NUMERICAL STUDIES WITH A PULP AND PAPER SECTOR MODEL IN JAPAN

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FOREWORD

The objective of the Forest Sector Project at IIASA is to study long-term development alternatives for the forest sector on a global basis. The emphasis in the Project is on issues of major relevance to industrial and governmental policy makers in different regions of the world who are responsible for forest policy, forest industrial strategy, and related trade policies.

The key elements of structural change in the forest industry are related to a variety of issues concerning demand, supply, and international trade in wood products. Such issues include the growth of the global economy and population, development of new wood products and of substitute for wood products, future supply of roundwood and alternative fiber sources, development of new technologies for forestry and industry, pollution regulations, cost competitiveness, tariffs and non-tariff trade barriers, etc. The aim of the Project is to analyze the consequence of future expectations and assumptions concerning such substantive issues.

The research program of the Project includes an aggregated analysis of long-term development of international trade in wood products, and thereby analysis of the development of wood resources, forest industrial production and demand in different world regions. The other main research activity is a detailed analysis of the forest sector in individual countries. Research on these mutually supporting topics is carried out simultaneously in collaboration between IIASA and the collaborating institutions of the Project. This article represents such a detailed study of the Japanese pulp and paper sector.

Markku Kallio
Leader
Forest Sector Project

ABSTRACT

The objective of this paper is to prepare a numerical model of the pulp and paper sector in Japan.

In order to accomplish this, we discuss the present situation and historical trends, starting with primitive materials and then proceeding to the demand and supply of chips, pulp, and paper, and paperboard.

Next, we discuss causal flow of the factors in the pulp and paper model. Then, I introduce the equations which express this numerically, and, associated with this, I have prepared several statistical studies and simulations.

Also, in connection with these analyses, I present several interesting economic features and finally consider problems which still remain to be solved.

CONTENTS

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1. INTRODUCTION,

According to the industrial statistic tables for 1980, the manufactured article shipment value for the pulp and paper industry was 6,799 trillion yen, and composed 3.2% of the total shipment value of the manufacturing industry, ranking 13th among the 19 industrial categories. The number of employees totalled 290,000, or 2.7% of the total number employed in manufacturing, and the ranking was 14th.

When we view the pulp and paper industry from the standpoint of functions of the manufactured articles, we see that it is an extremely important industry, which produces and supplies newspapers, books, and magazines, powerful media for information and knowledge; "shoji" paper, tissue paper, and toilet tissue for the household; and packaging material for industrial activities.

The volume of paper and paperboard consumption per capita was 143 kg, based on the 1981 figures. This is ninth highest consumption in the world, and is on the same level as that of the major European nations.

Paper and paperboard production volume (1981) was 16.98 million tons (about 10% of the total world production). Japan ranked second, next to the US.

The Japanese pulp and paper industry viewed from the raw material standpoint (based on 1980 figures) shows pulpwood at 35.87 milliion m^3, approximately, or 33% of the total timber demand—supply, next to logs for sawing (mainly construction lumber).

The purpose of this paper is to numerically clarify the structure of the Japanese pulp and paper sector, which has significant importance for both the entire Japanese economy and timber economy.

2. PULPWOOD, PULP AND PAPER DEMAND AND SUPPLY FLOWS

The demand and supply flows for pulpwood (logs and chips), and pulp and paper (hereafter referred to simply as "pulp and paper," including pulpwood) for 1982 are outlined in Figure 1.

For pulpwood broken down into softwood and hardwood, the total softwood supply totalled 14.09 million m³, of which 44.4%, or 6.26 million m³, was imported. Out of the imported material, the outstanding portion, 99.9%, was imported in the form of chips, mainly from North America.

Domestic softwood (comprising 55.6%of total softwood) was supplied in the form of chips, amounting to 82.3% of the total, or 6.45 million m³. The remaining 17.7%, or 1.38 million m³, was distribution to the pulpwood or pulp and paper mills in the form of logs.
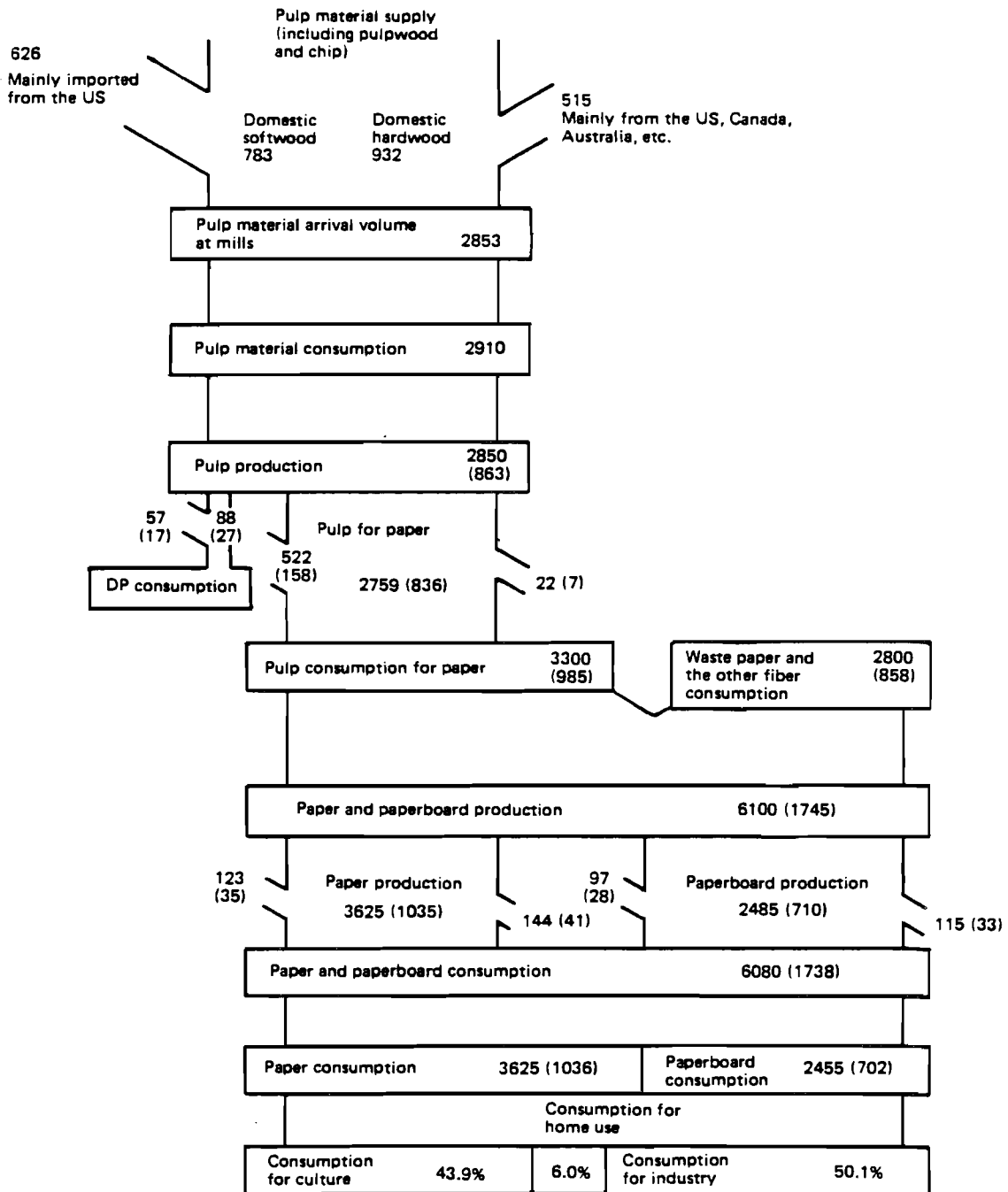
The total hardwood supply was 14.47 million m³, out of which 35.6%, or 5.15 million m³, was imported, 98.7% of which was imported in the form of chips, mainly from North America and Australia. Domestic hardwood, which accounted for 64.4%, or 9.32 million m³, of the total hardwood, was distributed to the pulpwood and pulp and paper mills in the form of chips, making up 95.3% of the total, with 4.7% in the form of logs.

The pulp production volume using the above-mentioned chips and pulp logs came to 8.63 million tons (about 28.5 million m³ when converted into logs), and if we consider only the pulp for paper manufacture, this would come to 8.36 million tons (27.59 million m³). When we add the 1.58 million tons (5.22 million m³) of imported pulp, mainly from North America, and then deduct from the remaining figure the 70,000 tons (220,000 m³) of exports, we see that 9.85 million tons (33 million m³) were consumed as pulp for manufacturing paper.

In addition, 8.58 million tons (28 million m³) of waste paper and fibers, etc., were used as materials for paper and paperboard production. The consumption of waste paper and fibers, etc., accounted for 46.6% of the 18.43 million ton (61 million m³) total consumption of pulp for paper manufacture in the same year.

The paper production volume based on this consumption of pulp for paper manufactured in the same year was 10.35 million tons (36.25 million m³). The consumption of the total paperboard production was 7.1 million tons (24.85 million m³). When we calculate the paper/paperboard consumption volume for the same year, taking both imports and exports into consideration, the total was 17.38 million tons (60.8 million m³). This, broken down into paper and paperboard, gives 59.6% of the total, or 10.36 million tons (36.25 million m³) for the former, paper, and 40.4%, or 7.02 million tons (24.55 million m³) for the latter, paperboard.

Paper/paperboard consumption volume by the principal end uses was 43.9% for cultural end uses (newspapers, printing, writing, and drawing papers, and the printing and writing papers of papers for miscellaneous use), 50.1% for industrial uses, and 6.0% for household uses (tissue paper and miscellaneous paper B).

Pulp material supply
(including pulpwood
and chip)

626
Mainly imported
from the US

515
Mainly from the US, Canada,
Australia, etc.

Domestic
softwood
783

Domestic
hardwood
932

| Pulp material arrival volume at mills | 2853 |

| Pulp material consumption | 2910 |

| Pulp production | 2850 (863) |

57 (17) 88 (27)

DP consumption

Pulp for paper

522 (158) 2759 (836) 22 (7)

| Pulp consumption for paper | 3300 (985) |

| Waste paper and the other fiber consumption | 2800 (858) |

| Paper and paperboard production | 6100 (1745) |

123 (35)

| Paper production | 3625 (1035) |

97 (28) 144 (41)

| Paperboard production | 2485 (710) |

115 (33)

| Paper and paperboard consumption | 6080 (1738) |

| Paper consumption | 3625 (1036) | Paperboard consumption | 2455 (702) |

Consumption for home use

| Consumption for culture | 43.9% | 6.0% | Consumption for industry | 50.1% |

Notes: (1) Unit: 10 thousand m^3. For pulp, waste paper, paper and paperboard, however, the figures in parentheses, for pulp and paper, are in thousand tons.
(2)

import

export

(3) Source: Japan Paper Association, "Pulp and Paper 1983".

FIGURE 1. Flow chart of pulpwood, chip, pulp and paper (1982).

3. HISTORICAL BACKGROUND OF PRODUCTION STAGES

In the preceding section I commented on the 1982 situation for pulpwood and pulp and paper demand—supply, but here I comment on the main aspects of the historical trends of each respective stage.

First, we take the raw material stage. Until World War II white fir (Abies mayriana M. & K.) and Yezo spruce (picea jezoensis Carr.) were used as the principal materials. After Japan was defeated, Sakhalin, rich in Yezo spruce and white fir resources, was lost, and pine became the dominant source.

After this, (1) there was an advance in pulp technology and it became possible to utilize much cheaper hardwoods, and (2) the demand for fuelwood and charcoal decreased and large-scale plantations increased. Owing to these changes, the utilization of tree species unsuitable for general use, the so-called low-grade hardwoods, began in the 1950s and became more widespread. Because of such reasons as (1) the greater efficiency in transportation, and (2) the intensive utilization of sawmill residue and waste wood, the form taken by the materials rapidly changed from logs to chips. Furthermore, concurrently with the progress of this conversion, chip imports began to increase and, in 1973, they accounted for 11.22 million m^3, or 34.7% of the total pulpwood shipment volume of 32.38 million m^3. In 1979, the volume increased to 15.16 million m^3, or 46.1% of the total shipment volume. Later, however, (1) between the end of 1979 and the beginning of 1980, starting with the decrease in sawmill residue, resulting from the sharp drop in housing starts in the US, the North American chip price escalated, and (2) as a result of the decline in the paper/paperboard demand, there was some decrease in the supply. In 1982 supply came to 11.41 million m^3, 40.0% of the total shipment volume of 28.6 million m^3 (refer to Table 1).

When we review the number of chip mills in Japan, which is interrelated with the supply of materials, we note that they gradually increased from 3,104 in 1961 to 5,820 in 1965, to 7,941 in 1971. Since then, with 1971 as the peak year, a decreasing trend continued, from 6,618 in 1979 to 6,305 in 1981.

The number of chip carriers was 20 in 1968, but increased to a maximum of 69 in 1979, after which it decreased somewhat; in 1983 there were 49 in operation.

Next, I discuss the pulp and paper production stages, but, first, I consider the pulp enterprises, which are the source of the products. As of 1979 a total of 511 were in existence. There were 431 (84.3%) corporations, 5 partnerships, 40 limited-responsibility companies, 6 associations, and 29 private individuals, with corporations notably the largest form. Using level of capital, there were 366 enterprises with less than ¥50 million, 67 with between ¥50 million and ¥500 million and 48 with ¥500 million or more. The number of enterprises with capital of ¥50 million or less totalled 481, or 96% of the enterprises. By the number of mills, according to the category of operations, as can be seen from Table 2, as of 1979 there was a total of 606 mills, clearly showing a gradual decrease from 679 in 1969 to 677 in 1974.

By operational category, in 1979 there were 13 mills specializing in pulp, 413 specializing in paper, 101 specializing in paperboard, 29 producing pulp and paper, 12 producing pulp and paperboard, 18 producing pulp, paper, and paperboard, and 20 producing paper and paperboard. All operational categories of mills showed a trend of gradual decreas, the same as the general trend.

As can be noted, pulp and paper mills gradually decreased in number, but what was the status of producing capacity?

First, let us refer to Table 3 for the estimated production capacity per day for pulp mills. In general, it increased from 59.5 tons per day in 1967 to 110.1 in 1979, or slightly less than double.

TABLE 1. Pulpwood arrival volume (units: 1000 m^3).

Year	Total Quantity	Total Ratio %	Domestic timber Sub-total Quantity	Domestic timber Sub-total Ratio %	S	H	SC	HC	Import timber Sub-total Quantity	Import timber Sub-total Ratio %	S	H	SC	HC	USSR	Sorth America	Others
1973	32381	100.0	21158	65.3	1742	1970	5401	12045	11223	34.7	131	536	7765	2791	417	7501	3305
1974	35521	100.0	21469	60.4	1919	1861	5511	12178	14052	39.6	245	987	8898	3922	579	8729	4745
1975	28787	100.0	16996	59.0	1595	1078	5042	8281	11791	41.0	59	519	7866	3347	723	7533	3535
1976	31961	100.0	18682	58.5	1665	1191	5365	10461	13279	41.5	52	349	8819	4059	768	8528	3983
1977	31959	100.0	18085	56.6	1580	921	5255	10329	13874	43.4	54	267	9014	4539	882	8745	4247
1978	30388	100.0	17057	56.1	1423	564	5192	9878	13331	43.9	51	219	8761	4300	853	8255	4223
1979	32897	100.0	17742	53.9	1368	483	5709	10182	15155	46.1	54	132	9815	5154	859	9293	5003
1980	34257	100.0	18687	54.6	1577	567	6333	10210	15570	45.4	71	197	9428	5874	621	9105	5844
1981	28711	100.0	16390	57.1	1340	429	5902	8720	12321	42.9	8	112	7140	5061	519	7391	4411
1982	28567	100.0	17153	60.0	1384	436	6446	8887	11414	40.0	8	67	6256	5083	489	6050	4875

Notes: S: Softwood, H: Hardwood, SC: Softwood chip, HC: Hardwood chip.

TABLE 2. Pulp and paper mill number by business line.

Business line		1969 (Dec)	1974 (Apr)	1979 (Dec)
Total		679	677	606
Details				
A	Specializing in pulp	29	17	13
B	Specializing in paper	429	460	413
C	Specializing in paperboard	127	118	101
D	Pulp and paper	39	29	29
E	Pulp and paperboard	13	17	12
F	Pulp, paper, and paperboard	18	15	18
G	Paper and paperboard	24	21	20
Total				
Pulp		99	78	72
Paper		492	543	499
Paperboard		182	171	151

Source: Japan Paper Association, *The Survey Report of Pulp and Paper Industry Equipment, 1969-1979.*

Next we examine the paper manufacturing enterprises. When we review the estimated capacity per day for paper machines and the capacity per paper machine on a time series basis, they also show impressive improvement (Table 4).

Let us review the pulp production situation for the pulp mills where such a production structure exits. Until around 1950, after the war, about 90% of the entire production consisted of GP (ground pulp) and SP (sulphite pulp), both suitable to softwood. However, owing to the change in the log situation, the high-productivity hardwood bleached KP (bleached kraft pulp) was produced from about 1951, using a combination of the KP process, suitable for converting hardwood and short hardwood fiber to pulp, and the multibleeding method invented after the war. The production of semichemical-mechanical (SCP) pulp began in 1953, and that of CGP (chemi-ground pulp) began in 1958. In 1970, RGP, a mechanical pulp which permits the utilization of chips, went into production, and in 1975 production of high-strength pulp, TMP (thermomechanical pulp), was started.

Table 5 summarizes annual pulp production volume by type during recent years.

In connection with the materials for paper production, it is necessary to comment on the utilization of waste paper, which has recently been utilized in large volumes (see the Japan Paper Association's 1983 *Special Issue for Paper and Pulp.*)

The utilization of waste paper in the paper sector was previously restricted to tissue for household use, but recently it has also been used for newsprint and lower-grade printing paper; the ratio of utilization in the paper sector was 31% in 1983, which is a 1.6-fold increase over the 19% in 1973, and the volume of consumption also increased by 2.2 times.

The recovery rate of waste paper in Japan was 48.1% in 1983, and the utilization ratio was 46.6%, the world's highest level.

TABLE 3. Estimated capacity of pulp production per day (unit: t per day).

Year		Total			
		Machines in use		Capacity per day	
		Number	Index	Number	Index
1967 (May)		115	147.4	21136	59.5
1969 (Dec)		99	126.9	25966	73.1
1974 (Apr)		78	100.0	35508	100.0
1979 (June)		72	92.3	39084	110.1
		Chemical Pulp			
	Mill number	Machines in use		Capacity per day	
		Number	Index	Number	Index
1967 (May)	81	332	95.7	17345	57.5
1969 (Dec)	77	345	99.4	21952	72.8
1974 (Apr)	68	347	100.0	30153	100.0
1979 (June)	65	309	89.0	32643	108.3
		Mechanical pulp			
	Mill number	Machines in use		Capacity per day	
		Number	Index	Number	Index
1967 (May)	51	233	108.9	3791	70.8
1969 (Dec)	40	220	102.8	4014	75.0
1974 (Apr)	25	214	100.0	5355	100.0
1979 (June)	23	230	107.5	6441	120.3

Notes:

1. Idled and converted facilities are excluded.

2. End of April 1974 = 100.

3. Source: *The Survey Report on Pulp and Paper Industry Equipment.*

TABLE 4. Estimated production capacity per day of a paper machine (in paper division) (units: t per day).

Year	Estimated production capacity		Capacity per machine	
1967	15852	(100.0)	15.2	(100.0)
1969	19392	(122.3)	16.7	(109.9)
1974	26839	(169.3)	22.1	(145.4)
1979	32071	(202.3)	28.8	(189.5)

TABLE 5. Pulp production by species (units: 1000t).

| Year | Pulp total | Dissolved pulp (DP) | Pulp for paper | | | | | | | Others |
			Sulphite pulp (SP)	Kraft pulp (KP)	Semichemical pulp (SCP)	Chemiground pulp (CGP)	Thermo-mechanical pulp (TMP)	Refiner pulp (RGP)	Ground pulp (GP)	
1966	5691	487	407	2793	277	711	–	–	985	31
1967	6232	533	418	3111	387	738	–	–	1014	31
1968	6861	515	431	3468	480	887	–	221	830	29
1969	7685	542	404	4004	571	1054	–	254	826	30
1970	8801	554	404	4608	712	1218	–	427	845	33
1971	9039	545	374	4990	644	1196	–	471	783	34
1972	9458	514	377	5389	618	1258	–	506	769	27
1973	10123	489	344	5897	678	1311	–	636	740	28
1974	10040	444	346	5967	601	1236	–	728	694	24
1975	8630	280	316	5239	421	1037	–	662	658	17
1976	9518	324	276	5937	468	1035	–	775	689	15
1977	9437	330	271	5973	487	849	–	861	652	15
1978	9392	321	216	6019	470	680	–	1039	632	15
1979	9993	316	208	6604	501	589	726	424	607	18
1980	9788	300	182	6519	456	546	794	397	579	16
1981	8612	256	143	5767	362	435	703	363	571	10
1982	8627	266	110	6079	319	302	656	324	560	10

For information, the waste paper recovery and distribution mechanisms in Japan are diverse and also complicated. For example, the direct delivery businesses, which have the largest of the recovery mechanisms, number approximately 600 in total, and the enterprises with less than 30 employees account for more than 80% of the total.

The recent production volumes of paper and paperboard by year, which are produced with this pulp and waste paper as the materials are as shown in Table 6. There has been a trend of increase since 1967.

In concluding the historical background of pulp and paper production, let us look at the ratio of net profit to sales in order to analyze the business performance. As shown in Table 7, this was 4.01% in 1955, but gradually decreased to 1.29% in 1976, after which there was gradual increase to 2.35% in 1979, after which it gradually decreased until 1981,. and, again increased somewhat in 1982.

When viewed in relation to the manufacturing industry in general, the level was lower, as a whole.

The preceding section contains a brief discussion of the historical trend of the respective production stages of pulpwood, pulp, waste paper, and paper, and, as may be understood from this, the changes were highly significant.

Thus, in preparing the numerical model for the pulp and paper sector in Japan, the main subject of this paper, I felt that such changes might result in the danger of departing too far from the current situation in utilizing statistics that go too far back into the past. I, therefore, proceeded with the preparation of the model by employing the data for 1965 and after, paying sufficient attention at the same time to the structural changes in the economy after the oil crisis.

TABLE 6. Production quantity of paper and paperboard (unit: 1000t).

Year	Total	Paper								Paperboard								
		Sub-total	Print	Write, draw	Pack kraft	Pack other	Thin paper	Tissue paper	Misc	Sub-total	Liner-board	Corrug medium	White board	Straw board	Chip-board	Color board	Bldg board	Misc
1967	9044	5509	1321	1529	629	344	115	–	1121	3985	1499	928	721	73	184	142	155	284
1968	9957	5489	1471	1643	687	424	145	402	715	4468	1764	1015	793	76	193	158	162	307
1969	11310	6147	1614	1973	725	413	165	447	811	5162	2120	1191	890	71	194	163	183	350
1970	12973	7135	1918	2410	772	436	195	499	907	5838	2411	1351	1051	66	201	170	210	378
1971	12907	7129	1951	2290	783	414	200	554	936	5778	2408	1317	1014	52	197	175	184	431
1972	13648	7471	2060	2448	714	419	222	632	976	6176	2630	1370	1069	31	196	168	214	499
1973	15975	8222	2106	2820	782	453	256	697	1108	7753	3292	1870	1315	31	220	196	263	567
1974	15646	8444	2233	2937	903	393	266	691	1021	7203	3217	1838	1087	17	186	148	225	485
1975	13601	7711	2160	2772	710	327	211	622	909	5890	2617	1419	952	15	161	127	189	409
1976	15394	8631	2341	3050	797	365	260	696	1123	6763	2900	1719	1088	19	192	149	203	492
1977	15702	8756	2370	3103	787	384	268	735	1112	6943	2923	1771	1149	20	208	155	201	517
1978	16500	9364	2482	3416	799	412	312	769	1172	7136	2955	1857	1198	20	204	157	229	516
1979	17861	9981	2566	3771	761	438	343	863	1239	7880	3379	1971	1275	29	233	158	257	579
1980	18088	10536	2674	4138	691	430	370	900	1335	7552	3131	1932	1245	25	202	149	250	617
1981	16980	9943	2575	3814	496	390	361	898	1409	7037	2613	1873	1311	21	204	139	220	656
1982	17453	10353	2580	4017	493	445	409	908	1501	7099	2613	1803	1345	22	210	139	223	745

TABLE 7. Ratio of net profit to sales in manufacturing industry and pulp and paper industry.

Year	Manufacturing	Pulp and paper
1955	3.14	4.01
1960	4.89	3.80
1965	2.69	1.27
1970	3.08	1.94
1976	3.11	1.29
1977	2.94	1.42
1978	4.21	1.43
1979	4.62	2.35
1980	4.35	1.63
1981	3.66	0.95
1982	3.55	2.01

4. CAUSAL FLOW AND NUMERICAL STRUCTURE OF THE PULP AND PAPER SECTOR

The total causal flow of the pulp and paper sector, based on the understanding of the demand—supply trends of pulpwood, pulp, waste paper, and paper, is as shown in Figure 2.

The arrows in the diagram clearly indicate the interrelationship of the factors.

The results of the calculations in Figure 2 are as follows.

(1) $X_{501} = X_{307} + X_{407}$

(2) $X_{308} = 94.8712 + 6.08577\delta_1 - 0.0126788X'_{305-2} - 7.8836 \times 10^{-3}X'_{305-1}$
(Note 1)

$\qquad r = 0.610388$, $DW = 1.20921$

(3) $X_{307} = 5133.6 - 41.9871X_{306} + 0.0277959X_{500} + 0.64081X_{307-1}$

$\qquad r = 0.991163$, $DW = 2.4914$

(4) $X_{306} = 471.054 - 246.611\delta_2 - 198.041\delta_3 + 0.954925X_{301}$

$\qquad r = 0.997529$, $DW = 3.0433$

(5) $X_{305} = X_{305-1} + X_{301} - X_{306}$

(6) $X_{301} = 376.523 - 146.929\delta_4 + 0.301164X_{208} + 0.464724X_{220}$

$\qquad + 0.0467628X_{302} + 0.235633X_{307-1}$

$\qquad r = 0.997907$, $DW = 2.14506$

(7) $X_{408} = 97.9436 - 0.011193X'_{405-2} - 0.049687X'_{405-1} + 0.0478521X'_{405}$
(Note 2)

$\qquad r = 0.762525$, $DW = 1.34923$

(8) $X_{407} = 1746.66 - 7.1977X_{406} + 0.0364026X_{500} + 0.385199X_{407-1}$

$\qquad r = 0.9535$, $DW = 1.7088$

Paper and paperboard consumption in $(t-1)$ period X_{501-1}

Price of domestic pulpwood X_{104}

(25)

Domestic pulpwood arrival volume X_{102}

Cutting volume in the US X_{212}

(24)

Chip inventory at the end of $(t-1)$ period X_{111-1}

(26) Chip import X_{105}

Domestic chip $X_{109-105}$

Chip arrival volume X_{109} (22)

(21) Chip price X_{113} (20)

Chip inventory at the end of t period X_{111} (23)

Chip consumption X_{112}

Labor for pulp production X_{204}

(19)

Pulpwood price X_{114}

(18) Pulp import X_{201}

Pulp production X_{202}

(17)

Pulp inventory at the end of $(t-1)$ period X_{207-1}

Pulp arrival volume X_{205} (16)

(15) Pulp price X_{209}

Retrieval rate of waste paper X_{221}

Pulp inventory at the end of t period X_{207}

(12)

Pulp consumption X_{208}

Waste paper consumption X_{220}

(13)

Paper and paperboard consumption in $(t-1)$ period X_{501-1}

(14)

Paper inventory at the end of $(t-2)$ period X_{305-2}

Moving equipment for paper production X_{302}

Moving equipment for paperboard production X_{402}

Labor for paperboard production X_{403}

Paperboard inventory at the end of $(t-2)$ period X_{405-2}

Paper inventory at the end of $(t-1)$ period X_{305-1}

(6) (11)

Paper production X_{301}

Paperboard production X_{401}

Paperboard inventory at the end of $(t-1)$ period X_{405-1}

Paper import X_n

Paper shipment X_{306}

(4)

Paperboard shipment X_{406}

(9)

(10)

Paperboard inventory at the end of t period X_{405}

Paper inventory at the end of t period X_{305}

(5) (2)

Paper price X_{308}

Paperboard price X_{408}

(7)

GNP X_{500}

Paper consumption in $(t-1)$ period X_{307-1}

Paper consumption X_{307}

Paperboard consumption X_{407}

(8)

Paperboard consumption X_{407-1}

GNP X_{500}

(3)

(1)

Paper and paperboard consumption in t period X_{501}
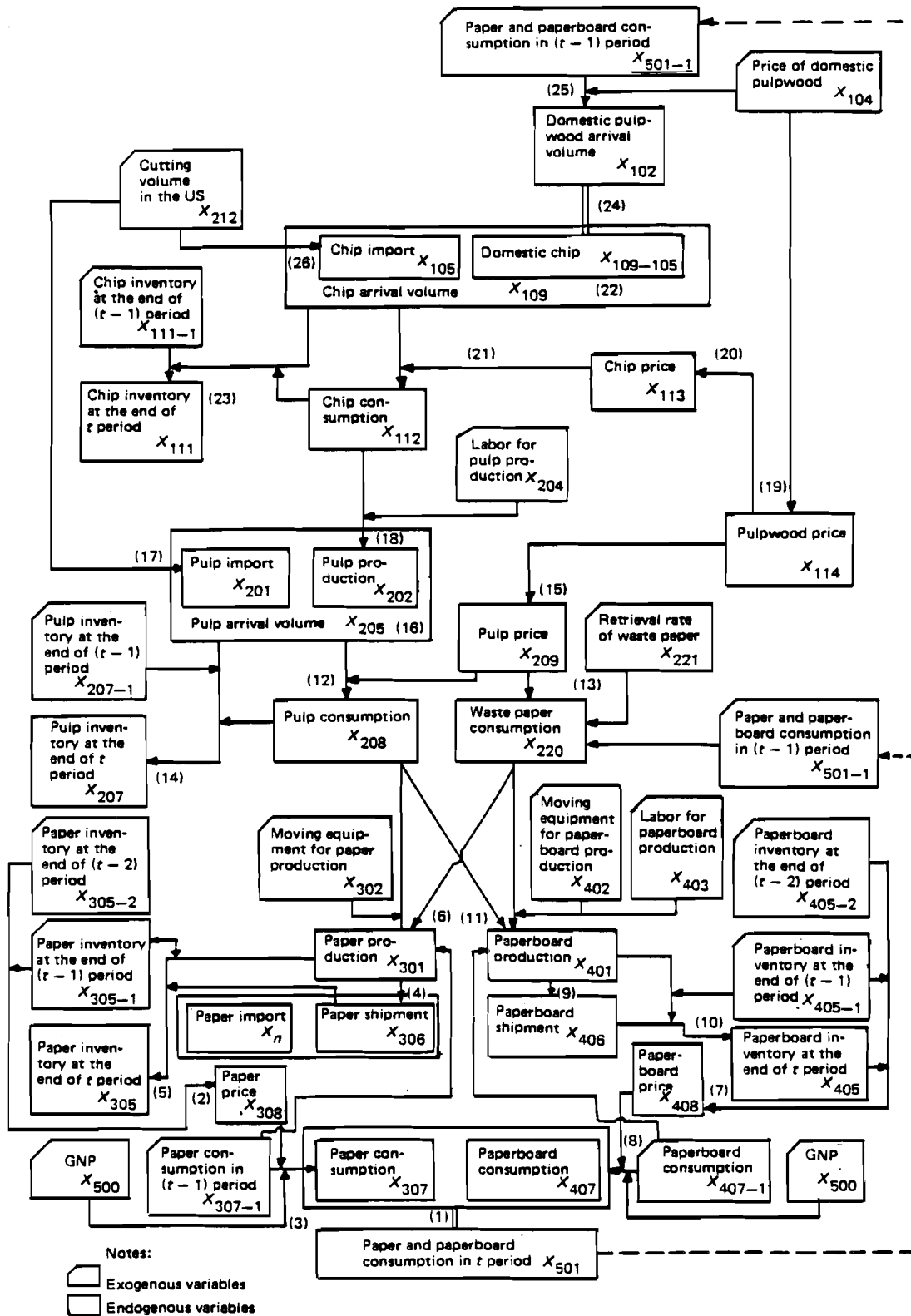
Notes:

☐ Exogenous variables

☐ Endogenous variables

FIGURE 2. Summary causal flow diagram of pulp and paper sector in Japan.

(9) $X_{406} = 2.96533 + 0.997428X_{401}$

$r = 0.997569, DW = 2.51569$

(10) $X_{405} = X_{405-1} + X_{401} - X_{406}$

(11) $X_{401} = -5961.53 + 130.991\delta_5 + 0.540893X_{208} + 0.521261X_{220} + 0.0868977X_{402}$

$0.588317X_{403} + 9.93799 \times 10^{-3}X_{407-1}$

$r = 0.997254, DW = 2.36357$

(12) $X_{208} = 579.051 + 0.976815X_{205} - 4.76573X_{209}$

$r = 0.999211, DW = 2.31585$

(13) $X_{220} = -2554.54 - 17.8213X_{209} + 123.911X_{221} + 0.368622X_{501-1}$

$r = 0.982497, DW = 2.40079$

(14) $X_{207} = X_{207-1} + X_{205} - X_{208}$

(15) $X_{209} = 55.0356 + 8.52987 \times 10^{-3}X_{114} + 2.24617\delta_6 + 24.7332\delta_7$

$r = 0.896675, DW = 1.63953$

(16) $X_{205} = X_{201} + X_{202}$

(17) $X_{201} = -3584.27 + 80.3437X_{year} + 55.0346X_{212}$

$r = 0.907012, DW = 1.32645$

(18) $X_{202} = -677.601 + 0.307244X_{112} + 0.0301823X_{204}$

$r = 0.999518, DW = 1.79027$

(19) $X_{114} = 1768.36 + 0.629268X_{104} - 784.836\delta_8$

$r = 0.781455, DW = 1.74736$

(20) $X_{113} = 2727.0 + 0.434968X_{114} + 159.413\delta_9 + 610.965\delta_{10}$

$r = 0.802345, DW = 2.5832$

(21) $X_{112} = 6839.56 + 1.00033X_{109} - 1.39743X_{113}$

$r = 0.993417, DW = 2.17573$

(22) $X_{109} = X_{105} + X_{109-105}$

(23) $X_{111} = X_{111-1}{}^k + X_{109} - X_{112}$

(24) $X_{109-105} = X_{102}$

(25) $X_{102} = 919.928 + 0.219578X_{501-1} - 1710.08\delta_{11} + 3.03457X_{104}$

$r = 0.825282, DW = 2.142$

(26) $X_{105} = -33947.4 - 4183.54\delta_{12} + 527.82X_{year} + 1622.53X_{212}$

$r = 0.974214, DW = 1.1333$

Note 1: X'_{305-1} and X'_{305-2} are obtained as follows.

First, take X_{305-1} and X_{305-2} as the exogenous variables. Then, take X^*_{305-1}, X^*_{305-2} obtained from

$X^*_{305} = -1763.06 + 115.734\delta_{13} + 45.2984X_{year}$ $\qquad r = 0.908499$

$DW = 2.33763$

and arrive at

$$X'305-1 = X_{305-1} - X^*_{305-1}$$

$$X'305-2 = X_{305-2} - X^*_{305-2}$$

Note 2: $X'405-1$ and $X'405-2$ are calculated as in note 1. In other words, derive $X_{405-1}^{\bullet}$ and $X_{405-2}^{\bullet}$ from

$$X_{405}^{\bullet} = -3389.094 + 12.6719 X_{year} \qquad r = 0.588883$$

$$DW = 1.23963$$

and arrive at

$$X'_{405-1} = X_{405-1} - X_{405-1}^{\bullet}$$

$$X'_{405-2} = X_{405-2} - X_{405-2}^{\bullet}$$

Note 3:

δ_1	:	−1978,	$\delta_1 = 1$;	1979−	$\delta_1 = 0$.
δ_2	:	−1972,	$\delta_2 = 1$;	1973−	$\delta_2 = 0$.
δ_3	:	1974−1977,	$\delta_3 = 1$;	others	$\delta_3 = 0$.
δ_4	:	−1978,	$\delta_4 = 1$;	1979−	$\delta_4 = 0$.
δ_5	:	−1973,	$\delta_5 = 1$;	1979−	$\delta_5 = 0$.
δ_6	:	−1973,	$\delta_6 = 1$;	1974−	$\delta_6 = 0$.
δ_7	:	1974−1977,	$\delta_7 = 1$;	others	$\delta_7 = 0$.
δ_8	:	1965−1971,	$\delta_8 = 1$;	1972−	$\delta_8 = 0$.
δ_9	:	1964−1973,	$\delta_9 = 1$;	1974−	$\delta_9 = 0$.
δ_{10}	:	1974−1977,	$\delta_{10} = 1$;	others	$\delta_{10} = 0$.
δ_{11}	:	1965−1970,	$\delta_{11} = 0$;	1971−	$\delta_{11} = 1$.
δ_{12}	:	1965−1972,	$\delta_{12} = 1$;	1973−	$\delta_{12} = 0$.
δ_{13}	:	−1978,	$\delta_{13} = 1$;	1979−	$\delta_{13} = 0$.

5. DURBIN-WATSON RATIOS IN EQUATIONS AND CERTIFICATION OF PARAMETERS

Regarding the statistical meaning of the above equations, I give the results only for the Durbin-Watson ratios in the equations, as well as the parameter certifications of the respective equations.

First, the Durbin-Watson ratios are as shown in Table 8, the dL and dU of significance level 5% with specific samples are given in Table 9, and the interpretation of the Durbin-Watson ratios utilizing these are shown in the notes to Table 9. Generally speaking, the above equations are statistically significant.

Sample number n is either 17, 18, or 19. Obtain P, d, $(4-d)$ from Table 8, and the significance may be determined from Table 9.

Next, the results of parameter certification for the respective equations are shown in Table 10.

In reading Table 10, if the calculated t-value is greater than $t_{n-p-1}(\alpha)$, the reference t-value corresponding to $n-p-1$ degrees of freedom and an error probability of α, then it may be considered that the addition of the explanatory variable is significant; t_{n-p-1} with α at 10% and 5%, in the respective degree of freedom, is shown in Table 11.

TABLE 8. Durbin-Watson ratios of equations.

Equation	Number of variables	Durbin-Watson ratio	
	P	d	$(4 - d)$
(2)	3	1.20921	2.79079
(3)	3	2.4914	1.5086
(4)	3	3.0433	0.9567
(6)	5	2.14506	1.85494
(7)	3	1.34923	2.65077
(8)	3	1.7088	2.2912
(9)	1	2.51569	1.48431
(11)	6	2.36357	1.63643
(12)	2	2.31585	1.68415
(13)	3	2.40079	1.59921
(15)	3	1.63953	2.36047
(17)	2	1.32645	2.67355
(18)	2	1.79027	2.20973
(19)	2	1.74736	2.25264
(20)	3	2.5832	1.4168
(21)	2	2.17573	1.82427
(22)	3	2.142	1.858
(23)	3	1.1333	2.8667

TABLE 9. dL and dU at the significant level of 5%.

n	$P = 1$		$P = 2$		$P = 3$		$P = 4$	
	dL	dU	dL	dU	dL	dU	dL	dU
15	0.95	1.23	0.83	1.40	0.71	1.61	0.59	1.84
20	1.08	1.28	0.99	1.41	0.89	1.55	0.79	1.70

Notes: Interpretation of Table: (1) if $d \leq dL$ or $(4-d) \leq dL$, significant;   (2) if $dU < d <$ $(4-dU)$, not significant;   (3) all other cases, no conclusion.

TABLE 10. t-values of equation parameter.

	Variable	t-value	Variable	t-value	Variable	t-value	Variable	t-value	Variable	t-value	Variable	t-value	$n-p-1$
(2)	δ_1	2.15008	X'_{305-2}	1.0453	X'_{305-1}	0.63192							13
(3)	X_{308}	2.8638	X_{500}	2.6898	X_{307-1}	5.5251							14
(4)	δ_2	1.400	δ_3	1.70063	X_{301}	79.9492							15
(6)	δ_4	0.78742	X_{208}	4.3443	X_{220}	3.30375	X_{302}	0.326123	X_{307-1}	1.58940			12
(7)	X'_{405-2}	0.74051	X'_{405-1}	3.12861	X'_{405}	3.24542							13
(8)	X_{408}	0.3509	X_{500}	2.3335	X_{407-1}	1.5286							14
(9)	X_{401}	59.0157											17
(11)	δ_5	0.47824	X_{208}	6.45705	X_{220}	5.51335	X_{402}	1.219572	X_{403}	3.95547	X_{407-1}	0.11290	12
(12)	X_{205}	99.4628	X_{209}	2.9487									16
(13)	X_{209}	2.44166	X_{221}	3.05722	X_{501-1}	9.09899							13
(15)	X_{114}	1.85109	δ_6	0.5247	δ_7	4.7556							15
(17)	X_{year}	25.870	X_{212}	2.54785									15
(18)	X_{112}	66.96	X_{204}	1.63172									16
(19)	X_{104}	6.88	δ_8	4.9369									15
(20)	X_{114}	2.0875	δ_9	0.8235	δ_{10}	2.5979							15
(21)	X_{109}	34.624	X_{113}	3.5853									16
(25)	X_{501-1}	0.94334	δ_{11}	1.12405	X_{104}	5.138113							14
(26)	δ_{12}	3.1824	X_{year}	4.3228	X_{212}	3.63674							14

TABLE 11. t_{n-p-1} at each significance level and degree of freedom.

$(n-0-1)$	$\alpha = 10\%$ t_{n-p-1}	$\alpha = 5\%$ t_{n-p-1}
12	1.782	2.179
13	1.771	2.160
14	1.761	2.145
15	1.753	2.131
16	1.746	2.120
17	1.740	2.110

6. SIMULATION OF PULP AND PAPER SECTOR MODEL

Now , we deal with the appropriateness of the numerical model for pulp and paper. To test the fitted model, historical values for the period 1974—1982 were used for exogenous variables as shown in Table 12. The corresponding values for the endogenous variables were then calculated. Comparisons between the calculated values and historical data for the same period are shown in Figures 3—26. Generally speaking, the actual and calculated values are in fairly good agreement.

However, the separation between the actual and calculated values is large for paper price in Figure 6. This is because the paper price is determined by the paper inventory (X_{305-1}, X_{305-2}), and it is assumed that there was a relatively large separation between the calculated and actual values of the paper inventory.

TABLE 12 Exogenous variables used for simulation.

Variables	Year 1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	Units
X_{501-1}	–	16359	–	–	–	–	–	–	–	–	–	1000t
X_{307-1}	–	8609	–	–	–	–	–	–	–	–	–	1000t
X_{407-1}	–	7750	–	–	–	–	–	–	–	–	–	1000t
X_{500}	–	–	79684	85210	91318	99737	87626	92813	96607	100278	103287	¥1 billion
X_{305-1}	472	302	–	–	–	–	–	–	–	–	–	1000t
X_{405-1}	147	150	–	–	–	–	–	–	–	–	–	1000t
X_{302}	–	–	9424	9660	9847	10174	10692	11315	11961	12209	12232	1000t/day
X_{402}	–	–	9750	10499	10561	10514	10263	9910	9925	9955	9923	1000t/day
X_{403}	–	–	6128	5345	5369	5234	4923	4695	4325	4269	4248	1000 persons
X_{221}	–	–	41.2	38.7	41.5	43.0	42.1	43.4	46.2	47.3	48.1	%
X_{207-1}	–	765	–	–	–	–	–	–	–	–	–	1000t
X_{204}	–	–	4355	4574	4474	4319	4089	3760	3546	3309	3199	1000 persons
X_{111-1}	–	1129	–	–	–	–	–	–	–	–	–	1000 m^3
X_{212}	–	–	12.1	11.1	12.4	12.6	12.9	13.0	12.0	11.0	10.0	10^9 cu.ft.
X_{104}	–	–	5486.7	4985.7	4694.3	4338.5	4450.6	4198.7	4565.2	4145.3	3833.2	¥1000

Note: Variable names refer to Figure 2.
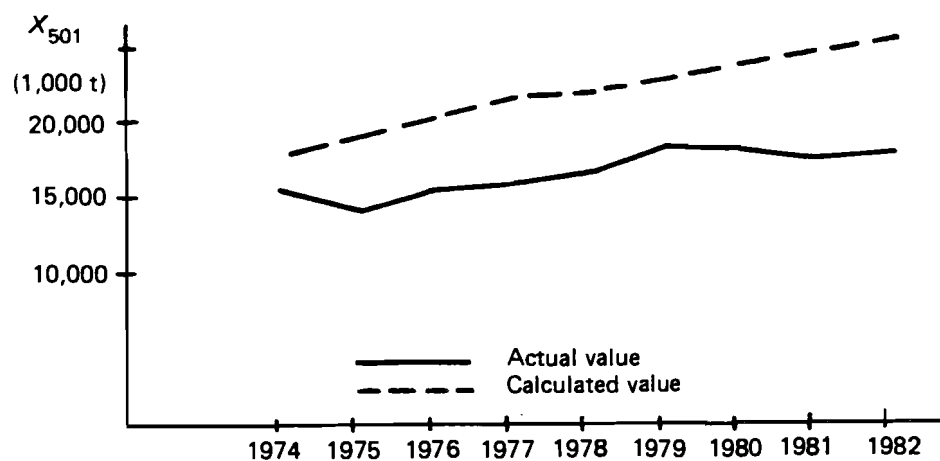
FIGURE 3. Paper and paperboard consumption at period t.
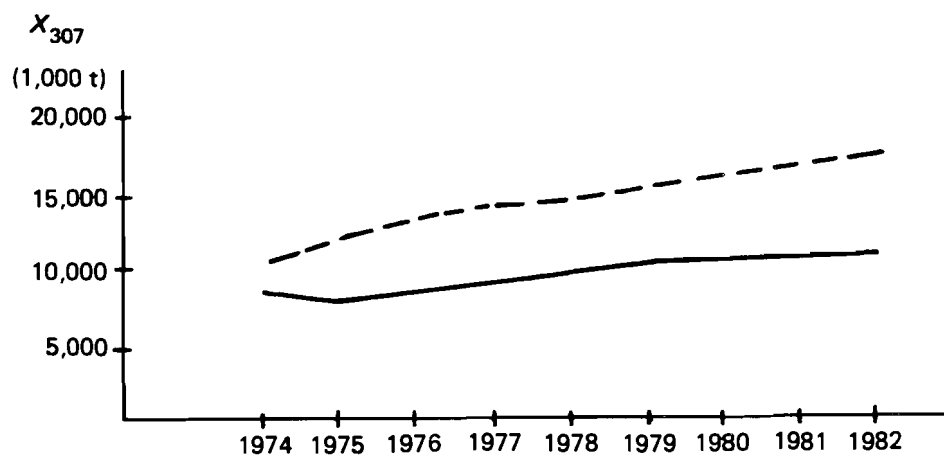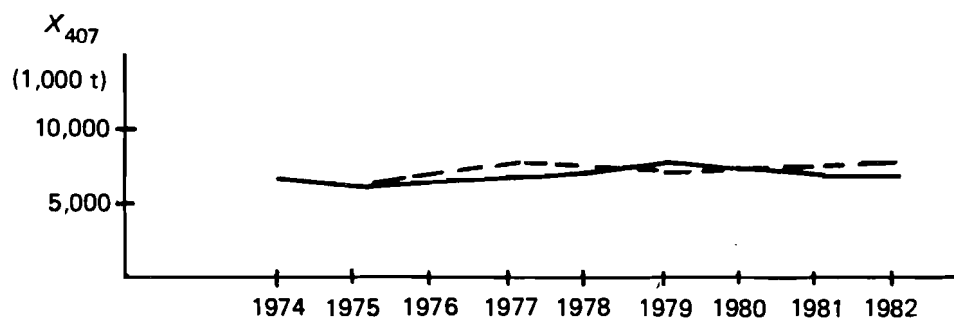

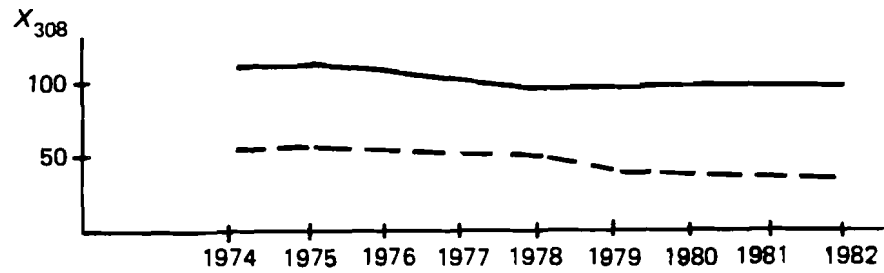**FIGURE 4.** Paper consumption.

FIGURE 5. Paperboard consumption.
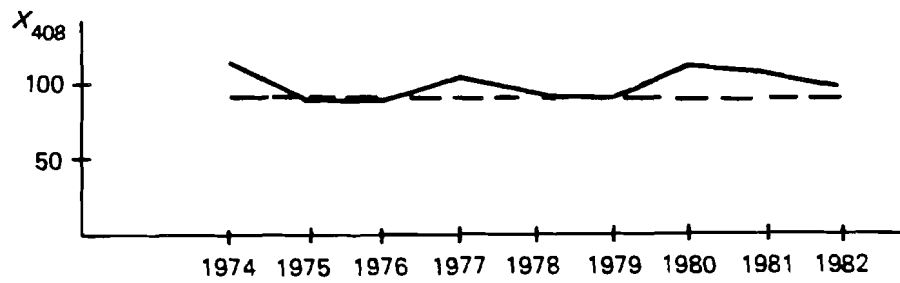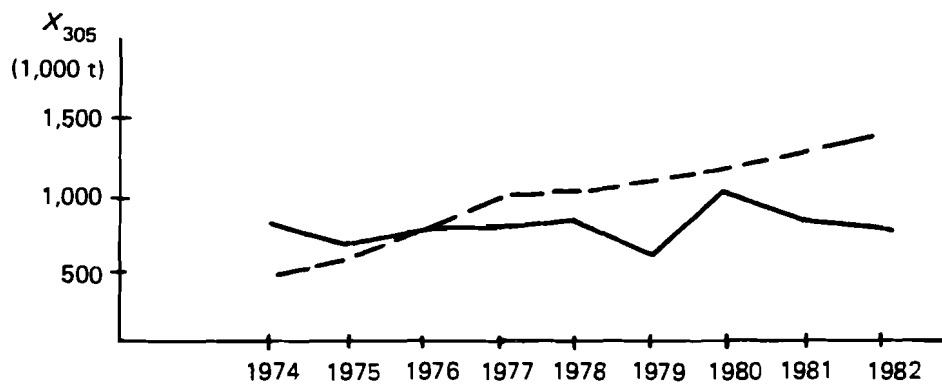
FIGURE 6. Paper price.
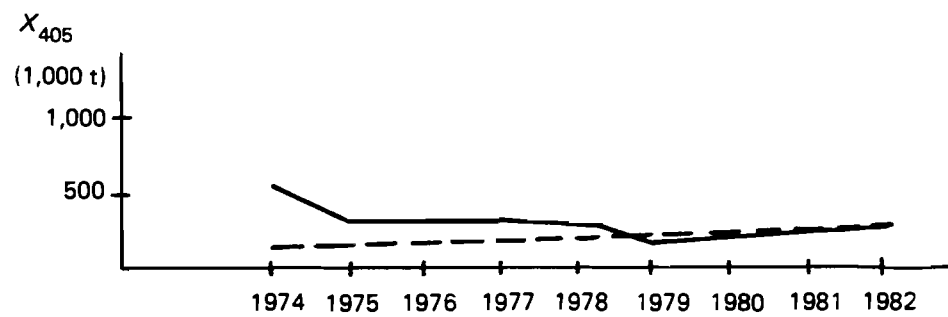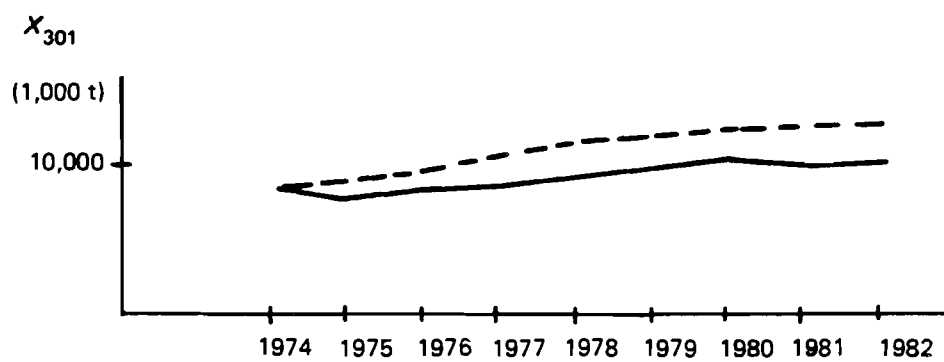

FIGURE 7. Paperboard price.

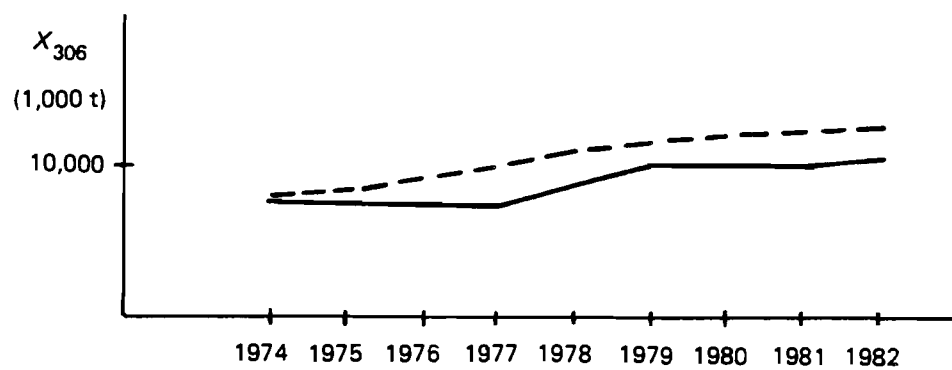**FIGURE 8.** Paper inventory at the end of period t.
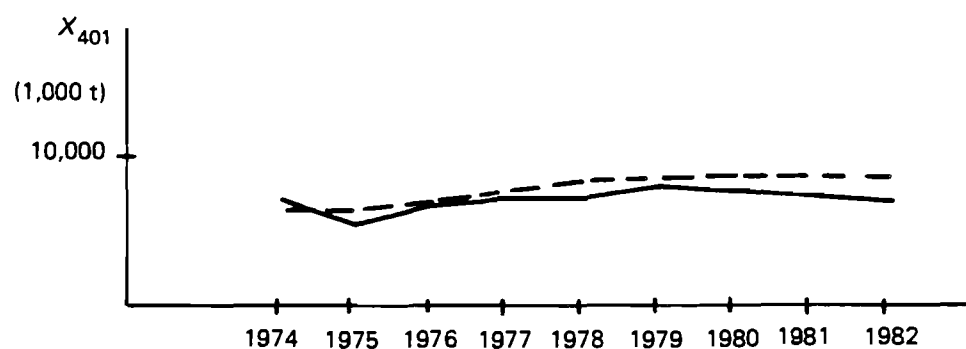
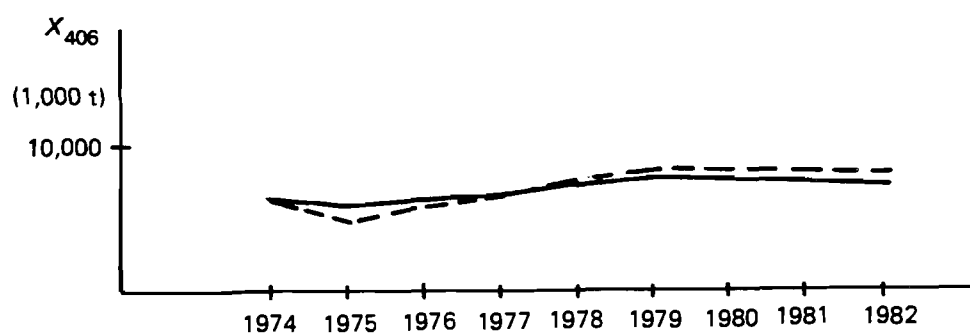**FIGURE 9.** Paperboard inventory at the end of period t.
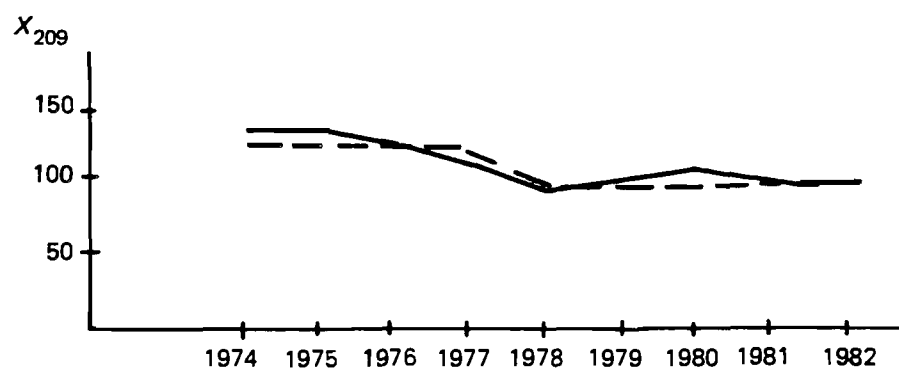

FIGURE 10. Paper production.

FIGURE 11. Paper shipment.

FIGURE 12. Paperboard production.

FIGURE 13. Paperboard shipment.
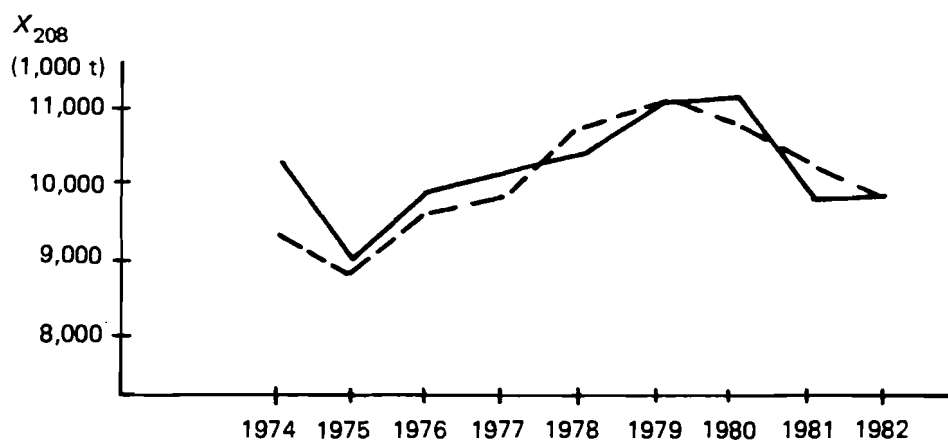

FIGURE 14. Pulp price.

X_{208}
(1,000 t)

11,000 —

10,000 —

9,000 —

8,000 —

1974 1975 1976 1977 1978 1979 1980 1981 1982

FIGURE 15. Pulp consumption.

(1,000 t)

10,000 —

9,000 —

8,000 —

7,000 —

6,000 —

5,000 —

4,000 —

3,000 —

2,000 —

1,000 —

Pulp production
X_{202}

Pulp import
X_{201}
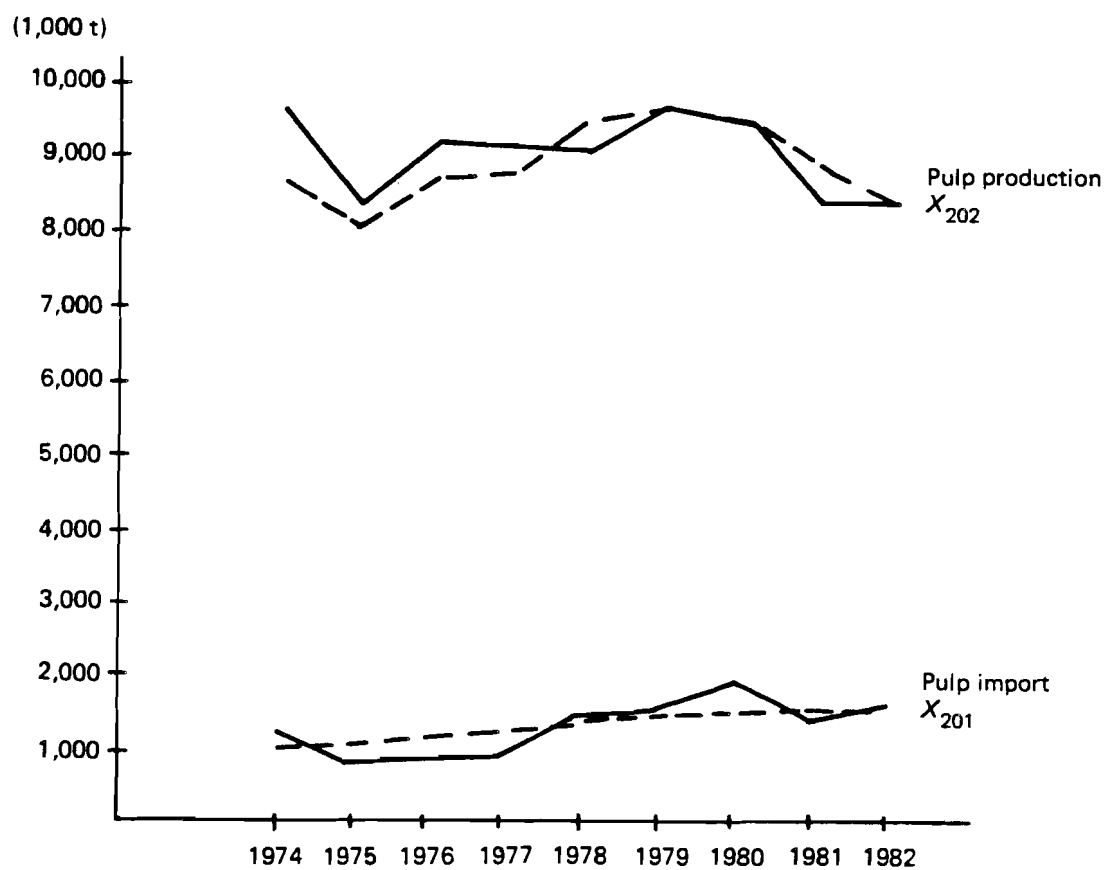
1974 1975 1976 1977 1978 1979 1980 1981 1982

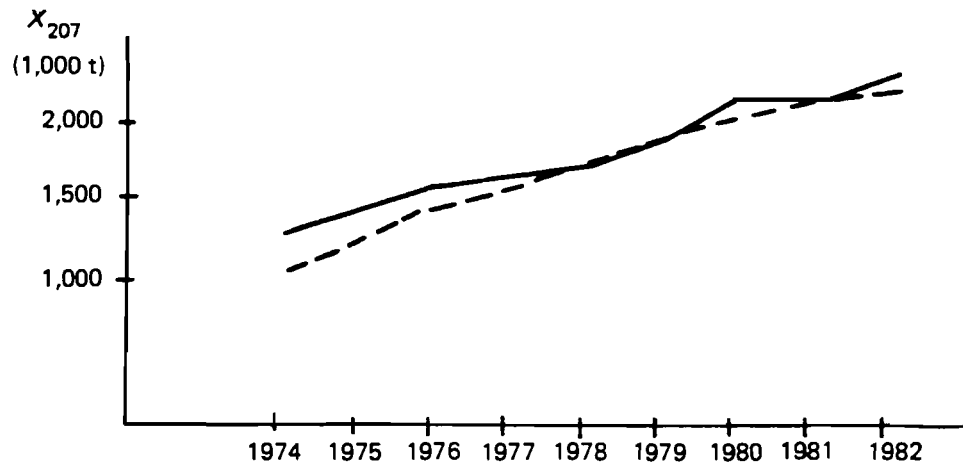**FIGURE 16.** Pulp production and import.

FIGURE 17. Pulp inventory at the end of period t.
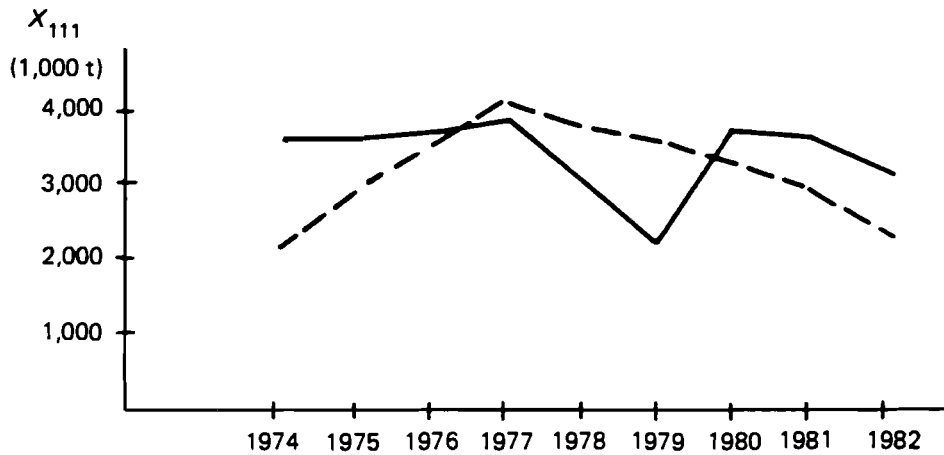
FIGURE 18. Chip inventory at the end of period t.
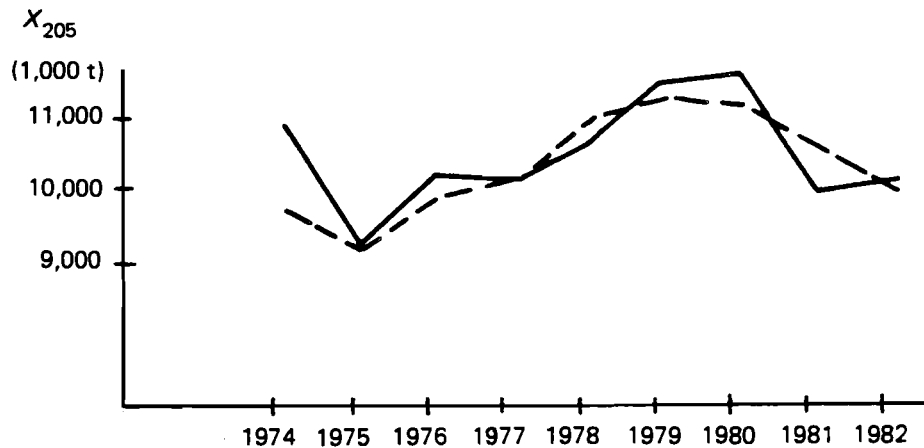
FIGURE 19. Pulp arrival volume.

X_{113}
(1,000 ¥)

6,000 ┼

5,000 ┼

4,000 ┼

1974 1975 1976 1977 1978 1979 1980 1981 1982

FIGURE 20. Chip price.

X_{114}
(1,000 ¥)

6,000 ┼

5,000 ┼

4,000 ┼

3,000 ┼

1974 1975 1976 1977 1978 1979 1980 1981 1982
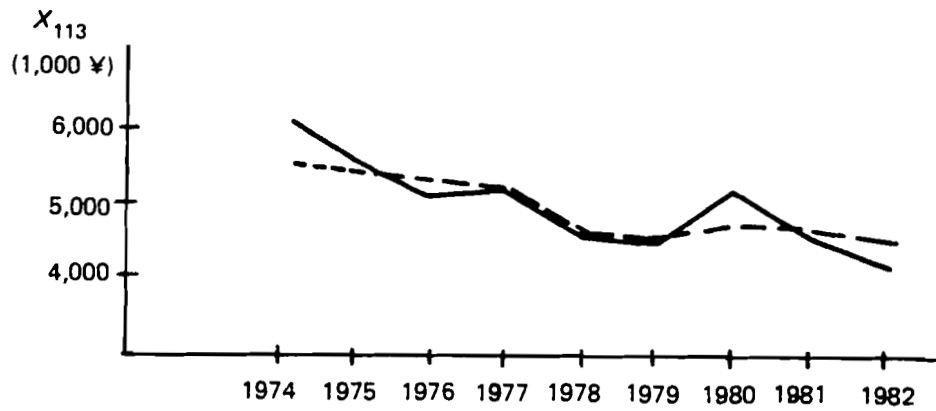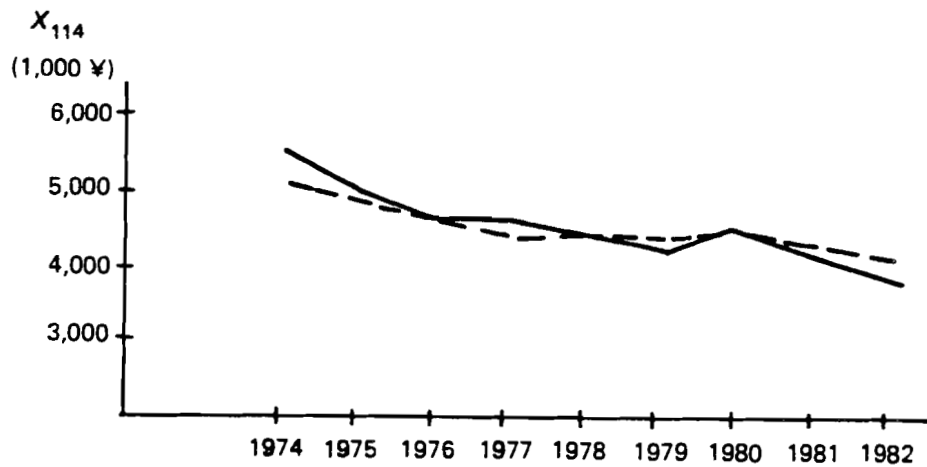
FIGURE 21. Pulpwood price.

X_{220}
(1,000 t)

10,000 ┼

5,000 ┼

1974 1975 1976 1977 1978 1979 1980 1981 1982

FIGURE 22. Waste paper consumption.

FIGURE 23. Chip shipment.
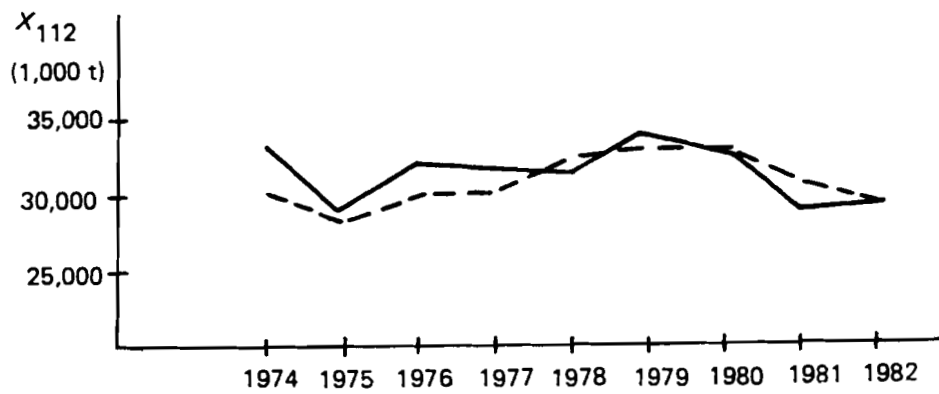
FIGURE 24. Chip consumption.

FIGURE 25. Chip import.

$X_{109}-X_{105}$

(1,000 m^3)

20,000

10,000

1974 1975 1976 1977 1978 1979 1980 1981 1982

FIGURE 26. Domestic chip production.

7. SOME INTERESTING ECONOMIC FEATURES

As to the economic features of the pulp and paper sector model in Japan I have calculated various elasticity coefficients, which are presented below with some comments.

Price of Domestic Pulpwood (X_{104}) and
Arrival Volume of Domestic Pulpwood (X_{102})

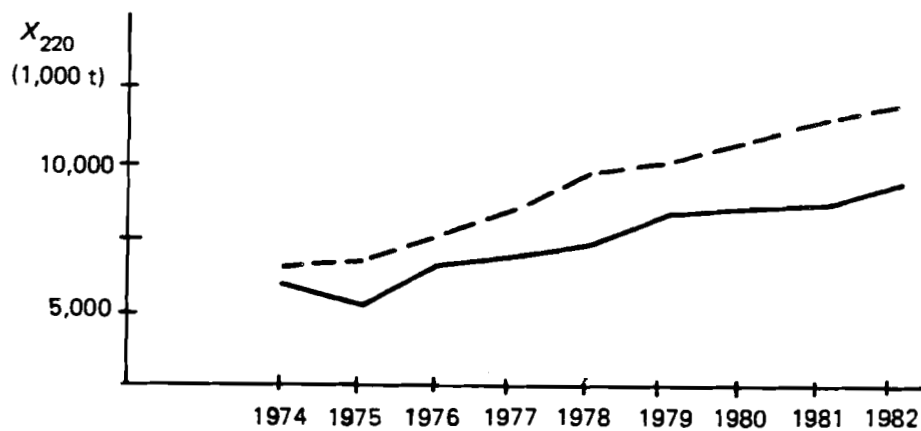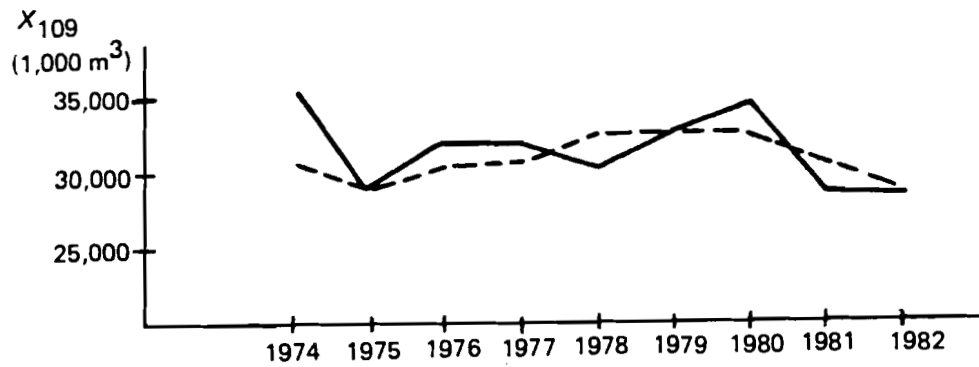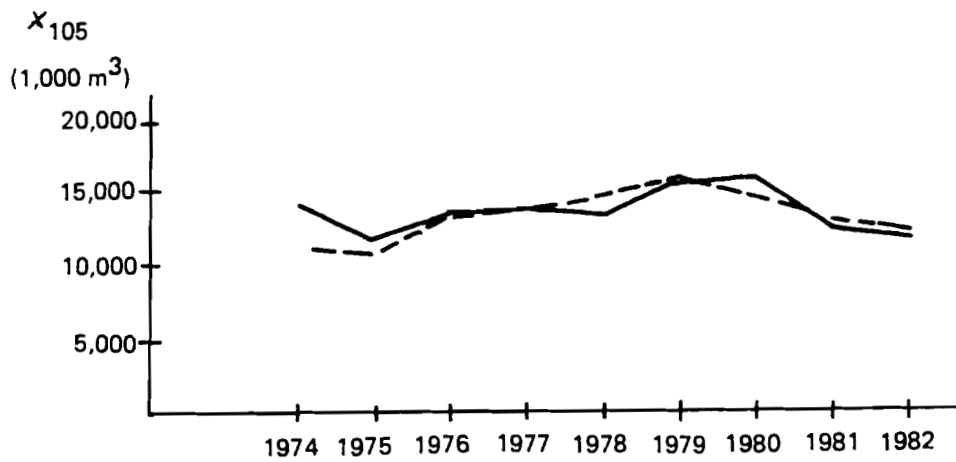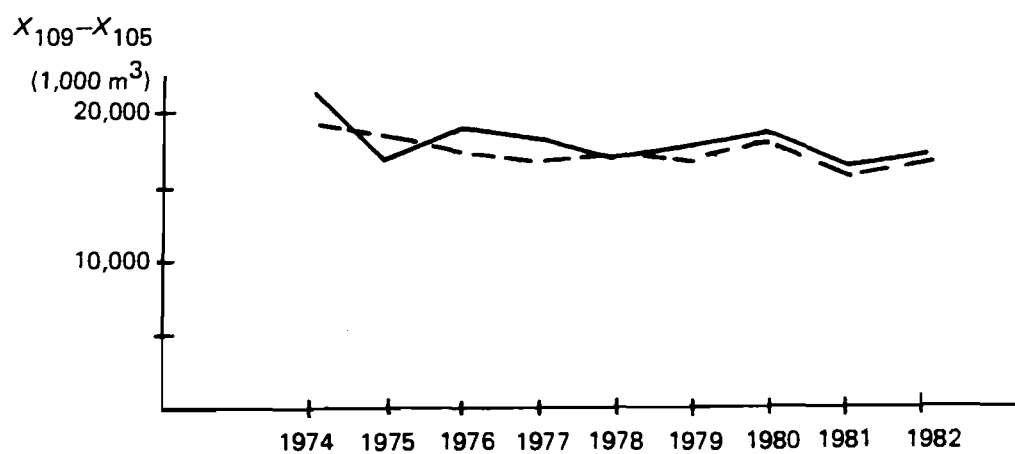The domestic pulpwood price elasticity of the domestic pulpwood arrival volume on a time-series basis shows a trend of decline, as may be noted from Table 13.

During 1965–1969, when there was a price fluctuation of 10%, the arrival volume showed a 8.9% fluctuation, and during 1978–1982 a 6.7% fluctuation.

Chip Price (X_{113}) and Chip Consumption (X_{112})

The chip price elasticity of the chip consumption volume also shows some fluctuation, as is shown in Table 14, but in general exhibits a fairly steady movement toward zero over the study period.

TABLE 13. Domestic pulpwood price elasticity of the domestic pulpwood arrival volume (a_1).

Period	a_1
1965–1969	0.88541
1966–1970	0.83797
1967–1971	0.80694
1968–1972	0.78665
1969–1973	0.76694
1970–1974	0.72374
1971–1975	0.73769
1972–1976	0.73620
1973–1977	0.72664
1974–1978	0.71601
1975–1979	0.70602
1976–1980	0.67994
1977–1981	0.68044
1978–1982	0.67172

TABLE 14. Chip price elasticity of the chip consumption volume (a_2)

Period	a_2
1965–1969	−0.34223
1966–1970	−0.30846
1967–1971	−0.28471
1968–1972	−0.26459
1969–1973	−0.24067
1970–1974	−0.23861
1971–1975	−0.24272
1972–1976	−0.23767
1973–1977	−0.23472
1974–1978	−0.23764
1975–1979	−0.22204
1976–1980	−0.21341
1977–1981	−0.21225
1978–1982	−0.20714

Pulp Price (X_{209}) and Pulp Consumption Volume (X_{208})

The pulp price elasticity of the pulp consumption volume is as shown i Table 15. There was a gradual decrease in absolute value over the period. However, as may be noted from the magnitude of the elasticities, the effect of pulp price on the chip consumption volume was minor.

Pulp Price (X_{209}) and Waste Paper Consumption Volume (X_{220})

The pulp price elasticity of the pulp consumption volume is as shown in Table 16. This, also, shows that the trend of gradual decline of the absolute value.

TABLE 15. Pulp price elasticity of the chip consumption volume (α_3).

Period	α_3
1965–1969	−0.073733
1966–1970	−0.066627
1967–1971	−0.061090
1968–1972	−0.056216
1969–1973	−0.052700
1970–1974	−0.053076
1971–1975	−0.055143
1972–1976	−0.056398
1973–1977	−0.056730
1974–1978	−0.055006
1975–1979	−0.050771
1976–1980	−0.046471
1977–1981	−0.043426
1978–1982	−0.041822

TABLE 16. Pulp price elasticity of the pulp consumption volume (α_4).

Period	α_4
1965–1969	−0.498564
1966–1970	−0.457744
1967–1971	−0.428295
1968–1972	−0.394544
1969–1973	−0.357223
1970–1974	−0.357094
1971–1975	−0.364888
1972–1976	−0.358821
1973–1977	−0.348946
1974–1978	−0.332231
1975–1979	−0.293626
1976–1980	−0.259135
1977–1981	−0.230766
1978–1982	−0.210594

Paper Price (X_{306}) and Paper Consumption Volume (X_{307})

The paper price elasticity coefficient of the paper consumption volume is as shown in Table 17. The relationship between these, of course, is negative. The absolute value gradually decreased from −0.80681 during 1965−1969 to −0.38540 in 1978−1982.

Paperboard Price (X_{406}) and Paperboard Consumption Volume (X_{407})

The paperboard elasticity of the paperboard consumption volume is as shown in Table 18. The two, of course, have a negative relationship, and the absolute value of −0.16188 in 1965−1969 decreased gradually to −0.09679 in 1978−1982.

TABLE 17. Paper price elasticity of the paper consumption volume (a_5).

Period	a_5
1965−1969	−0.80681
1966−1970	−0.72769
1967−1971	−0.66884
1968−1972	−0.61926
1969−1973	−0.56641
1970−1974	−0.53477
1971−1975	−0.53586
1972−1976	−0.52768
1973−1977	−0.51593
1974−1978	−0.50417
1975−1979	−0.47600
1976−1980	−0.43766
1977−1981	−0.40994
1978−1982	−0.38540

TABLE 18. Paperboard price elasticity of the paperboard consumption volume (a_6).

Period	a_6
1965−1969	−0.16188
1966−1970	−0.14897
1967−1971	−0.13678
1968−1972	−0.12598
1969−1973	−0.11560
1970−1974	−0.11456
1971−1975	−0.11008
1972−1976	−0.10572
1973−1977	−0.10522
1974−1978	−0.10453
1975−1979	−0.09605
1976−1980	−0.09601
1977−1981	−0.09847
1978−1982	−0.09679

National Income (X_{500}) and Paper Consumption Volume (X_{307})

The relationship of national income, which has a major effect on paper consumption volume, is expressed as the national income elasticity of paper consumption volume, and the values are as shown in Table 19. From 0.23247 in 1965–1969 this gradually increased to 0.2893 in 1973–1977 and after that decreased to 0.25956 in 1978–1982.

National Income (X_{500}) and Paperboard Consumption (X_{407})

Next, the national income elasticity of paperboard consumption volume is shown in Table 20. The absolute value of this elasticity, unlike that of paper, is large and shows a gradual increase over time. In other words, for a given increase in national income there was a greater increase in paperboard consumption than in paper consumption; and this difference is tending to increase over time.

TABLE 19. National income elasticity of the paper consumption volume (a_7).

Period	α_7
1965–1969	0.23247
1966–1970	0.24367
1967–1971	0.25685
1968–1972	0.27100
1969–1973	0.27700
1970–1974	0.27826
1971–1975	0.28558
1972–1976	0.28729
1973–1977	0.28983
1974–1978	0.28384
1975–1979	0.27917
1976–1980	0.27143
1977–1981	0.26725
1978–1982	0.25956

TABLE 20. National income elasticity of the paperboard consumption volume (a_8).

Period	α_8
1965–1969	0.39107
1966–1970	0.40130
1967–1971	0.41924
1968–1972	0.43668
1969–1973	0.43473
1970–1974	0.43734
1971–1975	0.45385
1972–1976	0.46047
1973–1977	0.47028
1974–1978	0.47783
1975–1979	0.47504
1976–1980	0.46773
1977–1981	0.47287
1978–1982	0.47478

8.　PROBLEMS FOR FUTURE SOLUTION

The two problems which could not be covered in this paper, or, which require greater study in the future, are as follows:

(1)　The production, or the supply, of domestic (softwood and hardwood) logs for pulp and chips, based on domestic timber resources and wages, and the supply of sawmill waste as chips require greater consideration. At the same time, the industry is studying this subject, and plans to coordinate research with this study.

(2)　The second remaining problem is that greater attention is necessary with regard to imports from overseas, particularly from North America.

APPENDIX: REFERENCE MATERIAL

TABLE A1. Domestic pulpwood price and pulpwood price.

| Year | Domestic pulpwood price | | Pulpwood price | |
	Nominal value	Actual price	Nominal price	Actual price (X_{114L})
1964	–	–	4681.4	4719.2
1965	5570*	5570.0	4639.9	4639.9
1966	5600*	5468.8	4569.0	4461.9
1967	6170*	5915.6	4919.3	4716.5
1968	6475*	6160.8	5018.0	4774.5
1969	6360*	6921.9	5152.3	4797.3
1970	6159	5924.6	5350.9	4803.3
1971	6800	6153.9	5738.7	5193.4
1972	6600	5820.1	5964.3	5259.5
1973	7600	5886.7	7199.5	5576.7
1974	9300	5486.7	9451.4	5576.0
1975	8700	4985.7	8749.1	5013.8
1976	8600	4694.3	8647.3	4720.1
1977	8700	4338.5	8784.2	4705.0
1978	8100	4450.6	8169.4	4488.7
1979	8200	4198.7	8320.8	4260.5
1980	10500	4565.2	10726.7	4663.8
1981	9700	4154.3	9900.2	4230.9
1982	9700	3833.2	9338.9	3933.8

Notes:

(1) Of the nominal values of prices for domestic pulpwood, those marked with * are for coniferous pulpwood in Iwate-machi, listed in *Ringyo Tokei Yoran* (*Forestry Statistics Survey* prepared under the survey, prepared under the supervision of the Forestry Agency), and the others (unmarked) are the all-Japan prices for coniferous pulpwood, obtained from *Mokuzai Shikyo Geppo* (*Timber Market Monthly Statistics*).

(2) The nominal value for pulpwood price is calculated with the following formula:

$$\frac{(S \text{ price } [\yen 1000/m^3] \times \text{volume of } S \text{ handled } [m^3] + H \text{ price} \times \text{volume of } H \text{ handled})}{(\text{volume of } N \text{ handled} + \text{volume of } L \text{ handled})}$$

where S = softwood and H = hardwood.

Source of S, H prices and volume of S, H handled: *Parupuzai Tokei* (*Pulp-wood Statistics*), Japan Paper Association.

(3) Actual values are based on wholesale price indexes, 1965, *Tokei Geppo* (*Monthly Statistics*).

TABLE A2. Wholesale price index

Year	Wholesale prices	SNA (Net) X_{500} (10 bill)
1964	99.2	–
1965	100.0	32065
1966	102.4	36488
1967	104.3	42271
1968	105.1	50046
1969	107.4	57364
1970	111.4	65981
1971	110.5	73226
1972	113.4	81794
1973	129.1	87599
1974	169.5	79684
1975	174.5	85210
1976	183.2	91318
1977	186.7	99737
1978	182.0	87626
1979	195.3	92183
1980	230.0	96607
1981	234.0	100278
1982	237.4	103287

Notes:

(1) The conversion of nominal to actual value is based on the wholesale price indexes in the above table.

(2) Wholesale price indexes and new SNA are both based on *Monthly Statistics*.

TABLE A3. Chip arrival volume and import.

Year	Shipment X_{109}	Consumption X_{112}	Import X_{105}
1964	16867	16434	–
1965	16613	16849	461
1966	18500	18484	752
1967	21544	20257	1564
1968	25577	22047	3226
1969	24341	24690	3994
1970	27901	28342	5285
1971	30168	29038	6231
1972	29913	30807	7529
1973	32381	32915	11223
1974	35521	33057	14052
1975	28787	28773	11791
1976	31961	31848	13279
1977	31959	31795	13874
1978	30388	31295	13331
1979	32897	33626	15155
1980	34258	32737	15570
1981	28711	28806	12321
1982	28567	29102	11414

Notes:

(1) Japan Paper Association, *Pulpwood Statistics*.

TABLE A4. Pulp production, import, consumption, and waste paper consumption, its retrieval rate.

| Year | Pulp | | | Waste paper | |
	Production X_{202} (1000t)	Import X_{201} (1000t)	Consumption X_{208} (1000t)	Consumption X_{220} (1000 t)	Retrieval rate X_{221} (%)
1964	4569	331	4824	2889	40.0
1965	4695	304	4975	2846	38.3
1966	5205	462	5606	3191	39.5
1967	5699	516	6165	3482	38.5
1968	6346	612	6906	3606	36.0
1969	7143	670	7702	4215	37.4
1970	8247	737	8877	4696	38.6
1971	8494	480	8973	4602	35.9
1972	8944	585	9361	5163	37.9
1973	9634	919	10438	6343	39.8
1974	9595	1235	10335	5866	41.2
1975	8350	849	9040	5235	38.7
1976	9194	887	9946	6264	41.5
1977	9107	962	10015	6552	43.0
1978	9070	1483	10464	6916	42.1
1979	9677	1612	11138	7753	43.4
1980	9488	1935	11138	7857	46.2
1981	8355	1489	9834	7920	47.3
1982	8361	1581	9845	8472	48.1

Note:

(1)   Japan Paper Association, *Pulp Statistics* and *The Annual Report on Paperboard*.

TABLE A5. Pulp price, paper price, and paperboard price.

Year	Pulp price		Paper price		Paperboard price	
	Nominal	Actual (X_{209})	Nominal	Actual (X_{308})	Nominal	Actual (X_{408})
1964	100.0	100.8	100.0	100.8	100.0	100.8
1965	98.9	98.9	99.7	99.7	89.6	89.6
1966	99.7	97.4	103.6	101.2	94.6	92.4
1967	101.3	97.1	104.9	100.6	96.9	92.9
1968	99.3	94.5	104.5	99.4	94.5	89.9
1969	104.4	97.2	105.1	97.9	98.9	92.1
1970	114.6	106.7	110.1	98.8	113.9	106.1
1971	110.1	99.6	110.5	100.0	105.8	95.7
1972	108.1	95.3	112.5	99.2	108.2	95.4
1973	132.6	102.7	126.5	98.0	132.9	102.9
1974	220.6	130.1	186.7	110.1	193.7	114.3
1975	225.8	129.4	192.3	110.2	159.8	91.6
1976	226.3	123.8	192.7	105.2	164.8	90.0
1977	198.9	106.5	183.1	98.1	192.4	103.1
1978	154.7	85.0	166.0	91.2	167.0	91.8
1979	184.3	94.4	184.1	94.3	175.5	89.9
1980	239.6	104.2	218.5	95.0	254.2	110.5
1981	208.5	89.1	218.2	93.2	249.1	106.5
1982	207.7	87.7	223.2	94.0	228.3	96.2

Notes:

(1) The nominal values of the prices are based on the Bank of Japan, *Wholesale Price Indexes.*

(2) The actual values are from the 1965 wholesale price indexes (*Monthly Statistics.*)

TABLE A6. Chip price.

TABLE A7. Timber production and construction starts.

Year	Nominal	Actual
1964	4884.2	4923.6
1965	4936.6	4936.6
1966	5138.5	5018.1
1967	5397.9	5175.4
1968	5353.7	4984.8
1969	5311.3	4954.3
1970	5570.7	5000.6
1971	5784.1	5234.5
1972	6948.5	5382.3
1973	7706.7	4546.7
1974	10747.0	6158.7
1975	10128.7	5528.8
1976	9622.2	5153.8
1977	9739.1	5216.4
1978	8916.1	4602.0
1979	8787.8	4499.6
1980	11871.9	5161.7
1981	10666.2	4558.2
1982	10061.6	4238.2

Year	Timber production (bill.cu.ft.) X_{212}	Construction starts X_{213}
1964	11.2	1529
1965	11.5	1473
1966	11.5	1165
1967	11.2	1292
1968	11.8	1508
1969	11.7	1467
1970	11.6	1434
1971	11.5	2052
1972	11.9	2357
1973	12.4	2045
1974	12.1	1338
1975	11.1	1160
1976	12.4	1538
1977	12.6	1987
1978	12.9	2020
1979	13.3	1743
1980	12.0	1292
1981	11.0	1084
1982	10.0	1062

Notes to Table A6:

(1) $\text{Nominalprice} = \dfrac{(SC \text{ price } [1000/\,\text{m}^3] \times \text{volume of } N \text{ handled } [\text{m}^3] + HC \text{ price } \times \text{volume of } HC \text{ handled}}{(\text{Volume of } SC \text{ handled } + \text{volume of } HC \text{ handled})}$

where SC = *softwood chips and* HC = *hardwood chips.*

(2) Actual values are based on the 1965 wholesale price indexes (*Monthly Statistics*).

Note to Table A7:

Forest Service: *An Analysis of the Timber situation in the United States 1952-2030.*

TABLE A8. Paper and paperboard inventory at the end of period t (1000 t).

Year	Paper X_{305}	Paperboard X_{405}
1964	221	120
1965	223	193
1966	207	83
1967	193	102
1968	241	87
1969	261	79
1970	393	252
1971	430	230
1972	472	147
1973	302	150
1974	766	506
1975	624	364
1976	729	367
1977	721	364
1978	763	290
1979	599	1269
1980	945	256
1981	761	238
1982	699	267

Note:
Calculations are based on
Annual Statistics on Paper.

TABLE A9. Paper production and shipment (t).

Year	Production X_{301}	Shipment X_{306}
1964	4204496	4152323
1965	4219260	4216125
1966	4615876	4631535
1967	5058874	5072876
1968	5489128	5444357
1969	6147345	6127430
1970	7135486	7003897
1971	7129055	7091942
1972	7471342	7429699
1973	8221162	8391441
1974	8443725	7979320
1975	7710992	7853287
1976	8631100	8526360
1977	8758831	8766878
1978	9363579	9321271
1979	9981007	10145376
1980	10536295	10190586
1981	9943449	10127598
1982	10353257	10415550

Note:
1964 inventories were assumed to be:
paper, 221 (M ton); paperboard, 120 (M ton);
$(X_{301-306})$, $(X_{401-406})$ for the next year
were added.

TABLE A10. Paperboard production and shipment (t).

Year	Production X_{401}	Shipment X_{406}
1964	3162468	3076102
1965	3079371	3105801
1966	3578755	3589080
1967	3985257	3966498
1968	4467644	4483006
1969	5162433	5170332
1970	5837754	5664687
1971	5777640	5800499
1972	6176274	6258617
1973	7752667	7749685
1974	7201442	6844551
1975	5889667	6031966
1976	6763041	6760482
1977	6943344	6945893
1978	7136248	7209911
1979	7879835	8000785
1980	7551520	7465215
1981	7036674	7055087
1982	7099496	7069667

Note:
(1) Japan Paper Association,
   Annual Report on Paper Statistics, 1980.

TABLE A11. Paper import (t)

Year	Import X_n
1964	89880
1965	16352
1966	26937
1967	58511
1968	126451
1969	173248
1970	97704
1971	66208
1972	123533
1973	218266
1974	383846
1975	86331
1976	145685
1977	148455
1978	187507
1979	188621
1980	219743
1981	223793
1982	351337

Note:
(1) Japan Paper Association,
   Annual Report on Paper Statistics, 1980.

TABLE A12 Equipment and labor for pulp, paper and paperboard.

Year	Pulp Equipment X_{203} (ton/day)	Pulp Labor X_{204} (1000)	Paper Equipment X_{302} (ton/day)	Paper Labor X_{303} (1000)	Paperboard Equipment X_{402} (ton/day)	Paperboard Labor X_{403} (1000)
1964	18422	7323	4820	17256	3363	6848
1965	19240	7386	5222	17461	3850	7526
1966	19848	7382	5336	17474	4169	7400
1967	19917	6962	5327	16665	4440	7194
1968	24478	6552	5915	16406	4682	6982
1969	25016	6341	6179	16773	4780	6837
1970	28696	5962	7077	16482	6035	6832
1971	30185	5660	7323	16313	6468	6520
1972	30541	5354	8357	16150	6843	6356
1973	31055	4966	8874	14601	7513	6291
1974	35031	4355	9424	14027	9750	6128
1975	37772	4574	9660	12816	10499	5345
1976	38776	4474	9847	12859	10561	5369
1977	38352	4319	10174	12769	10514	5234
1978	38469	4089	10692	12209	10263	4923
1979	40088	3760	11315	12319	9910	4695
1980	42486	3546	11961	11808	9925	4325
1981	40174	3309	12209	10910	9955	4269
1982	39628	3199	12232	10904	9923	4248

Notes:

(1)   Facilities = average of estimated daily capacity (at 100% operation level) for the 12 months of the year.

(2)   Actual labor = average of actual man-days/month for the 12 months of the year.