given in Figure 8.36 and 8.37. The estimated coherence indicates that the index of industrial activity does a little better than United States wool prices, but not as well as Dominion wool prices, in explaining United States mill consumption in the low frequency range. The gain is less than one at these frequencies, and the negative phase estimates indicate mill consumption <u>leads</u> the general industrial activity index, the lead being 7.25 months at the 33.3 month frequency $.06\pi$, at which the coherence is the highest, .672. Again, the coherence is low for the higher frequencies with peaks at the 8 month frequency, $.25\pi$, at the 3.7 month frequency, 54π, and at the 2.3 month frequency $.88\pi$. However, since the phase changes so rapidly in the

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[25]This series was taken from "Industrial Production .. 1957-59 Base," Federal Reserve Bulletin, Vol. XLVIII (October, 1962), pp. 1267-1276; and United States Council of Economic Advisers, The Annual Report of the Council of Economic Advisers (Washington, D.C.: U.S. Government Printing Office, 1965 and 1966).

higher frequency range, these estimates are probably not very reliable.

It seems apparent that short-run fluctuations with periods less than a year in United States mill consumption of wool are not closely related with either wool prices or with the general industrial activity in the United States. Thus, they probably are internally generated in the wool textile industry, and their study would require an analysis of the complex structure of this industry, with particular emphasis on the determination of inventories, new orders and unfilled orders at the different industry levels and the highly seasonal nature of the demand for wool products.[26] While the data problems facing such a study may be critical, the internal nature of these fluctuations that is implied by the above analysis suggests that many of the simultaneity problems faced in similar studies would probably be not as important for this industry.

8. Spectral and Cross-Spectral Analyses of Australian Wool Production and Annual Wool Prices

The annual model of the world wool market developed in the earlier chapters was found in Chapter 7 to imply the existence of long-run fluctuations in the wool market. Unfortunately, little reliable data exist that cover a time period long enough for the testing of these results by spectral analysis. Some long-run data on wool production and wool prices were found; and in this section the results are given of a spectral and cross-spectral analysis of Australian wool production and the Sauerbeck Merino Wool Price Index for the period 1863-1963. The production series

[26] A suggested outline of such a model is given in J. Donald, F. Lowenstein, and M. Simon, The Demand for Textile Fibers in the United States, Technical Bulletin No. 1301, U.S. Department of Agriculture (Washington, D.C.: U.S. Government Printing Office, 1963), Appendix B.

used is that of annual Australian wool production, greasy basis, for the years 1863 to 1913 and seasonal production for seasons 1914-15 to 1961-62.[27] The annual data for years t were taken as the seasonal data for years t-1, t, and the missing observation for season 1913-14 was estimated by linear interpolation between the two adjacent observations. In this rough way, a "seasonal" wool production series of 100 observations was constructed, which is long enough for the application of spectral analysis. The wool price series used was the annual Sauerbeck Merino Wool Price Index for the years 1863-1962.[28]

Estimates of the spectral density functions of the Merino Price Index and Australian wool production are given in Figures 8.38 and 8.39, where 36 lags were used in the estimation. A linear trend was estimated and removed from both series. The estimated spectra of the wool price index and of wool production have about 95 percent of their power in the low frequencies of 0 to $.3\pi$, which correspond to fluctuations with periods of 6.7 years or longer. In the analysis in Chapter 7 of the roots of the characteristic matrix of the annual model, complex roots with periods of 33.4, 11.89 and 8.61 years were found to be some of the more important roots to the system. Thus both analyses indicate the dominance of long-run movements in the world wool market. The spectral density function of the Merino Wool Price Index has a wide peak spanning the 3.8 year to the 2.5 year frequency band, $.53\pi$ to $.80\pi$, the highest point of this peak being at the 2.9 year frequency, $.7\pi$. The spectral density function of Australian wool production has two larger peaks at the 4.3 year frequency, $.47\pi$, and 3.1 year frequency, $.65\pi$, and two smaller peaks at the 2.5 year frequency, $.80\pi$, and the 2.2 year frequency, $.90\pi$. It is

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[27] Commonwealth of Australia, Bureau of Agricultural Economics, Handbook of the Sheep and Wool Industry (3d ed.; Canberra, Australia, 1961), Table 28, p.40.

[28] Ibid., Table 78, p. 91.

Figure 8.38. Sauerbeck Merino Price Index, Annual, 1863-1962.

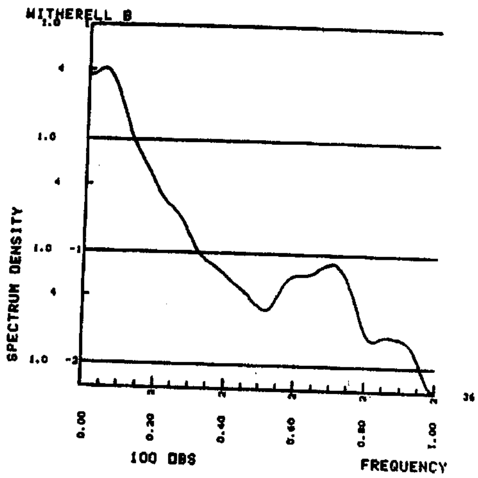


Figure 8.39. Australian Wool Production, greasy basis, Seasonal, 1862-63 to 1961-62.

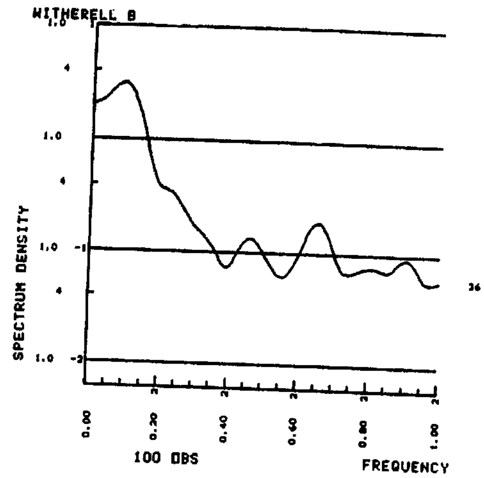


Figure 8.40. Sauerbeck Merino Price Index, Annual, 1863-1962 and Australian Wool Production, Seasonal, 1862-63 to 1961-62.

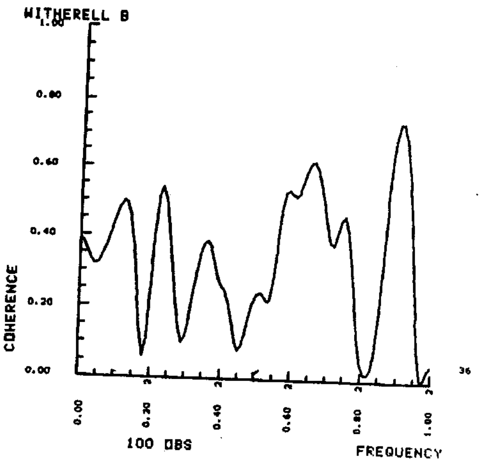
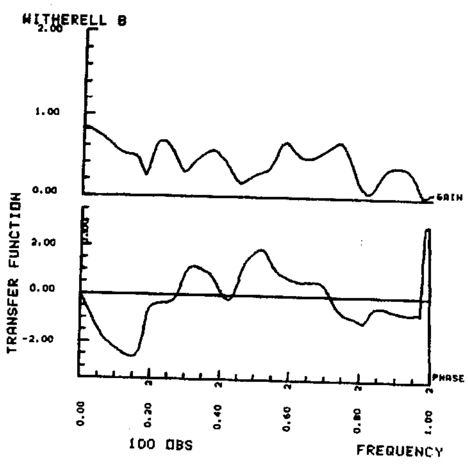


Figure 8.41. Sauerbeck Merino Price Index, Annual, 1863-1962 and Australian Wool Production, Seasonal, 1862-63 to 1961-62.



interesting that the complex roots of the short-run components of the annual model had periods of 4.22, 3.72, 2.43, 2.35 and 2.2 years. Thus both methods of analysis indicate the importance in the world wool market also of fluctuations with periods of a little more than two to a little more than four years. Such fluctuations would develop in a market where many of the relations are of the cobweb type with explanatory dependent variables lagged one and two years.

The cross-spectral estimates of coherence, gain and phase between the Merino Wool Price Index and Australian wool production are given in Figures 8.40 and 8.41, where wool production was taken as the input series. The coherence between the series is fairly low, with a bump in the 3.8 to 2.5 year frequency range, $.53\pi$ to $.80\pi$, that corresponds to the bump in the Merino Wool Price Index spectrum, and peaks at 16.7 year frequency, $.12\pi$, the 8.7 year frequency, $.23\pi$, the 5.6 year frequency, $.36\pi$, and at 2.2 year frequency, $.91\pi$. The gain is less than one at all frequencies and declines in the higher frequencies. In the very low frequency range, the phase is negative, indicating wool production leads prices in the very long-run. In all but a small part of the frequency range of $.3\pi$ to $.72\pi$ (6.6 years to 2.8 years), wool prices lead wool production, with the lead at three years being about .8 years. A zero crossing occurs at the 2.8 year frequency, $.72\pi$, and production again leads prices in the higher frequencies.

Since seasonal and annual production data were joined together and then compared with an annual index of wool prices, these cross-spectral estimates are certainly questionable, especially with respect to the estimates of time lags from the phase estimates. Yet they do suggest that the effect of production on price is much stronger than the effect of price on production and that fluctuations in the world wool market are dominated by very long-run fluctuations and, to a lesser extent, by fluctuations of two to four years.

APPENDIX TO CHAPTER 8

THE SHORT-RUN FORECASTING OF WOOL PRICES

The monthly wool price model given by (8.16) suggests that a simple way of obtaining routine forecasts of monthly wool prices could be developed. Such forecasts would be useful to all who deal in the Dominion wool markets and especially useful to any wool marketing authority, such as the New Zealand and South African Reserve Boards, who have to make a large number of such routine forecasts in order to determine the proper course of action that will meet their policy objectives and avoid undesirably large accumulations or depletions of their stocks.

Lagging equation (8.16) one month yields

$$(8.25) \qquad P_{t-1} = -\frac{(1-\alpha)}{a}\,\varepsilon_{t-1} - \frac{(1-\alpha)}{a+b}\sum_{\tau=2}^{\infty}\alpha^{\tau}\varepsilon_{t-\tau}\,.$$

Subtracting (8.25) from (8.16) yields

$$(8.26) \qquad P_t = P_{t-1} - \frac{(1-\alpha)}{a}(\varepsilon_t - \varepsilon_{t-1}) - \frac{(1-\alpha)}{(a+b)}\,\alpha\,\varepsilon_{t-1}$$

$$= P_{t-1} - \frac{(1-\alpha)}{a}\varepsilon_t + \left(\frac{a(1-2\alpha+\alpha^2) + b(1-\alpha)}{a(a+b)}\right)\varepsilon_{t-1} \quad .$$

Thus current price can be expressed as the price in the previous month plus a weighted average of the current and last periods' disturbance terms.

Equation (8.26) suggests that a simple short-run forecasting equation for monthly wool prices could be obtained by regressing current price on the price in the last period. This regression was carried out for monthly Dominion prices for 70s wool, 1952-64, the result being equation (8.27).

$$(8.27) \quad Pw_t = \underset{(2.166)}{3.202} + \underset{(.016)}{.973} \, Pw_{t-1}$$

$$R^2 = .96, \text{ D.W.} = 1.55, \text{ s.e.} = 4.983 \quad ,$$

where R^2 is the coefficient of multiple correlation, D.W. is the Durbin-Watson statistic, and s.e. is the standard error of estimate. A constant term was included to allow for a trend in the mean. The estimated standard deviations of each coefficient estimate are given below the coefficients. Thus, the coefficient of Pw_{t-1} is within two standard deviations of 1.000. The value of the Durbin-Watson statistic indicates that the hypothesis of positively autocorrelated residuals is not rejected at the 5 percent significance level. However, this test is not valid when applied to equations containing lagged endogenous variables. The estimated first-order autocorrelation coefficient of the residuals is +.2191, and the values of the higher order coefficients drop off sharply. When the next twelve past prices were added sequentially to this regression, the coefficient of multiple correlation increased by less than .01, and the coefficients of these prices were statistically insignificant. Thus, model (8.26), derived from (8.16), which describes the generation of wool prices as a first-order Markov process with an error term that is a weighted average of the current and the previous month's stochastic disturbance, appears to give a good approximation to the actual process generating Dominion wool prices.

Equation (8.27) was used to generate forecasts one month ahead for all of 1965 and the first five months of 1966, and the results are given in Table 8.1. The average absolute forecast error is 3.27, and, since the average price in the 17 month period was 118.47, the percentage absolute error is 2.76.

TABLE 8.1

ONE MONTH FORECASTS, DOMINION 70s WOOL PRICES
(U.S. Cents Per Pound, Clean Basis)

Month	Actual Price*	Forecast Price	Forecast Error= (actual-forecast)
1/65	114	114.4	- .4
2/65	115	114.1	+ .9
3/65	112	115.1	-3.1
4/65	113	112.2	+ .8
5/65	113	113.1	- .1
6/65	111	113.1	-2.1
7/65	114	111.1	+2.9
8/65	113	114.1	-1.1
9/65	114	113.1	+ .9
10/65	121	114.1	+6.9
11/65	124	120.9	+3.1
12/65	122	123.8	-1.8
1/66	125	121.9	+3.1
2/66	127	124.8	+2.2
3/66	130	126.7	+3.3
4/66	133	129.7	+3.3
5/66	113	132.6	-19.6

*Actual prices from The World Wool Digest, various issues.

It is interesting to compare these results with those of Jarrett, who investigated the possibility of developing a routine method for making short-run forecasts of Australian wool prices.[29] He developed a considerably more complex forecasting model, using exponentially weighted moving averages and allowing for seasonal and trend components, both of which are continually updated. He made one-month-ahead forecasts with his model for prices of Australian average 70s quality wools (and for other qualities) for the period February 1961 to June 1964, obtaining a percentage absolute forecast error of 4.2 for the 70s prices. While it is difficult to compare his results, which are for a different observation period and for only one component of the Dominion wool prices,[30] it is interesting to note that when he uses a simple model

$$P_{t+1} = \frac{P_t + P_{t-1}}{2} \quad , \tag{8.28}$$

he obtains a percentage absolute forecast error of 4.1 for the 70s prices.[31] It does appear that little is gained by attempting to take account of moving seasonal components (this was indicated by the estimates of the spectral density functions of wool prices in which the seasonal peaks, while present, were not very large); and that, if routine forecasts are desired, simple models such as (8.26) or (8.28) may do about as well as more complex models such as that derived by Jarrett.

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[29]Frank G. Jarrett, "Short Term Forecasting of Australian Wool Prices," Australian Economic Papers, Vol. IV (June-December, 1965) pp. 93-102.

[30]However, we have shown that Dominion and Australian price series move very close together.

[31]Frank G. Jarrett, op. cit., p. 100.

CHAPTER 9

CONCLUDING REMARKS

1. Summary

The aim of this study was to examine the dynamic structure of a major world commodity market, that of raw wool, in order to understand better the causes of the high variability of prices that are generated in commodity markets that are comparatively free of control by governments and international commodity agreements. The approach followed was the construction and analysis of an annual econometric model of this market for the period 1949 to 1964. Also, monthly movements in wool prices and mill consumption and seasonal movements in Australian wool production were studied by means of spectral and cross-spectral analysis. The major findings of this study are summarized in this section.

In developing the supply sector of the model, that is, the equations explaining seasonal wool production in the major producing countries and a "Rest-of-the-World" sector, we found the responsiveness of production to changes in wool prices to be uniformly low in all countries studied. Similarly, the importance of prices of complementary products, such as lamb, and substitute products, such as wheat, is also small. Australian wool production was found to be affected positively by fertilizer usage, which was used as a proxy variable for technological change. Seasonal rainfall was found to be a significant factor for the production in Australia, South Africa and Argentina. The production equations for the different countries are all quite similar and indicate that world wool production grows slowly and fairly steadily over time, responding weakly to economic factors and then only after a long lag.

In contrast, the stocks of wool held in the producing and consuming countries are highly variable. The amounts of stocks carried over to the next season in producing countries were found to be strongly affected by current and expected future wool prices. Consumer stocks of raw wool held in the United States and the United Kingdom were found to be determined by current and expected future mill consumption of wool, while stocks in Japan were found to be determined also by speculation on wool prices.

The construction of the consumption demand sector of the model, that is, the equations explaining the net consumption of wool in the major wool consuming countries and a "Rest-of-the-World" sector, indicated that the determination of consumption varies significantly in the countries studied with respect to the importance, timing and direction of the effects of the wool price, income, change-in-income and net-consumption-of-synthetics variables. In all countries except the United States, the wool price elasticity of demand was found to be low. Income or change-in-income variables were found to be important positive determinants of consumption in the United States, the United Kingdom, Japan, West Germany and the "Rest-of-the-World" sector but were found to be less important and in some cases negative factors in France, Italy, Belgium and the Netherlands. The introduction in the middle 1950's of synthetic fibers which could complete in many sectors of the industrial fiber market previously dominated by wool was found to have had a differential impact on wool consumption in the countries studied. In some cases, Japan and the United Kingdom, the impact was quite strong; and in others, Netherlands and France, it was negligible. These differences are probably due to differences in the structure and technology of the wool industries and in the preferences of the consumers in the different countries.

An attempt to isolate a separate price equation which would explain world wool prices by changes in a variable that indicates the disequilibrium between measured world supply and demand was unsuccessful; so the New Zealand stock equation was renormalized on the wool price variable. The addition of this equation and a market-clearing identity to the production, consumption and stock equations resulted in a closed linear model, the reduced form of which contains an equation for wool prices. This equation takes account of the simultaneous relationships between prices and the other variables in the model. The low price inelasticity of production and consumption in the wool market implies that, when either production or consumption is changed due to a change in an exogenous factor, such as a drought or a war, prices and/or stocks will have to change considerably to restore equilibrium to the market. The reduced-form equations for wool prices and producer stocks indicate that these variables are indeed sensitive to changes in most of the other variables in the model. The variability of prices is also affected by the amount and method of price speculation in the market. While price speculation was not found in most cases to be an important factor in the determination of consumer stocks (mainly stocks held by mills), it was found to be very significant in the determination of producers' stocks.

An analysis of the dynamic multipliers of the model for one-shot and sustained unit changes in the exogenous variables indicated the way such changes affect wool prices and the other dependent variables in the model over the next eight years following the change. In some cases, responses that were small in the initial year grow to considerable size four or five years after the change. The response pattern of the dependent variables was often found to be a fluctuating one. The analysis of the roots of the characteristic matrix of the model also indicated the existence of fluctuating components in the responses of the market to exogenous shocks, for many of these roots are complex valued.[1]

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[1]A third indication of the importance of these fluctuations was given by the results of a spectral and cross-spectral analysis of seasonal Australian wool production and a wool price index.

This analysis of the characteristic roots showed the system to be stable, thus implying that the market responses are in the direction of a new market equilibrium.

Spectral and cross-spectral analyses of various monthly wool prices indicated that prices of similar quality wools sold in the different Dominion markets move very close together in the short-run as well as the long-run. In contrast, the relationships between the short-run movements of prices of wools of different qualities or between prices of wools sold in the South American or United States markets and prices of wools sold in the Dominion markets was found to be not very strong, although the long-run movements in these prices are closely related. Since the estimated spectra for all of the wool price series had most of their power in the lower frequencies, long-run variations in wool prices are relatively more important than the shorter-run variations in determining the total variance of these series. These analyses suggest that the concept of an integrated world wool market with one product and one world price may be a useful simplification for analysis of the long-run structure and functioning of the market but is probably too great a simplification for the analysis of the short-run aspects of the market.

2. Suggested Directions for Future Research

There are a number of lines along which the research done in this study could be extended. First, the annual world model could be refined by the introduction of non-linearities into the model where they are most needed and by the disaggregation of the product wool into a number of major quality classes. Also, the statistics of some of the large wool producing countries (mainly Australia, New Zealand and the United States) should be disaggregated into their major regions so that better estimates of the effects of weather and other crops can be obtained; and for all producing countries, research should be done on the effects of changing costs on wool production. When adequate data become available, the nature of the competition between synthetics and wool should be analyzed more closely and the competative effects of other fibers, in particular cotton, should be studied. While it would require a very large amount of hard-to-obtain data and severe computational problems, the natural direction for the model to evolve would be toward a model of the world industrial fiber market.

A second direction for future research is the development of quarterly or monthly models of the wool textile industries of the main consuming countries, which would permit the study of the complicated structure of these industries and the generation of short-run movements in stocks of raw wool and semifinished and finished wool products, in mill consumption and output, and in wool prices.

Finally, the short-run functioning of the major auction markets should be studied in some detail with particular emphasis on the efficiency and stability of these markets, the process by which prices are generated, the degree and effects of collusion among buyers and sellers and the role of the middlemen, the dealers and brokers, in the market. Such studies of the short-run behavior of the wool market would not only be useful in themselves but would also shed some light on how the longer-run annual model could be improved, particularly in respect to price and stock determination and the role played by speculation in the market.

COMPUTATIONAL APPENDIX

In this appendix, the nature and amount of computation that was used in this study is described.

Three computer programs were used to obtain most of the results of this study. The Bimed 34 stepwise regression package[1] was used to estimate the equations explaining seasonal wool production that are given in Chapter 4, as well as the autoregressive equation for Australian wool prices given in the Appendix to Chapter 8. A program written by M. Norman of the University of Pennsylvania which estimates equations by two-stage least-squares with principal components of all predetermined variables used as instrumental variables and also by ordinary least squares was used to obtain the other equations of the annual world wool market model. A third program written by M. D. Godfrey and modified by E. P. Howrey, both of Princeton University, which computes spectral and cross-spectral density functions, autocorrelation and cross-correlation functions and histograms of time series data was used in the spectral and cross-spectral analyses of Chapter 8. Various other programs used in this study, in particular, those used to compute the estimates of the impact and dynamic multipliers and the forecasts of the annual model that are given in Chapter 7 and those that were used to process the raw data, were written by the author.

All computations were done on an IBM 7094 computer at Princeton University's Computation Center. The total computation time used over a period of a year was approximately 10.5 hours.

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[1]This program is part of a UCLA Medical School Program written at the Health Sciences Computing Facility, UCLA, and modified by Hodson Thornber at the Center for Mathematical Studies in Business and Economics at the University of Chicago.

While a more experienced programmer, beginning with a complete set of the necessary data and a very clear idea of the structure of the study, would have required less computer time, anyone wishing to extend this study along the lines suggested in Chapter 9[2] or to carry out a similar study on another world commodity market should expect the study to require a substantial amount of computer time. He also should note that the size of the annual model in this study just about filled up the available core space of the 7094 computer, and thus the estimation of a larger model would require either a larger computer or considerable rewriting of the two-state least-squares with principal components program that was used.

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[2]Note that most of the suggestions given in Chapter 9 require more data and larger models than were used in this study.

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