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ECONOMETRIC ANALYSIS OF THE U.S. CHEESE INDUSTRY:

-PRODUCTION -CONSUMPTION -PRICES -MARKETING

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FOREWORD

The authors are indebted to many people who have helped in the presentation of this report. We are especially grateful to Ms. Becky Dethlefsen for typing the manuscript. Mrs. Carol VavRosky prepared the graphs and figures. Dr. Jerome E. Johnson, Dr. William W. Wilson, Mr. John F. Mittleider, Mr. Donald E. Thomson, and Dr. David W. Cobia were very helpful in reviewing the manuscript and making helpful suggestions. The authors are grateful to these and the entire Department of Agricultural Economics for their help and cooperation.

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Highlights

Natural cheese production has been using increased quantities of milk since 1950. Nearly 26 percent of the total milk supply was used to manufacture cheese in 1979, of which almost 70 percent was used in the production of American cheese.

Cheese production is concentrated in the Midwest and Lake state regions, with Wisconsin the principal cheese producer. Wisconsin accounted for 37.3 percent of total domestic production in 1980. North Dakota ranked 16th in 1980.

The number of cheese plants has declined from 2,158 in 1950 to 737 in 1980. The average production per plant has increased from 0.6 million pounds in 1950 to 5.4 million pounds in 1980.

Cheese consumption has risen sharply in the past 30 years to about 17.6 pounds per person in 1979 from 7.7 pounds in 1950, an increase of 228 percent.

Imitation cheese is presenting increased competition for natural cheese, accounting for 5 percent of the total natural cheese output in 1980, an increase of 150 percent from the 1978 output. The major use of imitation cheese is in the production of frozen pizzas. Favorable taste, less cholesterol, fewer calories, and lower price may explain the increasing consumer acceptance of this product.

A distributed lag model was used to estimate the demand for cheese. Results determined that price elasticity was -0.5, and income elasticity was 0.7. This indicates that consumption of cheese is influenced more by changes in income than by changes in its own price.

The model used to forecast monthly cheese production and price is a multiplicative seasonal moving average model based on the Box-Jenkins time series algorithm. The total cheese production in 1981 was estimated at 4,355,965 tons, 10 percent higher than 1980 production.

Investigative results were highly satisfactory. Distributed lag model worked well with annual data for analyzing the demand for cheese, and the Box-Jenkin time series model showed merit in forecasting production and prices using monthly data.

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CHEESE: PRODUCTION, CONSUMPTION, PRICES, AND MARKETING

by

Won W. Koo, Eduardo Loma, and Gordon W. Erlandson*

Cheese is one of the most important manufactured products in the dairy industry in terms of value of product. Domestic United States cheese production increased from 1,191 billion pounds in 1950 to 3,893 billion pounds in 1980. Per capita consumption in the United States was 7.7 pounds in 1950 and increased to 17.6 pounds in 1980. It can be inferred that the United States is one of the largest cheese producing and consuming nations in the world.

This report presents the patterns of production, consumption, and marketing of cheese in the United States, and analyzes the price behavior for the 30-year period 1950 through 1979. Cheese production was forecast using the Box-Jenkins methodology (described in Appendix A). A compound geometric lag model was used to estimate the demand function for cheese (described in Appendix B).

I. United States Cheese Industry and Market Structure

Total milk supply and utilization for manufacturing cheese from 1950 to 1979 for the United States is presented in Table 1. Total milk supply ranged from 115 to 127 billion pounds from 1950 to 1979. Milk production has shown considerable fluctuation but it trended upward from 1950 to 1964, when it peaked at 127 billion pounds. Then production declined, reaching the minimum in 1975 of 115 billion pounds. Milk production in 1979 was 124 billion pounds, 7 billion pounds more than in 1950 (23).[1]

All dairy products compete for raw milk supplies. Nearly 47 percent of total milk supply was consumed in fluid form in 1979. The increasing proportion of milk used in manufacturing dairy products reached its peak in 1979 with 67.4 billion pounds, almost 55 percent of the total milk supply. The proportion of milk used for production of cheese increased from 10 percent in 1950 to 26 percent in 1979.

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*Koo is Associate Professor, Loma is a former graduate student, and Erlandson is Professor, Department of Agricultural Economics.

[1]Numbers underlined in parentheses refer to publications in the list of references, page 45.

TABLE 1. MILK SUPPLY AND UTILIZATION IN MANUFACTURING CHEESE IN THE UNITED STATES, 1950-1979 (PHYSICAL QUANTITIES ARE MEASURED IN MILLION POUNDS, PERCENTAGES ARE OF TOTAL SUPPLY)

Year	Total Milk Supply	Manufactured Products		American Cheese		Other Cheese		Total Cheese	
	mil. lbs.	mil. lbs.	percent	mil. lbs.	percent	mil. lbs.	percent	mil. lbs.	percent
1950	117,358	55,170	47.0	8,972	7.6	2,883	2.5	11,855	10.1
1951	115,065	51,603	44.8	8,791	7.6	2,779	2.4	11,569	10.0
1952	114,992	51,568	44.8	8,551	7.4	3,088	2.7	11,639	10.1
1953	120,662	57,616	47.7	10,239	8.5	3,104	2.6	13,343	11.1
1954	122,339	58,704	48.0	10,475	8.5	3,258	2.7	13,733	11.2
1955	122,919	58,027	47.2	10,073	8.2	3,480	2.8	13,553	11.0
1956	124,864	59,406	47.6	9,936	8.0	3,797	3.0	13,733	11.0
1957	124,563	59,212	47.5	9,974	8.0	3,488	2.8	13,462	10.8
1958	123,287	58,860	47.7	9,543	7.8	3,250	2.6	12,793	10.4
1959	121,997	58,408	47.9	9,227	7.5	3,396	2.8	12,623	10.3
1960	123,102	59,751	48.5	9,686	7.9	3,678	3.0	13,364	10.9
1961	125,734	63,560	50.6	11,179	8.9	3,682	2.9	14,861	11.8
1962	126,325	64,141	50.8	10,689	8.5	3,652	2.9	14,341	11.4
1963	125,335	62,667	50.0	10,920	8.7	3,890	3.1	14,810	11.8
1964	127,020	64,538	50.8	11,454	9.0	4,162	3.3	15,616	12.3
1965	124,339	61,768	49.7	11,458	9.2	4,277	3.4	15,735	12.7
1966	121,283	57,900	47.7	12,154	10.0	4,521	3.7	16,675	13.7
1967	120,109	58,770	49.8	12,701	10.6	4,507	3.8	17,208	14.3
1968	117,421	59,230	50.4	12,716	10.8	4,660	4.0	17,376	14.8
1969	116,402	58,315	50.1	12,668	10.9	4,948	4.2	17,616	15.1
1970	117,538	60,013	51.1	14,240	12.1	5,301	4.5	19,541	16.6
1971	118,759	61,614	51.9	15,136	12.7	5,826	4.9	20,962	17.7
1972	120,217	62,319	51.8	16,422	13.7	6,433	5.4	22,855	18.0
1973	116,313	58,678	50.4	16,760	14.4	6,845	5.9	23,605	20.3
1974	115,734	61,327	53.0	18,550	16.0	7,119	6.2	25,669	22.2
1975	115,498	60,524	52.4	16,452	14.2	7,431	6.4	23,883	20.7
1976	120,057	64,673	53.7	20,581	17.1	8,182	6.8	28,763	23.9
1977	122,910	67,068	54.6	20,480	16.7	8,385	6.8	28,865	23.5
1978	121,830	65,945	54.1	20,737	17.0	9,182	7.5	29,919	24.6
1979	123,871	67,401	54.4	21,844	17.6	9,734	7.9	31,578	25.5

SOURCE: (23).

American cheese used 18 percent of the total milk supply in 1979, 232 percent more than in 1950. Italian, Swiss, and other varieties used 8 percent of the total supply in 1979, an increase of 316 percent over the amount used in 1950.

Total natural cheese production and principal types of cheeses are shown in Table 2. Total cheese production was 4 billion pounds in 1980, 234 percent above the 1.2 billion pounds produced in 1950. After temporary declines in 1951-1952 during the Korean conflict, annual production peaked at 1.6 billion pounds in 1961. During the 1960s, production increased fairly steadily, reaching 2 billion pounds in 1969. The sharpest growth occurred during the late 1970s when production reached 4 billion pounds in 1980.

Leading Producing States

Cheese production is concentrated in the Midwest and Lake state regions of the United States. Wisconsin was the principal cheese producer with a total of 1.5 billion pounds in 1980. Although Wisconsin remains the leading producing state, its share of total output has declined steadily. Its production accounted for 37.3 percent of the total domestic production in 1980, which was 10 percentage points less than in 1950. Minnesota ranked second, with 13 percent of the total 1980 production. The other leading states were New York, Iowa, Missouri, and Pennsylvania (Table 3). North Dakota ranked 16th in 1980.

States tend to specialize in the types of cheese produced. Wisconsin produced 42 percent of the total United States output of American cheese in 1980, and 32 percent of the total Italian cheese (Tables 4 and 5). Illinois manufactured the most Swiss cheese (24 percent of the total, Table 6). Minnesota ranked second in American cheese (19 percent). New York was the second largest producer of Italian cheese (32 percent). Wisconsin was second in the production of Swiss cheese with 18 percent of the total.

Number of Plants

Two trends are apparent with respect to the size and number of plants manufacturing natural cheese. The number of plants has declined from 2,158 in 1950 to 737 in 1980. The average production per plant has increased from 0.6 million pounds in 1950 to 5.4 million pounds in 1980 (Table 7). The Italian cheese industry has had an increase in both the number and size of plants since 1950. Technological improvements may explain the movement toward

TABLE 2. TOTAL NATURAL CHEESE PRODUCTION AND PRINCIPAL TYPES IN THE UNITED STATES, 1950-1980

Year	American Cheese	Italian Cheese	Swiss Cheese	Other Cheese	Total Natural Cheese
	- - - - - - - - - - - -	- - - -	thousand pounds	- - - -	- - - - - - - - - - - -
1950	892,706	60,481	99,483	138,817	1,191,487
1951	873,458	55,434	92,049	140,363	1,161,304
1952	849,817	60,572	108,032	151,841	1,170,262
1953	1,021,056	67,834	103,780	151,730	1,344,400
1954	1,042,345	71,204	113,529	156,160	1,383,234
1955	1,004,269	86,018	116,664	159,942	1,366,893
1956	991,254	101,738	123,216	171,484	1,387,692
1957	1,021,728	111,620	100,048	174,027	1,407,423
1958	977,973	130,557	107,114	167,417	1,399,384
1959	942,517	140,765	222,901	187,878	1,383,061
1960	996,118	157,533	121,081	203,241	1,477,973
1961	1,148,761	161,799	120,508	203,437	1,634,505
1962	1,094,487	172,002	109,412	216,121	1,592,022
1963	1,108,351	192,228	119,906	211,332	1,631,817
1964	1,157,311	219,718	121,844	224,763	1,723,636
1965	1,158,285	244,470	122,732	229,969	1,755,456
1966	1,220,580	271,119	136,664	225,639	1,854,602
1967	1,276,339	284,456	132,204	343,885	1,918,830
1968	1,276,336	314,855	129,613	225,632	1,943,916
1969	1,266,428	361,254	131,612	230,295	1,989,589
1970	1,423,399	393,668	143,957	240,404	2,201,428
1971	1,511,508	453,861	153,843	255,103	2,374,315
1972	1,644,287	512,143	177,773	270,402	2,604,605
1973	1,672,515	565,270	164,221	283,344	2,685,350
1974	1,858,602	606,096	175,345	297,327	2,937,370
1975	1,645,495	671,860	173,758	311,065	2,811,178
1976	2,048,828	747,405	196,327	327,686	3,320,246
1977	2,043,063	793,489	189,259	332,724	3,358,535
1978	2,074,202	875,656	209,362	360,464	3,519,864
1979	2,189,899	929,090	213,283	303,109	3,717,241
1980	22,375,756	982,731	218,940	406,839	3,984,266

SOURCE: (23).

TABLE 3. LEADING STATES IN THE PRODUCTION OF ALL NATURAL CHEESE IN THE UNITED STATES, 1950-1980

Year	California	Idaho	Illinois	Iowa	Minnesota	Missouri	New York	Penn.	Ohio	Wisconsin	United States
	thousand pounds										
1950	10,136	20,895	79,850	11,312	52,329	63,767	87,582	12,073	45,773	557,951	1,191,487
1955	16,147	26,445	87,966	26,786	73,502	90,281	102,794	10,417	41,094	598,512	1,366,893
1960	18,259	36,733	78,505	42,885	72,569	93,591	118,540	11,165	37,183	641,119	1,477,973
1961	19,845	37,926	84,695	57,775	76,248	105,416	129,429	13,968	41,442	671,808	1,634,505
1962	19,739	37,764	86,302	55,666	57,440	109,878	119,174	22,085	42,528	668,069	1,592,022
1963	19,081	40,703	92,731	64,871	59,457	103,734	117,881	24,091	43,188	704,381	1,631,817
1964	19,584	42,481	89,934	74,779	70,704	102,299	122,209	21,157	47,019	761,969	1,723,636
1965	20,354	42,313	85,654	70,646	74,742	103,956	132,927	20,534	47,090	770,398	1,755,456
1966	19,090	43,019	86,220	85,494	91,408	94,443	138,899	20,751	46,380	820,379	1,854,002
1967	13,473	47,046	86,643	87,890	100,094	118,506	134,101	20,871	47,456	828,976	1,918,830
1968	12,481	52,707	85,207	93,294	111,188	108,093	133,140	18,346	41,316	847,007	1,943,916
1969	13,675	53,690	80,899	94,244	130,721	93,395	146,164	21,951	40,025	866,593	1,989,589
1970	17,460	58,141	86,186	103,516	161,539	98,562	158,317	24,684	43,525	947,591	2,201,428
1971	21,788	59,792	92,597	118,205	202,348	104,754	176,483	29,962	48,718	986,369	2,374,315
1972	26,604	67,230	92,448	147,321	234,620	108,363	198,365	34,827	54,602	1,063,712	2,604,605
1973	45,588	72,949	90,915	162,644	297,160	93,494	203,939	35,624	53,257	1,071,041	2,685,350
1974	69,051	82,385	89,988	177,460	315,924	101,335	218,404	68,955	62,774	1,129,037	2,937,370
1975	92,877	74,770	86,113	146,916	316,189	68,196	217,560	67,985	66,107	1,089,978	2,811,178
1976	112,112	88,637	94,724	179,125	430,491	69,916	255,639	87,743	80,748	1,241,180	3,320,246
1977	125,777	87,789	90,213	174,854	410,628	72,621	260,327	93,706	77,948	1,278,890	3,358,535
1978	136,956	92,811	90,213	178,951	451,569	82,297	282,927	95,617	87,848	1,332,005	3,519,684
1979	151,802	97,999	96,968	191,794	479,952	92,250	304,400	93,908	95,147	1,400,829	3,717,241
1980	181,463	109,351	98,500	204,577	512,361	100,796	319,579	101,262	95,166	1,484,251	3,984,266

SOURCE: (23).

TABLE 4. LEADING STATES IN THE PRODUCTION OF AMERICAN CHEESE, 1950-1980

Year	Idaho	Iowa	Minnesota	New York	Wisconsin	United States
	- - - - - - - - - - - - - - -	-	-	thousand pounds	- - - - - - - - - - - - - -	-
1950	18,342	10,477	45,597	37,021	418,289	892,706
1955	20,016	25,992	53,540	39,140	459,422	1,004,269
1960	27,883	41,376	49,617	41,995	438,487	996,118
1961	30,019	56,823	55,830	47,814	469,153	1,148,761
1962	30,402	54,918	51,035	35,821	464,049	1,094,487
1963	32,604	63,215	57,072	32,768	483,013	1,108,351
1964	33,854	72,532	63,423	34,403	522,198	1,157,311
1965	32,360	65,987	63,902	39,136	519,921	1,158,285
1966	32,730	76,757	74,304	44,717	559,764	1,220,580
1967	32,528	76,202	88,631	40,884	580,650	1,276,339
1968	34,808	72,017	91,881	37,745	586,525	1,276,336
1969	36,289	68,892	104,655	41,738	579,972	1,266,428
1970	39,724	73,852	128,243	45,572	652,340	1,423,399
1971	38,639	80,589	163,771	53,972	671,417	1,511,508
1972	43,237	93,298	191,232	60,414	731,704	1,644,287
1973	50,794	97,487	245,620	61,212	720,104	1,672,515
1974	57,751	111,046	261,940	76,895	764,420	1,858,602
1975	53,663	76,174	260,039	56,130	705,995	1,654,495
1976	66,785	101,531	365,162	80,313	835,505	2,048,828
1977	62,904	95,137	344,573	78,907	869,291	2,043,063
1978	67,981	91,301	381,597	81,766	877,226	2,074,202
1979	72,076	96,967	419,304	87,672	926,301	2,189,899
1980	82,487	96,517	453,459	75,530	993,926	2,374,619

SOURCE: (23).

TABLE 5. LEADING STATES IN THE PRODUCTION OF ITALIAN CHEESE, 1950-1980

Year	Illinois	California	New York	Penn.	Wisconsin	United States
	thousand pounds					
1950	2,915	1,088	18,349	1,446	31,334	60,481
1955	3,648	3,527	25,883	2,932	37,601	86,018
1960	9,278	4,623	26,078	2,926	95,273	157,533
1961	9,372	5,529	29,840	4,529	94,653	161,799
1962	10,831	5,712	32,261	9,970	90,055	172,002
1963	12,677	5,791	35,042	11,305	110,417	192,228
1964	13,101	6,290	38,102	9,175	110,609	219,718
1965	13,185	6,961	44,326	7,271	118,615	244,470
1966	14,220	5,909	46,999	6,805	127,228	271,119
1967	14,888	6,242	45,548	8,740	124,689	284,456
1968	16,163	7,269	46,512	7,426	135,085	314,855
1969	18,801	8,373	55,830	8,430	153,710	361,254
1970	19,720	11,863	63,261	8,449	154,343	393,668
1971	20,266	15,123	75,312	11,120	165,566	453,861
1972	17,628	19,085	82,748	10,790	179,435	512,143
1973	18,072	35,584	81,430	10,502	199,674	565,270
1974	19,091	55,541	82,388	12,492	217,017	606,096
1975	19,930	76,321	95,251	20,763	230,886	671,860
1976	22,380	91,008	108,381	29,213	240,031	747,405
1977	24,896	98,842	117,229	35,657	243,469	793,489
1978	26,840	106,066	126,955	39,568	282,617	875,656
1979	27,377	111,181	140,550	39,657	304,257	929,090
1980	27,850	117,633	160,467	41,476	312,461	982,731

SOURCE: (23).

TABLE 6. LEADING STATES IN THE PRODUCTION OF SWISS CHEESE, 1950-1980

Year	Illinois	Ohio	Penn.	Utah	Wisconsin	United States
	- - - - - - - - - - - -		thousand pounds		- - - - - - - - - - - -	
1950	23,091	8,293	*	*	52,260	99,483
1955	31,300	7,200	769	*	38,761	116,654
1960	37,750	6,961	1,657	*	29,707	121,081
1961	37,237	8,584	3,536	*	31,599	120,508
1962	39,109	8,624	3,455	*	31,618	109,412
1963	45,058	9,726	3,983	*	37,479	119,906
1964	45,145	10,344	4,272	*	38,546	121,844
1965	46,652	10,077	2,591	*	38,067	122,637
1966	51,500	10,021	5,570	*	40,554	136,664
1967	52,756	9,615	5,746	*	36,085	132,204
1968	49,321	9,165	5,744	*	33,771	129,613
1969	44,677	8,168	7,730	*	35,801	131,612
1970	44,751	10,069	9,975	10,776	38,201	143,957
1971	48,880	11,879	*	12,760	35,312	153,843
1972	52,425	13,482	*	15,206	37,747	177,773
1973	46,784	13,598	*	16,660	32,764	164,221
1974	49,236	17,897	14,162	18,386	29,795	175,345
1975	44,203	21,767	11,839	19,654	33,349	173,758
1976	46,358	28,478	12,928	20,173	36,508	196,327
1977	45,573	30,321	10,726	19,189	36,884	189,259
1978	47,730	33,695	10,145	19,991	38,131	209,362
1979	49,992	35,336	8,861	21,244	35,293	213,283
1980	52,206	37,262	6,969	21,144	38,830	218,940

*Production data are not shown for individual states when volume is not consistently significant or when less than three plants were in operation.

SOURCE: (23).

TABLE 7. NUMBER AND AVERAGE PRODUCTION OF NATURAL CHEESE MANUFACTURING PLANTS, 1950-1980

Year	Total		Cheese Type or Variety: American		Italian		Swiss	
	Plants	Average Plant Production	Plants	Average Plant Production	Plants	Average Plant Production	Plants	Average Plant Production
	Number	1,000 pounds	Number	1,000 pounds	Number	1,000 pounds	Number	1,000 pounds
1950	2,158	552	1,620	551	167	362	274	363
1951	2,061	563	1,592	549	158	351	274	336
1952	1,954	590	1,478	575	138	439	264	409
1953	1,883	714	1,459	700	138	492	264	393
1954	1,829	756	1,406	741	132	539	236	481
1955	1,785	766	1,356	741	157	548	228	512
1960	1,419	1,042	1,008	988	193	816	164	738
1961	1,410	1,159	1,024	1,122	193	838	158	763
1962	1,355	1,175	974	1,124	196	878	147	744
1963	1,283	1,272	924	1,200	185	1,039	133	902
1964	1,252	1,377	899	1,287	185	1,188	129	945
1965	1,209	1,452	864	1,341	182	1,343	123	998
1966	1,160	1,598	836	1,460	178	1,523	119	1,148
1967	1,121	1,712	815	1,566	182	1,563	115	1,150
1968	1,048	1,855	750	1,702	186	1,693	107	1,211
1969	995	2,000	694	1,825	188	1,922	99	1,329
1970	963	2,286	669	2,036	197	1,998	90	1,600
1971	921	2,577	637	2,373	194	2,339	82	1,876
1972	901	2,890	613	2,682	199	2,574	76	2,339
1973	869	3,090	592	2,825	189	2,991	75	2,190
1974	866	3,392	608	3,057	189	3,207	70	2,505
1975	838	3,355	567	2,918	185	3,632	70	2,482
1976	809	4,104	542	3,780	192	3,893	70	2,805
1977	796	4,219	536	3,813	186	4,266	69	2,743
1978	778	4,524	507	4,091	192	4,561	67	3,125
1979	754	4,930	487	4,497	185	5,022	66	3,232
1980	737	5,404	483	4,916	187	5,255	63	3,475

SOURCE: (23).

larger sized plants. Presently, more steps in the manufacture of cheese have been automated, and larger sizes are needed to capture economies of size.

Consumption of Cheese

Civilian per capita consumption of most dairy products has been declining since 1950. This decline is found particularly among items rich in milk fat. The total per capita consumption of all dairy products was 561 pounds in 1979 in terms of fat content basis, a 24 percent decline from 1950. However, total domestic consumption has increased from 112 million pounds in 1950 to 121 million pounds in 1979 due to the increased population.

Per capita civilian consumption of all natural cheese and principal types of cheeses in the United States are presented in Table 8. Cheese consumption has risen sharply in the past 30 years to about 17.6 pounds per person in 1979 from 7.7 pounds in 1950, an increase of 228 percent. The per capita consumption of American cheese, which contains as much fat as whole milk, was up 78 percent during the period. Italian cheese consumption increased 809 percent and Swiss cheese increased 199 percent from 1950 to 1979.

Of the 9.8 pounds of American cheese consumed per person in 1979, an estimated 7.2 pounds were cheddar and 2.6 pounds were other varieties. Consumption of Italian cheese varieties expanded steadily during the 1970s. Mozzarella was the principal variety among Italian cheeses. The increase in consumption resulted from the popularity of pizza, for which Italian cheese is an important ingredient. Nearly 67 percent of Italian cheese consumption was mozzarella in 1979 (Table 9).

Imitation Cheese

Imitation cheese is presenting increased competition for natural cheese. The United States International Trade Commission reported that imitation cheese production accounted for 5 percent of the total natural cheese output in 1980, an increase of 150 percent from the 1978 output.

The major use of synthetic cheese is in the production of frozen pizzas. Imitation Italian cheese claimed about one-third of the market for mozzarella natural cheese in 1980. Current consumer preferences and tastes are toward products which contain less cholesterol and fewer calories. Imitation cheese is produced with vegetable fat and nonfat milk solids which may explain why this product has gained increasing acceptance with consumers. A Wisconsin

TABLE 8. PER CAPITA CIVILIAN CONSUMPTION OF ALL NATURAL CHEESE AND PRINCIPAL TYPES OF CHEESES IN THE UNITED STATES, 1950-1979

Year	Total Cheese	American	Italian	Swiss	Other
	pounds				
1950	7.7	5.5	0.54	0.70	0.96
1951	7.2	5.1	0.47	0.66	0.97
1952	7.6	5.3	0.52	0.75	1.03
1953	7.5	5.1	0.57	0.75	1.08
1954	7.9	5.5	0.58	0.79	1.03
1955	7.9	5.4	0.66	0.81	1.03
1956	8.0	5.4	0.75	0.80	1.05
1957	7.7	5.1	0.77	0.69	1.14
1958	8.1	5.5	0.88	0.68	1.04
1959	8.0	5.2	0.93	0.73	1.14
1960	8.3	5.4	1.01	0.76	1.13
1961	8.6	5.7	1.02	0.73	1.15
1962	9.2	6.1	1.08	0.74	1.28
1963	9.2	6.1	1.18	0.72	1.20
1964	9.4	6.2	1.30	0.74	1.16
1965	9.6	6.2	1.40	0.73	1.27
1966	9.8	6.2	1.53	0.80	1.27
1967	10.1	6.4	1.59	0.81	1.30
1968	10.6	6.6	1.75	0.93	1.33
1969	11.0	6.7	1.97	0.85	1.48
1970	11.5	7.1	2.09	0.90	1.41
1971	12.2	7.4	2.34	0.95	1.51
1972	13.2	7.8	2.65	1.08	1.67
1973	13.7	8.0	2.86	1.08	1.76
1974	14.6	8.6	3.02	1.21	1.77
1975	14.5	8.3	3.31	1.12	1.77
1976	15.9	9.1	3.65	1.28	1.87
1977	16.3	9.4	3.82	1.24	1.84
1978	17.2	9.7	4.17	1.37	1.96
1979	17.6	9.8	4.37	1.39	2.04

SOURCE: (25), (26).

TABLE 9. PER CAPITA CIVILIAN CONSUMPTION OF CHEDDAR AND MOZZARELLA VARIETIES OF CHEESES, SELECTED YEARS

Year	Cheddar	Mozzarella
	- - - - - pounds - - - - -	
1950	5.2	*
1955	4.9	*
1960	4.8	*
1965	5.3	*
1968	5.4	0.95
1969	5.7	1.14
1970	5.9	1.21
1971	6.0	1.41
1972	6.1	1.60
1973	6.2	1.80
1974	6.4	1.90
1975	6.1	2.16
1976	6.6	2.37
1977	6.9	2.63
1978	7.1	2.77
1979	7.2	2.90

*Not available.

SOURCE: (25).

study reported that pizzas made with a blend of natural cheese and imitation cheese tasted the same as pizzas made with natural mozzarella only (22).

The price differentials between imitation cheese and natural cheese products may be an additional factor responsible for the increasing demand of synthetic cheese. Prices for imitation cheese averaged 30 percent less than natural cheese. Mozzarella and process imitation cheeses accounted for the largest price differential, 54 percent and 57 percent less, respectively.

Production Trend

The quadratic form of the single equation regression model was used to show cheese production trends over time. The estimated parameters for this equation, with standard errors in parentheses, are:

$$Q_c = \underset{(54{,}874.8)}{1{,}342.2} - \underset{(7{,}905.5)}{31{,}657.5}\,T + \underset{(239.7)}{3{,}679.2}\,T^2$$

$$R^2 = 0.99$$

Where: Q_c = total cheese production
T = time in years (1950 = 1)

Analysis of the regression coefficients indicated that they were statistically significant at the 1 percent probability level. The quadratic equation shows the upward trend in cheese production after the low cheese production of the early 1950s.

The same production trend was observed in different types of cheese as in total production. American cheese production was 1.1 billion pounds in 1961, 28 percent above the 0.9 billion pounds produced in 1950. About 1.4 billion pounds were produced in 1970 with the peak amount of 2.4 billion pounds in 1980, 166 percent above the production of 1950.

Italian cheese production increased dramatically during the last 30 years. Production of Italian cheese in 1980 was 16 times greater than in 1950.

Swiss cheese production temporarily dropped during the last 30 years, although the upward trend was clearly noted. Swiss cheese output fell to 0.3 billion pounds in 1979, but rose to 0.4 billion pounds in 1980, 193 percent above the 1950 output.

The quadratic form of the single equation model was used to analyze production trends of American, Italian, and Swiss types of cheeses. The estimated equations, with standard errors in parentheses, are:

$$Q_a = \underset{(45,141.8)}{993,971.5} - \underset{(6,503.3)}{21,469.8}\,T + \underset{(197.2)}{2,066.9}\,T^2$$

$$R^2 = 0.97$$

$$Q_i = \underset{(11,106.5)}{97,056.77} - \underset{(1,600.1)}{11,307.5}\,T + \underset{(48.51)}{1,286.2}\,T^2$$

$$R^2 = 0.99$$

$$Q_s = \underset{(4,650.8)}{108,346.4} - \underset{(670.0)}{1,420.1}\,T + \underset{(29.31)}{161.6}\,T^2$$

$$R^2 = 0.96$$

Where: Q_a = production of American cheese
Q_i = production of Italian cheese
Q_s = production of Swiss cheese
T = time in years (1950 = 1)

All American, Italian, and Swiss cheese equations have negative sign on the trend term and positive sign on the trend-squared term indicating that production of cheese has increased at an increasing rate over the study period.

Institutional Marketing Arrangements

A number of agencies and programs influence the pricing of cheese, directly or indirectly. Grade A milk is produced under strict sanitary conditions and is consumed in fluid form. Grade B milk meets somewhat lower standards and is used only for manufactured dairy products. Grade A milk accounted for about 82 percent of the total milk production in the United States in 1980, and about 45 percent of the total Grade A production went into fluid milk products, with the remaining amount used in the manufacture of dairy products.

Federal Milk Marketing Orders

Federal milk marketing orders have three main objectives: orderly marketing, equitable dealings between dairy producers and milk handlers, and a dependable supply of wholesome milk at fair prices for consumers. To achieve these objectives, each order includes provisions for a classified pricing plan, a system of minimum class prices, a plan for payment of uniform prices to producers, and provisions for administering the order. Most federal orders establish three classes of milk: Class I milk is used as fluid or beverage milk; Class II milk is used for ice cream and frozen desserts, cottage cheese, yogurt, fluid cream, and cream products; and Class III milk is used for cheese, butter, milk powder, and evaporated milk. Prices are based on supply and demand conditions affecting the marketing area. These conditions are reflected in the value of milk for manufactured uses as reported in the Minnesota-Wisconsin (M-W) Price Series (the average price paid by dairy plants in the two states making butter, cheese, or milk powder). This price is the basis for all Class I, II, and III prices within the marketing areas.

Federal Price Supports

Each year the Secretary of Agriculture is required to announce a minimum support price for manufacturing grade milk for the coming marketing year. The support price is the basic price for bulk milk sold by farmers. The support price is achieved through purchases of cheddar cheese, nonfat dry milk, and butter by the Commodity Credit Corporation. Historically, the price of milk has been supported at various levels between 75 and 90 percent of parity. Currently, the support price has encouraged production to the extent that surplus commodities are taxing storage capacities. The 1982 support price is $12.80 nationally for milk used for manufacturing purposes, adjusted to 3.5 percent milkfat.

The National Cheese Exchange

The National Cheese Exchange (NCE), Green Bay, Wisconsin, is the only central market for cheese in the United States. The NCE has 44 members among sellers and buyers of cheese, who meet every Friday for one-half hour, or longer if considered necessary. The volume of cheese marketed on the NCE represents a small portion of total domestic output. Sales of American cheese on the NCE ranged between 0.04 percent to 0.99 percent of total American cheese production from 1970 to 1977 (Table 10). There was an increase of sales during the 1970s, but they never accounted for more than 1 percent of total output.

TABLE 10. PERCENTAGE OF TOTAL UNITED STATES AMERICAN CHEESE PRODUCTION SOLD ON WISCONSIN CHEESE EXCHANGE, SELECTED YEARS

Year	Total American Cheese Production	American Cheese Sold on NCE Sales	American Cheese Sold on NCE Percentage of Production
	thousand pounds		percent
1960	996,118	3,287	0.33
1961	1,148,761	4,709	0.41
1962	1,094,487	1,532	0.14
1963	1,108,351	3,435	0.31
1964	1,157,311	5,207	0.45
1965	1,158,285	7,876	0.68
1970	1,423,399	6,818	0.48
1971	1,511,508	4,208	0.28
1972	1,644,287	2,520	0.15
1973	1,672,515	828	0.04
1974	1,658,602	1,764	0.09
1975	1,654,495	7,056	0.43
1976	2,048,828	18,180	0.89
1977	2,043,063	20,376	0.99

SOURCE: (15), (7).

The price provided by the NCE influences the entire cheese industry. The price at the cheese-plant level is determined by a formula price contract. This price is based on the NCE reported price plus a prenegotiated premium. The transactions between cheese processing and marketing firms, and retail, food service, and industrial users are basically determined using the NCE prices. The cheese sold to retailers is formulated on the basis of a weekly price list with a strong propensity to follow changes in the NCE price. Weekly prices may be stable for several weeks during periods when the NCE price does not change (11).

There is a close relationship between the cheese support price and the NCE price. The support price is considered a kind of floor price for the NCE price. Cheese support prices have generally been closely parallel to the NCE price.

Hayenga (11), in his 1979 study of pricing systems in the cheese industry, indicated that the NCE was a thinly traded market. Trading on the NCE was regularly done by four or five largest firms, and the volume of cheese traded represented less than 1 percent of the total United States cheese production.

A perfectly competitive market structure assumes that price is determined by supply and demand. It also assumes that market participants have perfect or complete knowledge of market conditions. Knowledge of market conditions is important because of its relationship to price discovery. If price is established by the interaction of only a few sellers and buyers, other firms may be at a disadvantage.

A small volume of transactions may imply less information and less reliable prices representing the market. In perfect competition, a producer takes the market price as warranted. In a thin market, prices may deviate from this norm. The small volume of trading at a central market can result in price behavior not warranted by economic conditions as manipulation of prices is more feasible. The entire industry is affected if a central market price is the basis for other transactions.

II. Methodology

Both Box-Jenkins time series and distributed lag models are used in this study. While Box-Jenkins model is used to forecast U.S. cheese production and price, a distributed lag model is applied to analyze demand for cheese.

Box-Jenkins Time Series Model

Formulation of the Box-Jenkins time series model is based solely on the past behavior of the variable of primary concern. Consequently, it does not require a set of explanatory variables related to the variable. This model, therefore, could be used in cases where little information is known about the determinants of the variable. A major limitation of the model is that it does not provide the economic relationship between dependent and independent variables which is useful to understand the behavior of the dependent variable. Because of the complex dynamic relationship of the United States cheese industry with other dairy industries under various government policies for those industries, the determinants of monthly cheese production and price behavior are not known. The Box-Jenkins time series model is, therefore, used to forecast monthly production of cheese and price behavior. The Box-Jenkins model used in this study combines the ARIMA (p, d, q) and ARIMA (P, D, Q)s processes to obtain the general multiplicative seasonal model, GMSM (p, d, q) (P, D, Q)s. This model can be expressed mathematically as follows:

$$(1 - \phi_1 B - \phi_2 B^2 - \ldots - \phi_p B^p)(1 - \Phi_s B^s - \Phi_{2s} B^{2s} - \ldots - \Phi_{Ps} B^{Ps})(1-B)^d (1-B)^D Z_t =$$
$$\delta + (1 - \theta_1 B - \theta_2 B^2 - \ldots - \theta_q B^q)(1 - \Theta_s B^s - \Theta_{2s} B^{2s} - \ldots - \Theta_{Qs} B^{Qs}) u_t$$

where: B = backward shift operator

Z_t = dependent variable (Z_t is either cheese production or cheese price)

U_t = disturbance term

$$(1 - \phi_1 B - \phi_2 B^2 - \ldots - \phi_p B^p) = \phi_p (B)$$

is the nonseasonal autoregressive operator of order p,

$$(1 - \Phi_s B^s - \Phi_{2s} B^{2s} - \ldots - \Phi_{Ps} B^{Ps}) = \Phi_p(B^s)$$

is the seasonal autoregressive operator of order P,

$$(1 - \theta_1 B - \theta_2 B^2 - \ldots - \theta_q B^q) = \theta_q (B)$$

is the nonseasonal moving average operator of order q,

$$(1 - \Theta_s B^s - \Theta_{2s} B^{2s} - \ldots - \Theta_{Qs} B^{Qs}) = \Theta_Q(B^s)$$

is the seasonal moving average operator of order Q, and

$$(1 - B)^d = \nabla^d, \nabla = Z_t - Z_{t-1}$$

represents the difference operator of order d.

A simplified form for the GMSM (p, d, q) (P, D, Q)s is given by:

$$\phi_p (B) \phi_p(B^s) \nabla^d \nabla_s^D Z_t = \theta_q (B) \theta_Q (B^s) u_t + \delta$$

A detailed description of the Box-Jenkins time series model can be found in Appendix A.

Distributed Lag Model

The distributed lag model used to analyze demand for cheese is a compound geometric lag model which is a combination of adaptive expectation and partial adjustment models. Unlike the Box-Jenkins time series model, the distributed lag model is a standard econometric model with a dependent variable and a set of explanatory variables. Justification for using the lag model in demand analysis is based on the dynamic behavior in consumers' demand with the formation of price expectation and/or expectation of final consumption. The formation of price expectation used in demand is based on a linear relationship between dependent and lagged price variables with geometrically declining weights on lagged price backwards in time. This model is known as the adaptive expectation model (17). After the Koyck transformation, this specification can be reduced to a first order difference equation in the dependent variable (demand for cheese). Partial adjustment model is based on an assumption of that expectation of final consumer's demand. This model directly implies a difference equation in the dependent variable with a suitable transformation.

The statistical model postulated to estimate the demand equation for cheese in the United States may be summarized as follows:

$$D_t = b_o \, Y_t^{b_1} \, P_t^{b_2} \, D_{t-1}^{b_3} \, D_{t-2}^{b_4} \, E_t$$

Where: D_t = quantity of cheese demanded at period t

Y_t = per capita disposable income

P_t = retail price for cheese

D_{t-1} = quantity of cheese demanded at time t-1

D_{t-2} = quantity of cheese demanded at time t-2

E_t = disturbance term

The model specified above is a multiplicative relationship between dependent and explanatory variables. Consequently, the model can be expressed as a linear form with logarithmic transformation. A detailed description of the model can be found in Appendix B.

Data

American, Italian, and Swiss cheese were considered as principal types of cheese in this study. This study is based on secondary data, mostly from reports published by the United States Department of Agriculture. Trend and seasonal influences in U.S. cheese production and price are analyzed on the basis of monthly data from 1950 to 1980. Annual data (from 1950 to 1980) for cheese consumption, price and income are used to estimate demand for cheese.

III. Production Patterns and Forecast

Production of cheese is dependent upon price of cheese and availability of milk. Since cheese is storable, cheese could be produced as a means of milk storage. To forecast monthly cheese production in the United States, it is useful to understand monthly production patterns of cheese in the United States.

Seasonality of Cheese Production

A seasonality production function for cheese is estimated using a multiple regression model with monthly dummy variables. The 12 months for each year were represented by zero-one variables X_1, X_2, . . . X_{12}, respectively, in the model. The multiple regression equation model in the analysis is as follows:

$$P_{ij} = a_o + T_j + \sum_{i=1}^{12} B_i X_{ij} + e_{ij} \qquad \begin{matrix} j = 1, 2, \ldots 31 \\ i = 1, 1, \ldots 12 \end{matrix}$$

Where: i = index for the ith month
j = index for the jth year
X_{ij} = ith month dummy variable in the jth year
B_i = coefficient for dummy variable, X_{ij}
T_j = variable representing annual trend
e_{ij} = disturbance terms

Singular matrix and indeterminate solutions are avoided by dropping the dummy variable representing the month of May from the regression equation. Therefore, May should be interpreted as the base month of production. The estimated coefficients, standard errors, and t values are presented in Table 11.

TABLE 11. ESTIMATED PARAMETERS FOR TOTAL CHEESE SEASONALITY FUNCTION, UNITED STATES, 1950-1980

Parameter	Estimate	t-ratio	PR ≥ t	Standard Error	R^2
Intercept	97,011.2	19.51	0.0001	4,972.41	0.89
Trend	7,161.6	50.22	0.0001	142.59	
January	-58,441.5	- 9.35	0.0001	6,248.14	
February	-62,806.8	-10.05	0.0001	6,248.14	
March	-34,406.7	- 5.51	0.0001	6,248.14	
April	-26,128.3	- 4.18	0.0001	6,248.14	
June	- 1,554.5	- 0.25	0.8037	6,248.14	
July	-24,752.4	- 3.96	0.0001	6,248.14	
August	-39,257.6	- 6.28	0.0001	6,248.14	
September	-55,082.7	- 8.82	0.0001	6,248.14	
October	-54,757.8	- 8.76	0.0001	6,248.14	
November	-63,041.7	-10.09	0.0001	6,248.14	
December	-48,101.6	- 7.70	0.0001	6,248.14	

All coefficients are significantly different from zero at the 1 percent level of significance, except for June. Analysis of the regression coefficients indicates that May and June are the months of largest production. The smallest coefficients are for February and November, indicating the least production relative to the other months and the average May production. A positive trend-term coefficient reflects an upward trend in production during the last 30 years.

Estimated seasonality functions for American, Swiss, and Italian cheeses are shown in Tables 12, 13, and 14, respectively. The method used to estimate the cheese equations is the same as the one used for the all-cheese function.

All coefficients in the American cheese model (Table 12) are different from zero at the 1 percent level of significance (except June). The coefficients show that May and June production were largest relative to the other months.

TABLE 12. ESTIMATED PARAMETERS FOR AMERICAN CHEESE SEASONALITY FUNCTION, UNITED STATES, 1950-1980

Parameter	Estimate	t-ratio	PR ≥ t	Standard Error	R^2
Intercept	87,260.7	28.25	0.0001	3,088.61	0.87
Trend	3,721.9	42.02	0.0001	88.57	
January	-49,913.4	-12.86	0.0001	3,888.03	
February	-52,271.1	-13.47	0.0001	3,888.03	
March	-33,943.2	- 8.75	0.0001	3,888.03	
April	-22,476.8	- 5.79	0.0001	3,888.03	
June	1,188.8	0.31	0.7595	3,888.03	
July	-18,663.5	- 4.81	0.0001	3,888.03	
August	-32,941.0	- 8.49	0.0001	3,888.03	
September	-48,171.8	-12.41	0.0001	3,888.03	
October	-51,306.0	-13.22	0.0001	3,888.03	
November	-58,967.4	-15.19	0.0001	3,888.03	
December	-49,206.8	-12.68	0.0001	3,888.03	

The smallest production is during November. Seasonality for American cheese follows the same general pattern as total cheese production. American cheese production accounts for about 59 percent to 75 percent of total cheese output during the last 30 years.

Unlike American cheese, the regression equation for Swiss cheese uses August as the base month. The t values are more significant when August is removed from the regression equation relative to the other months. May and

June are the months of largest production with February being the month of smallest output. The F test indicates that all the coefficients are different from zero at the 1 percent level of significance (Table 13).

The month of December is used as the base month to estimate the seasonality of the Italian cheese production function. The coefficients for January, February, August, September, and November were significant at the 10 percent level of significance (Table 14), with December and March being the months of largest and smallest production, respectively.

TABLE 13. ESTIMATED PARAMETERS FOR SWISS CHEESE SEASONALITY FUNCTION, UNITED STATES, 1950-1980

Parameter	Estimate	t-ratio	PR ≥ t	Standard Error	R^2
Intercept	8,140.9	29.26	0.0001	278.18	0.84
Trend	311.8	39.09	0.0001	7.97	
January	-2,705.3	-7.74	0.0001	349.55	
February	-3,296.6	-9.43	0.0001	349.55	
March	-1,593.7	-4.56	0.0001	349.55	
April	-1,164.0	-3.33	0.0010	349.55	
May	873.1	2.50	0.0129	349.55	
June	1,049.9	3.00	0.0029	349.55	
July	- 741.8	-2.12	0.0345	349.55	
September	-2,000.0	-5.72	0.0001	349.55	
October	-2,366.4	-6.77	0.0001	349.55	
November	-3,232.3	-9.25	0.0001	349.55	
December	-2,443.5	-6.99	0.0001	349.55	

TABLE 14. ESTIMATED PARAMETERS FOR ITALIAN CHEESE SEASONALITY FUNCTION, UNITED STATES, 1950-1980

Parameter	Estimate	t-ratio	PR ≥ t	Standard Error	R^2
Intercept	-8,186.9	- 4.98	0.0001	1,645.18	0.89
Trend	2,486.9	52.71	0.0001	47.18	
January	-3,760.8	- 1.82	0.0697	2,067.27	
February	-5,001.4	- 3.42	0.0160	2,067.27	
March	- 284.6	- 0.14	0.8906	2,067.27	
April	-1,526.7	- 0.74	0.4607	2,067.27	
May	-1,026.3	- 0.50	0.6199	2,067.27	
June	-1,925.0	- 0.93	0.3524	2,067.27	
July	-3,819.4	- 1.85	0.0655	2,067.27	
August	-3,495.4	- 1.69	0.0917	2,067.27	
September	-4,156.9	- 2.01	0.0451	2,067.27	
October	-2,719.2	- 1.32	0.1892	2,067.27	
November	-3,313.9	- 1.60	0.1098	2,067.27	

Monthly average production for each type of cheese as a percentage of May production is plotted in Figure 1. As expected, Italian cheese shows a different pattern than American, Swiss, and total cheeses. The latter three had similar patterns of seasonal production. Italian cheese shows that its seasonality has very little pattern of movement among the months.

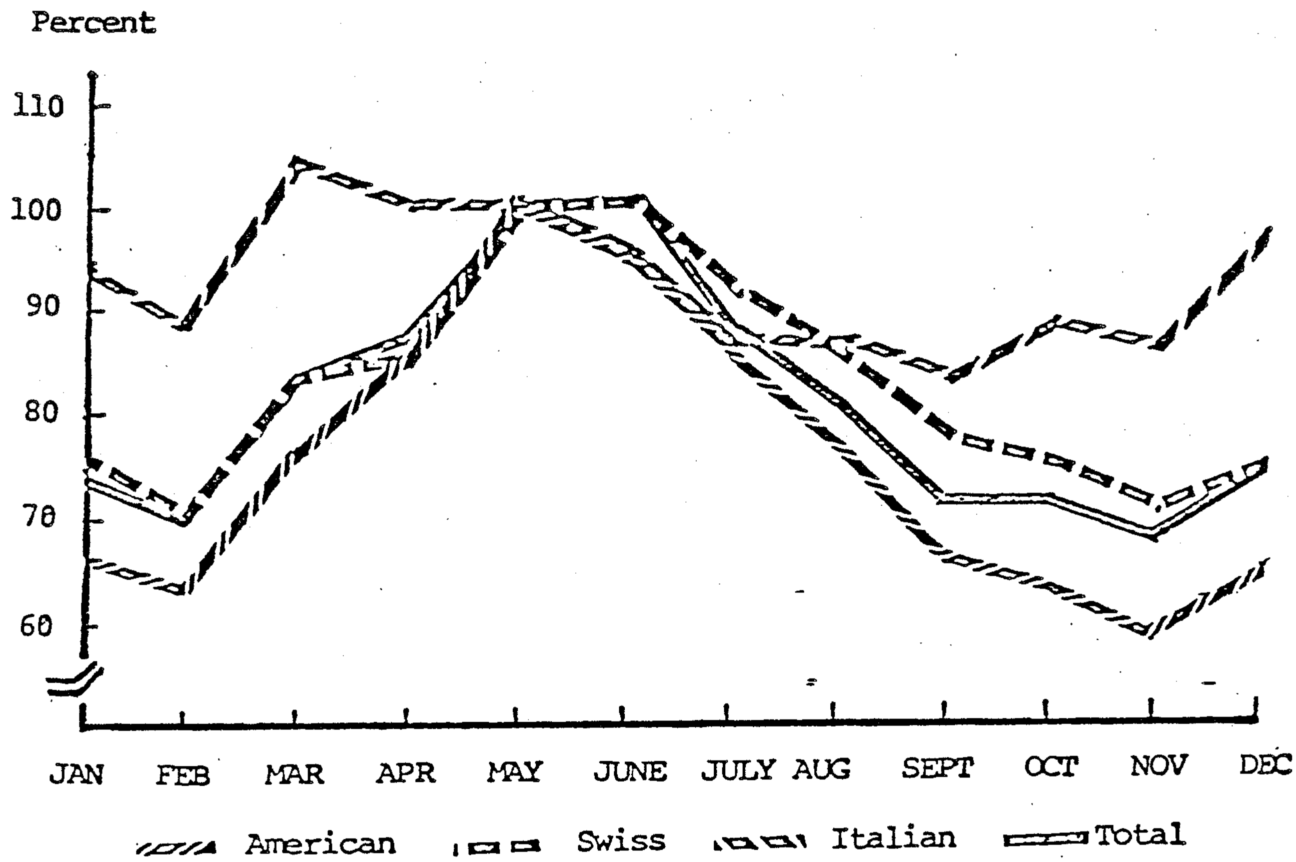

Figure 1. Average Monthly Production for 30 Years as a Percentage of May Production for Total Cheese and Principal Types of Cheeses, United States, 1950-1980

Forecast of Cheese Production

The Box-Jenkins method was used to determine a model to forecast cheese production in the United States. The time series data used in this study are monthly cheese production amounts from 1956 to 1980.

Specification of the Model

The plot of the original series shows nonstationarity with a steadily upward trend. It appears that seasonal variation is increasing with the level of time series. This indicates the need for logarithmic transformation.

The autocorrelation function and the partial autocorrelation function of the logarithms of the original series were calculated for 24 lags. The sample autocorrelation function does not decrease with large lags. This means that the lagged original series is nonstationary. First differences were calculated to obtain stationarity on the original time series. Analysis of the sample autocorrelation function of the first differences shows stationarity, except at lags 12 and 24. This indicates seasonality exists; the final differencing factors to achieve stationarity with seasonal adjustments were:

$$(1 - B)\ (1 - B^{12})\ \log Z_t$$

Where: B is a backward shifter and Z_t is monthly cheese production.

The sample autocorrelation function of the stationary series cut off after lag 13, with autocorrelations larger than twice their standard deviations at lags 4 and 12. This indicates that two seasonal and nonseasonal moving average parameters were needed, one at lag 4 and the other at lag 12.

Analysis of the sample partial autocorrelation function indicated partial autocorrelations different from zero at lags 4, 12, and 24, suggesting two autoregressive parameters, at lags 4 and 12, respectively.

With the information obtained from the time series data, different theoretical models were tested. It was concluded that the best model to fit the data was a multiplicative moving average with three moving average factors of order 4, 6, and 12. The model is given by:

$$(1 - B)\ (1 - B^{12})\ \log Z_t = (1 - \phi_4 B^4)\ (1 - \phi_6 B^6)\ (1 - \phi_{12} B^{12})\ U_t$$

Where: U_t is disturbance term of monthly cheese production

A detailed description of the Box-Jenkins time series model is given in Appendix A.

Estimation and Forecasts

Estimated coefficients of the model are shown in Table 15. Diagnostic checking of the model indicates that the estimation satisfies all requirements of an adequate model. None of the residual autocorrelations exceed twice their standard errors. The hypothesis that the residuals are uncorrelated is tested and the chi-square statistic does not fall in the critical rejection region at the 5 percent probability level. The model is, therefore, accepted at the 95 percent probability level.

TABLE 15. ESTIMATED PARAMETERS AND 95 PERCENT CONFIDENCE INTERVALS OF THE TIME SERIES MODEL USING THE BOX-JENKINS METHODOLOGY

Parameter Number	Parameter Type	Parameter Order	Estimated Value	95 Percent	
				Lower Limit	Upper Limit
1	Moving Average 1	4	0.186	0.06824	0.30456
2	Moving Average 2	6	0.192	0.07411	0.31074
3	Moving Average 3	12	0.674	0.58242	0.76533

Monthly forecast of total cheese production for 1981 is shown in Table 16. The forecasted values of monthly cheese production are within the 95 percent confidence limits. Cheese production in 1981 is slightly larger than in 1980. Total cheese production in 1981 is estimated at 4,355,965 tons which is approximately 10 percent higher than 1980 production.

The forecasted cheese production is seasonal because it is dependent upon supply of milk. Months of the highest cheese production are May, June, and July. November is the month of the lowest cheese production.

IV. Demand for Cheese

A distributed lag model (Nerlove) is used to estimate the demand for cheese in the United States. The estimation is based on an assumption that cheese consumption is not seasonal in the United States. Consequently, annual demand for cheese instead of monthly demand is estimated on the basis of annual data from 1962 to 1980. Logarithmic transformation is performed to capture the multiplicative effects of prices and income on quantity of cheese demanded.

The estimated demand equation for cheese is:

$$\ln D_t = -3.0746 - \underset{(2.245)}{0.5006} \ln (P_{ct}) + \underset{(5.484)}{0.702} \ln (Y_t) + \underset{(7.388)}{0.9456} \ln (D_{t-2}) + e_t$$

$$e_t = \underset{(8.276)}{0.3683}\, e_{t-1} + \underset{(4.254)}{0.4193}\, e_{t-2} + V_t$$

$$R^2 = 0.980$$

where: D_t = annual demand for cheese
P_{ct} = average price of cheese deflated by consumer price index
Y_t = per capita income deflated by consumer price index
e_t = stochastic disturbance term
V_t = stochastic disturbance term associated the autoregressive error structure

approximate t-ratios (absolute values) are in parentheses below respective parameter estimates.

The model specified for the demand analysis is the second order difference equation. However, the one year lagged dependent variable, D_{t-1}, is deleted from the model because the variable does not enter significantly in the model. The estimated regression coefficients for the demand equation have the right sign and are significant at the 99 percent probability level except for its own price. The price of cheese is significant at the 97 percent probability level.

Since the demand equation is estimated in a logarithmic form, the estimated coefficients of price and income represent price and income elasticities of cheese, respectively. While price elasticity of cheese is -0.5, income

TABLE 16. MONTHLY FORECAST OF TOTAL CHEESE PRODUCTION FOR 1981 AND 95 PERCENT CONFIDENCE LIMITS

Month	Lower Confidence Limit	Forecast	Upper Confidence Limit
January	326,353.6	343,742.6	362,057.9
February	305,091.1	328,331.6	353,342.2
March	346,402.2	378,991.6	414,646.5
April	338,916.2	375,995.3	417,130.6
May	362,703.2	405,722.8	453,844.4
June	358,868.6	404,533.6	456,008.9
July	326,330.0	369,426.8	418,214.8
August	311,802.3	354,438.8	402,904.9
September	294,687.3	336,323.9	383,843.2
October	305,694.8	350,241.9	401,280.3
November	293,019.6	337,136.4	387,895.1
December	321,208.8	371,083.6	428,702.0

elasticity is 0.7. The elasticities indicate that the consumption of cheese is more influenced by consumers' taste and needs and less by changes in income and its own price.

Price elasticity estimates were compared with earlier studies. Rojko found price and income elasticities of -0.9 and 1.01, respectively, using time series data from 1947 to 1954 (20). Brandow reported a price elasticity for cheese of -0.7 in his policy study in 1961 (4). Burk, using data from 1947 to 1967 found a price elasticity of -0.13 (5). Boehm and Babb using a time series model in 1975, found a price elasticity of demand for natural cheese of -0.85 (1). American cheese, in the same study, had an elasticity of -2.17 and -1.81, respectively. Results from the present study may be comparable to the ones obtained by Boehm and Babb.

V. Price Determination and Behavior

Price of a commodity is determined in a competitive market at the point where the amount demanded of a commodity is equal to the amount supplied of the commodity. Consequently, there is no excess demand or supply of the commodity at the equilibrium price. Market price will be seasonal if either demand or supply is seasonal and the other is constant over a given year. The seasonality in price is a source of uncertainty in farm income. The market price of seasonal products has been often controlled by either private or public agencies to reduce price seasonality. However, the reductions in seasonalities in price require storage costs for a particular commodity. Thus, the limitation in price control might produce seasonality in price.

In the United States, price of cheese is discovered by the National Cheese Exchange. However, the determination of cheese price reflects demand for and supply of cheese as well as the economic situation in the dairy industry. As discussed in the previous section, cheese production is seasonal while demand for cheese is constant over time of a year, leading to unstable cheese price in a competitive market. The price behavior of cheese is analyzed on the basis of monthly cheese prices from 1950 to 1977. The method used in analyzing cheese price is the Box-Jenkins time series model.

Model Specification

The plotted time series data showed nonstationarity. Prices had small variations from 1950 to 1960. Thereafter prices displayed an upward trend which was greatest during the 1970s. This suggests that seasonal variations were increasing with the level of time series. This implied the need for a logarithmic transformation. Also, the plotting of the series showed that the values of the time series did not fluctuate around a constant mean, suggesting that these values were nonstationary. The autocorrelation and partial autocorrelation functions were calculated from the original series. The sample autocorrelation function died down extremely slowly, indicating that the original series values were nonstationary. Stationary time series values were produced by taking the second differences of order 2 of the original time series values.

Analysis of the autocorrelation and partial autocorrelation functions of the second differences showed almost stationarity except at lag 12, 24, and 36. First seasonal differences were applied after the stationarity was achieved. The final differencing factors to obtain stationarity were:

$$(1 - B)^2 (1 - B^{12}) \log Z_t$$

The sample autocorrelation function of the stationary series cut off after lag 12, with autocorrelation larger than twice its standard deviation at lag 1. This means that two seasonal and nonseasonal moving average parameters were needed, one at lag 1 and the other at lag 12.

Analysis of the sample partial autocorrelation function indicated partial autocorrelations different from zero at lags 1, 2, and 24 implying the need for two autoregressive parameters, one at lag 1 and the other at lag 12.

With the information obtained from autocorrelation and partial correlation functions, different theoretical models were tested. The test model to fit the time series data was a multiplicative moving average at lags 1 and 12. This model is given by:

$$(1 - B)^2 (1 - B^{12}) \log Z_t = (1 - \phi_1 B) (1 - \phi_{12} B^{12}) U_t$$

Estimations and Forecasts

Estimated coefficients of the model are shown in Table 17. The residual autocorrelations show that no residual exceeds twice its standard error. The chi-square statistics do not fall in the critical rejection region at the 5 percent level. Therefore, the hypothesis that the residuals are uncorrelated cannot be rejected at the 5 percent probability level, and the model is accepted.

Forecasts of prices and the 95 percent confidence limits are given in Table 18. The forecasted prices are highly constant over months except for November and December. Prices in these two months are higher than the

TABLE 17. ESTIMATED PARAMETERS AND 95 PERCENT CONFIDENCE INTERVALS OF THE TIME SERIES MODEL USING THE BOX-JENKINS METHODOLOGY

Parameter Number	Parameter Type	Parameter Order	Estimated Value	95 Percent Lower Limit	95 Percent Upper Limit
1	Moving Average 1	1	0.707	0.62829	0.78659
2	Moving Average 2	12	0.664	0.57805	0.75058

TABLE 18. MONTHLY FORECAST OF AMERICAN CHEESE PRICES FOR 1978 AND 95 PERCENT CONFIDENCE LIMITS

Month	Lower Confidence Limit	Forecast	Upper Confidence Limit
	- - - - - - - - - - - - - - - - cents per pound - - - - - - - - - - - - - - - -		
January	172.2539	176.8467	181.5618
February	169.9151	176.7860	183.9346
March	167.8758	176.7602	186.1147
April	166.1288	176.9453	188.4658
May	164.6534	177.3900	191.1115
June	162.4215	177.0119	192.9128
July	160.1152	176.5490	194.6693
August	158.2776	176.6116	197.0692
September	156.7301	177.0214	199.9395
October	155.7017	178.0547	203.6165
November	155.0604	179.5828	207.9833
December	153.6839	180.3084	211.5452

other months. This is mainly due to reductions in milk production in the two months.

VI. Conclusions

Cheese production is highly seasonal because it is dependent upon fluctuating milk supplies. Months of the highest cheese production are May, June, and July. November is the month of the lowest cheese production. The model used to forecast monthly cheese production is a multiplicative seasonal moving average model of order 12 based on the Box-Jenkins time series algorithm. The model forecasts that total cheese production in 1981 is estimated at 4,355,965 tons which is approximately 10 percent higher than 1980 production.

A distributed lag model is used to estimate the annual demand for cheese in the United States. The basic structure of the model is a second order difference equation with prices and income as explanatory variables. The study shows that price elasticity of cheese is -0.5 and income elasticity is 0.7. This indicates that the consumption of cheese is more influenced by consumers' taste and needs than by changes in income and its own price.

Dynamic behavior of cheese prices is investigated to forecast cheese prices. Cheese prices are seasonal; the lowest cheese prices are in August and September and the highest prices in January and February. This shows the existence of lag between cheese production and prices. The lag is mainly due to the need to age cheese before final consumption. According to a study by United States Department of Agriculture, American cheese is stored for an average of 34 days in small plants and about 50 days in large plants, Swiss cheese for 60 days and hard Italian type cheese for 180 days. The model used to forecast monthly cheese price is a multiplicative seasonal moving average model which is similar to one used to forecast monthly cheese production. The model performed well to capture the complex dynamic behavior of cheese prices. The model forecasts an average annual cheese price of 177.50 cents per pound in 1981. The estimated monthly prices range between 176.55 cents per pound (the lowest price) in July and 180.31 cents per pound (the highest price) in December.

APPENDIX A: BOX-JENKINS METHODOLOGY

The Box-Jenkins approach to model building was used to forecast cheese production in the United States for years 1981 to 1982. The Box-Jenkins model has two important components; the autoregressive (AR) and the moving average (MA) components. The Box-Jenkins methodology based on stationary time series is generally used to forecast future values for a time series.

Moving Average Models

The MA model is given by:

$$Z_t = \mu + U_t - \phi_1 U_{t-1} - \phi_2 U_{t-2} \cdot \cdot \cdot - \phi_q U_{t-q}$$

Where: μ = mean of the time series model
ϕ_i = moving average parameter i = 1, 2, . . ., q
U_t = random disturbance

This is known as a moving average process of order q, MA(q). Each observation, Z_t, is generated in the MA(q) by a weighted average of random disturbances (U_t) going back q periods. The U_t's are serially uncorrelated disturbances with a constant variance over time. Each disturbance is assumed to be a normal random variable with mean 0, and constant variance. The mean of the moving average process is independent of time, since $E(Z_t) = u$. The variance of the MA(q) is given by:

$$\text{Var}\ (Z_t) = \gamma^0 = \sigma_u^2 \quad (1 + \Theta_1^2 + \Theta_2^2 + . . . + \Theta_q^2)$$

Covariances between observation Z_t and Z_{t+j} are dependent upon the order of moving average process.

For the moving average process of order 1, $Z_t = U + \Sigma_t - \Theta_1 \Sigma_{t-1}$, the covariance for a one-lag displacement, γ_1, is:

$$\gamma_1 = E(Z_t - U)\ (Z_{t-1} - U) = -\Theta_1 \sigma_u^2$$

In general, we can determine the covariance for a k-lag displacement to be

$$\gamma_k = E(Z_t - U)\ (Z_{t-k} - U) = 0 \quad \text{for } k \geq 1$$

This indicates that the moving average of order 1 has a memory of only one period; any value Z_t is correlated with Z_{t-1} and with Z_{t+1}, but with no other time series values.

The covariance for a j-lag displacement for the moving average of order 2 is:

$\gamma_1 = -\theta(1 - \theta_2)\ \sigma_u^2$

$\gamma_2 = -\ \theta_2\ \sigma_u^2$

$\gamma_j = 0$ for $j \geq 2$

The moving average process of order 2 has a memory of exactly two periods. Similarly, the moving average process of order q has a memory of exactly q periods.

γ_j is known as the autocovariance at lag j because it refers to the covariance between different observations in the same series. Correlation coefficients are found by dividing the autocovariances by the variance. The set of correlation coefficients are known as the autocorrelation function, and are given by:

$$\rho_j = \frac{\gamma_j}{\gamma_o}$$

The important characteristic of a MA(q) is that the autocorrelation function cuts off after lag q.

Autoregressive Models

The autoregressive process, AR, is the other component of the Box-Jenkins model. The AR model is represented by the equation:

$$Z_t = \delta + \phi_1 Z_{t-1} + \phi_2 Z_{t-2} + \ . \ . \ . + \phi_p Z_{t-p} + u_t$$

Where: Z_t = time series
δ = constant term
ϕ_i = parameters
u_t = random disturbances $\qquad i = 1, 2, \ldots . p$

In the autoregressive process of order p, AR(p), the current value of the time series is expressed as a function of the weighted average of past observations going back p periods together with a random disturbance in the current period. U_t has a mean zero and a constant variance. Assuming that the AR(p) process is stationary, then the mean is given by:

$$\mu = \frac{\delta}{1 - \phi_1 - \ldots . - \phi}$$

If μ is to be finite, it is necessary that $\phi_1 + \phi_2 + \ . \ . \ . + \phi_p \leq 1$ for stationarity.

The autoregressive process of order 1, AR(1), is expressed in a functional form as follows:

$$Z_t = \phi_1 Z_{t-1} + \delta + e_t$$

mean of the process is:

$$\mu = \frac{\mu}{1 - \phi_1}$$

where $\phi_1 \leq 1$ if Z_t is stationary

The variance of Z_t in the process of order 1 [AR(1)] assuming stationarity are:

$$\gamma_0 = \frac{\sigma e^2}{1 - \phi_1^2}$$

The covariance of Z_t for a j-lag displacement is:

$$\gamma_j = \frac{\phi_1{}^k \phi^2}{1 - \phi_1^2}$$

The autocorrelation function for AR(1) is thus expressed as:

$$\rho_j = \frac{\gamma_j}{\gamma_0} = \phi_1^j$$

For the autoregressive process of order 2, AR(2), Z_t is expressed as a function of Z_{t-1}, and Z_{t-2} as follows:

$$Z_t = \phi_1 Z_{t-1} + \phi_2 Z_{t-2} + \delta + e_t$$

mean of the AR(2) is:

$$\mu = \frac{\delta}{1 - \phi_1 - \phi_2}$$

The variance of Z_t in the process of order 2 is:

$$\gamma_0 = \frac{(1 - \phi_2)\ \sigma e^2}{(1 - \phi_2)\ [(1 - \phi_2)^2 - \phi_1^2]}$$

The covariance of Z_t is:

$$\gamma_1 = \frac{\phi_1 \gamma_0}{1 - \phi_2}$$

$$\gamma_j = \phi_1\ \gamma_{j-1} + \phi_2\ \gamma_{j-2} \quad \text{for } j \geq 2$$

The autocorrelation function can be calculated dividing γ_j by γ_0 as follows:

$$\rho_1 = \frac{\phi}{1 - \phi_2}$$

$$\rho_2 = \phi_2 + \frac{\phi_1^2}{1 - \phi_2}$$

$$\rho_j = \phi_1\ \rho_{j-1} + \phi_2\ \rho_{j-2} \quad \text{for } j \geq 2$$

Similar procedure can be used to calculate autocorrelation function for the higher order autoregressive process. The autocorrelation function for the process is geometrically damped with higher order of the process.

Now, look at the autoregressive process of order ρ, AR(ρ), the covariance with displacement j is determined from:

$$\gamma_k = E[Z_{t-k}\ (\phi_1 Z_{t-1} + \phi_2 Z_{t-2} + \phi_3 Z_{t-3} + \ldots + \phi_p\ Z_{t-p} + E_t)]$$

Letting k = 0, 1, 2, ... p, we obtain the following p + 1 difference equation for variance and covariances:

$$\gamma_0 = \phi_1\gamma_1 + \phi_2\gamma_2 + \ldots + \phi_p\gamma_p + \sigma e^2$$

$$\gamma_1 = \phi_1\gamma_0 + \phi_2\gamma_1 + \ldots + \phi_p\gamma_{p-1}$$

\- -

$$\gamma_p = \phi_1\gamma_{p-1} + \phi_2\gamma_{p-2} + \ldots + \phi_p\gamma_0$$

For displacements j greater than p the covariance are determined from:

$$\gamma_j = \phi_1\gamma_{j-1} + \phi_2\gamma_{j-2} + \ldots + \phi_p\gamma_{j-p}$$

Dividing the variance and covariance equations by yields the partial autocorrelation function as follows:

$$\rho_1 = \phi_1 + \phi_2\rho_1 + \ldots + \phi_p\ \rho_{p-1}$$

\- -

$$\rho_p = \phi_1\rho_{p-1} + \phi_2\rho_{p-2} + \ldots + \phi_p$$

$$\rho_j = \phi_1\rho_{j-1} + \phi_2\rho_{j-2} + \ldots + \phi_p\ \rho_{j-p}$$

Mixed Autoregressive - Moving Average Models

An autoregressive-moving average model is produced by mixing an autoregressive and a moving average processes of order p and q, denoted by ARMA (p, q) and represented by the

$$Z_t = \phi_1\ Z_{t-1} + \ldots + \phi_p Z_{t-q} + \delta + u_t - \theta_1 u_{t-1} - \ldots - \theta_p u_{t-q}$$

The mean of an ARMA(p, q) is given by the equation:

$$\mu = \frac{\delta}{1 - \phi_1\ \ldots\ -\phi_p}$$

The covariances, autocovariances, and autocorrelation function for the general ARMA(p, q) are given by the equations:

$$\gamma_j = \phi_1\gamma_{j-1} + \sigma_2\gamma_{j-2} + \ldots + \phi_p\gamma_{j-p} \qquad j \geqq q + 1$$

$$\rho_j = \phi_1\rho_{j-1} + \phi_2\ \rho_{j-2} + \ldots + \phi_p\rho_{j-p} \qquad j \geqq q + 1$$

The autocorrelation function of an ARMA (p, q) dies down in a damped exponential function.

Most time series found in economics are likely to be nonstationary, that is, the mean of the process is not constant. If the nonstationary time series is homogeneous, stationary time series values may be produced by taking differences of the original series values. First differences on the original series are usually stationary; however, if the transformed values are still nonstationary, taking the second differences of the original time series will usually produce stationary values.

The differences on the nonstationary time series may be represented by:

$$W_t = \nabla^d Z_t \qquad t = 1, 2, \ldots. n \quad d = 1, 2, \ldots. h$$

Where ∇ expresses differencing. For example, the first differences, $d = 1$, will be:

$$W_t = \nabla Z_t = Z_t - Z_{t-1}$$

and the second differences:

$$W_t = \nabla^2 Z_t = \nabla Z_t - \nabla Z_{t-1}$$

The backshift operator is an important symbol used in time series analysis. This operator is denoted by B and shifts the subscript of a time series observation or error term backward in time by one period lag. For example:

$$Z_{t-1} = B\, Z_t$$

In general:

$$Z_{t-k} = B^k Z_t$$

Where k is the number of periods. The first and second differences of Z_t can be represented by:

$$Z_t - Z_{t-1} = Z_t - B\, Z_t = (1 - B)\, Z_t$$

$$(Z_t - Z_{t-1}) - (Z_{t-1} - Z_{t-2}) = (1 - B)^2\, Z_t$$

Therefore, the backshift operator can be expressed by:

$$\nabla = (1 - B)$$

and in general:

$$\nabla^d Z_t = (1 - B)^d Z_t$$

Where $(1 - B)$ is known as the difference operator, d the number of differencing factors, and k the number of periods.

The stationary series, which comes from the differencing of the series Z_t, can be modeled as an ARMA process. The general model may be written as:

$$W_t = \phi_1 w_{t-1} + \ldots + \phi_p\, w_{t-p} + u_t - \theta_1 u_{t-1} - \ldots \quad \theta_q\, u_{t-q}$$

Where W_t is the differenced stationary series. Therefore, Z_t is referred to as the integration of W_t series and the process as an integrated autoregressive-moving average process, ARIMA (p, d, q). Variance, autocovariance, and autocorrelation function for an ARIMA (p, d, q) are found using the same procedure as described for an ARMA (p, q).

Box and Jenkins have developed models to describe and forecast time series which have seasonal variation. The general approach to modeling seasonal time series is the same as it is for the nonseasonal time series discussed previously.

The seasonal moving average process is given by the equation:

$$Z_t = u_t + \theta_s u_{t-s} + \ldots + \theta_{Qs} u_{t-Qs}$$

Where: θ_{si} = seasonal moving average parameter, i = 1, 2, ... Q

s = the number of observations per seasonal period

Q = the order of the seasonal moving average

The seasonal autoregressive process, AR(P)s, will be of the form:

$$Z_t = \Phi_s Z_{t-s} + \ldots + \Phi_{Ps} Z_{t-Ps} + u_t$$

Where: Φ_{si} = seasonal autoregressive parameter

P = the order of the seasonal autoregressive process

Generalization of the seasonal AR and MA processes brings a mixed seasonal autoregressive and moving average model, ARMA(P, Q). This model is given by the equation:

$$Z_t = \Phi_s Z_{t-s} + \Phi .. + \ _{Ps} Z_{t-Ps} + u_t - \theta_s u_{t-s} - \ldots - \theta_{Qs} u_{t-Qs}$$

This equation may be represented in terms of the backshift operator as follows:

$$(1 - \Phi_s B^s - \phi \ldots - \phi_p B^{Ps}) Z_t = (1 - \theta_s B^S - \theta \ldots - \theta_{Q_s} B^{Qs}) u_t$$

Variance, autocovariance, and autocorrelation function are obtained using the same procedure as it was for the ARMA process.

A seasonal integrated autoregressive-moving average parameter model, ARIMA (P, D, Q)s can be determined if the time series Z_t are nonstationary. The ARIMA (P, D, Q)s in terms of the B operator will be of the form:

$$(1 - \Phi_s B^s - \ldots - \Phi_{Ps} B^{Ps}) (1 - B^s)^d Z_t = (1 - \theta_s B^s - \ldots - \theta_{Ps} B^{Qs}) u_t$$

Model Specification

Plot of Original Series

Observations of original series may indicate if the series are stationary or nonstationary, and in turn, will suggest the appropriate degree of differencing. Nonstationary series will produce autocorrelations that persist through long lags. In most economic time series, first differences may exhibit stationarity, otherwise second differences will be required. The correlogram for stationary series will show spikes which either cut off or tail off, such as shown in Figure 1. Spikes at lags 12, 24, 36 will suggest that seasonal differencing is necessary. The autocorrelations are compared to twice their standard errors to determine whether or not they are significantly different from zero.

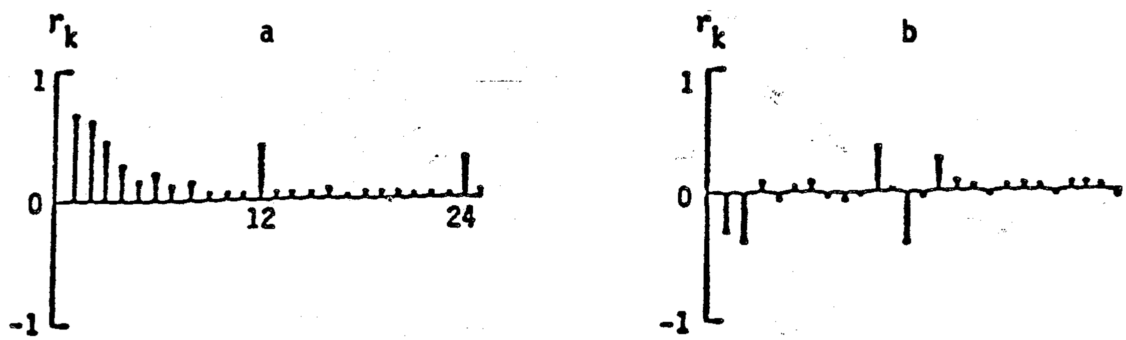

Figure 1. Sample Autocorrelation Functions That Tail Off (2a) or Cut Off (2b) With Spikes at Lags 12 and 24

<u>Identification of Moving Average Parameters</u>

Analysis of the autocorrelation function may suggest the number of moving-average parameters to be considered in the model. Autocorrelation significantly different from zero may be detected at early lags and around the seasonal lag. If autocorrelations different from twice their standard errors are detected at lags 1, 2, and 12, it is likely that the model may have two nonseasonal and one seasonal moving average parameters. The partial autocorrelation function may die down fairly quickly.

<u>Identification of Autoregressive Parameters</u>

Analysis of the partial autocorrelation function may suggest the number of autoregressive parameters to be considered in the model. The partial autocorrelations are compared with twice their standard errors. Partial autocorrelations different from zero may determine the number of autoregressive parameters in the model. If partial autocorrelations are found at lags 1, 2, and 12, it may suggest that three autoregressive parameters are needed, one at lag 12 and two as lags 1 and 2. The partial autocorrelation function will cut off after lag 12 and the autocorrelation function may die down fairly quickly.

A mixed model is more difficult to estimate. Analysis of a combination of characteristics of both the autoregressive and the moving average processes may be helpful. Autocorrelation functions of theoretical time series models should be compared with the autocorrelation function being considered in order to find a suitable match. This procedure may be straightforward in many cases, but in some complex processes it may be convenient to test several models.

Estimation

The formulation of a time series model generates preliminary estimates of the parameters. These parameters are the beginning parameters for an iterative search procedure used in most time series computer programs. The initial parameters come from the relationship between the autocorrelation function of the theoretical model and the model parameters.

Diagnostic Checking

The adequacy of a tentative model is tested after it has been fit the data. The autocorrelations are compared to twice their standard errors to see if they are significantly different from zero. A chi-square test for lack of correlation also is computed on the residuals. A Box-Pierce chi-square statistic is calculated by:

$$Q = (N - d - D_s) \sum_{j=1}^{k} r_j^2 (u_t)$$

Where: N = number of observations in the original time series
d = nonseasonal degree of differencing
D_s = seasonal degree of differencing
r_j = the sample of autocorrelation of the residuals at lag k

The Box-Pierce statistic is approximately distributed as chi-square with (k-p-q-P-C-1) degrees of freedom. The null hypothesis is that the residuals are uncorrelated, and it can not be rejected if the chi-square value does not fall in the critical region.

Confidence intervals for the estimated parameters are calculated to determine if they are significantly different from zero. If the $(1 - \alpha)$ confidence interval for a parameter does not contain zero, it is concluded that the parameter being analyzed is significantly different from zero. Correlations between parameters also are calculated. High correlations between these parameters may indicate an inadequate model.

APPENDIX B: DISTRIBUTED LAG MODEL

The model specified is a compound geometric lag model which is a combination of adaptive expectation and partial adjustment models. The model is based on the assumption that expected annual aggregate demand for cheese is expressed as a function of expected cheese price and income levels as follows:

(1) $D_t^* = \alpha_0 + \alpha_1 P_t^* + \alpha_2 Y_t^*$

where: D_t^* = expected quantity of cheese demanded in time period t
P_t^* = expected price of cheese in time period t
Y_t^* = expected income in time period t

Dynamic adjustments of actual demand to the expected demand can be adjusted as follows:

(2) $D_t - D_{t-1} = \delta(D_t^* - D_{t-1})$

where δ is the coefficient of adjustment and D_t is actual demand in time period t. Combining equations 1 and 2 yields a first order difference equation:

(3) $D_t = \delta \alpha_0 + \delta\alpha_1 P_t^* + \delta\alpha_2 Y_t^* + (1 - \delta) D_{t-1}$

The price and income variables are now the only variables left in the expectation form. These variables can be removed by making certain assumptions as follows:

(4) $P_t^* - P_{t-1}^* = \gamma(P_t - P_{t-1}^*)$

(5) $Y_t^* - Y_{t-1}^* = \gamma(Y_t - Y_{t-1}^*)$

where γ is the coefficient of adjustment, Y_t is actual income in time period t, and P_t is actual price in time period t.

Continuous iteration of equations 4 and 5 gives:

(6) $P_t^* = \sum_{i=0}^{\infty} (1 - \gamma)^i \gamma P_{t-i-1}$

(7) $Y_t^* = \sum_{i=0}^{\infty} (1 - \gamma)^i \gamma Y_{t-i-1}$

Substituting equations 6 and 7 into equation 3 results in the following geometric lag model:

(8) $$D_t = \delta \alpha_0 + \delta\alpha_1 \sum_{i=0}^{\infty} (1 - \gamma)^i \gamma P_{t-i-1} + \delta\alpha_2 \sum_{i=0}^{\infty} (1 - \gamma)^i \gamma Y_{t-i-1} + (1 - \delta) D_{t-1}$$

The Koyck transformation of equation 8 is performed as follows: Equation 5 is lagged one year and multiplied by $(1 - \gamma)$ as shown in equation 9.

$$(9) \quad (1 - \gamma) D_{t-1} = (1 - \gamma)\delta\alpha_0 + (1 - \gamma)\delta\alpha_1 \sum_{i=0}^{\infty} (1 - \gamma)^i P_{t-i-2}$$
$$+ (1 - \gamma)\delta\alpha_2 \sum_{i=0}^{\infty} (1 - \gamma)^i \gamma Y_{t-i-2} + (1 - \gamma) (1 - \delta) D_{t-2}$$

Subtracting equation 10 from equation 1 gives:

$$(10) \quad D_t = \gamma\delta\alpha_0 + \delta\alpha_1\gamma P_t + \delta\alpha_2\gamma Y_t + (2 - \gamma - \delta) D_{t-1}$$
$$+ (1 - \delta) (1 - \gamma) D_{t-2}$$

Equation 10 can be generally expressed as follows:

$$D_t = b_o + b_1 P_t + b_2 Y_t + b_3 D_{t-1} + b_4 D_{t-2}$$

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