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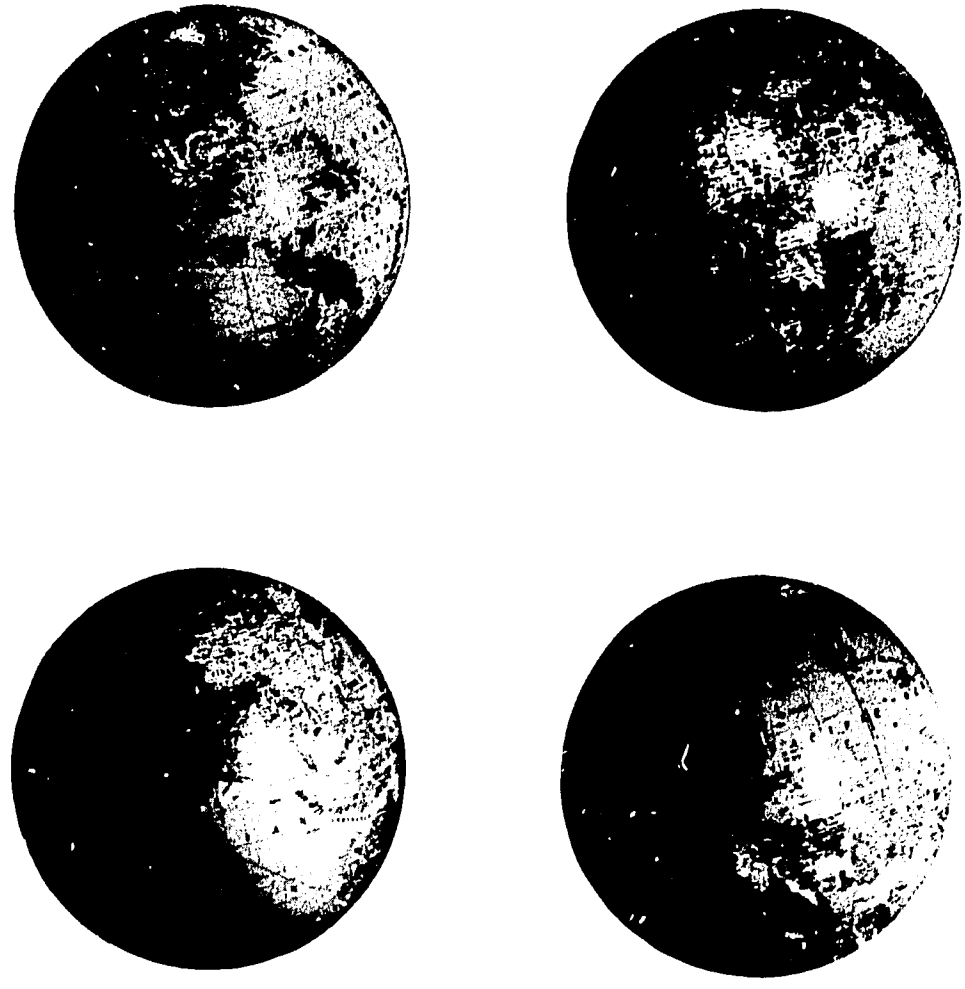

THE OUTLOOK FOR NATURAL RUBBER IN THE 1980s

Abu Bakar Man and David Blandford

DEPARTMENT OF AGRICULTURAL ECONOMICS
New York State College of Agriculture and Life Sciences
A Statutory College of the State University
Cornell University, Ithaca, New York

June 1980

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THE OUTLOOK FOR NATURAL RUBBER IN THE 1980's

by

Abu Bakar Man and David Blandford*

INTRODUCTION

Rubber is an important export commodity for less-developed countries (LDCs). In terms of value it is their fourth largest agricultural export, averaging almost $1.5 billion per year during the early 1970's (Blandford). Over 50 percent of world rubber exports come from Malaysia, and the commodity has typically accounted for over 20 percent of the country's total earnings of foreign exchange.

Rubber is also a major import of developed countries (DCs). In 1978, for example, the United States spent almost $679 million on rubber imports (dry and latex) --- roughly 5 percent of the total value of the country's agricultural imports (USDA).

During the 1950's and 1960's, natural rubber experienced increasing competition from synthetic substitutes derived from petroleum. Relatively low and stable oil prices resulted in low and stable synthetic rubber prices. This, coupled with the development of improved synthetic varieties, had a marked price-depressing effect. From a postwar high of 61 cents per pound in 1951 the price of natural rubber on the NY market declined to just over 18 cents in 1971. The steady deterioration in prices caused considerable concern in producing countries. Malaysia, for example, introduced various measures to restrict output and exports in an effort to prevent the decline. There was general agreement among commodity analysts that natural rubber had a bleak future -- and then came OPEC!

The actions of the oil cartel in raising the price of the primary feedstock for synthetic rubber had a marked effect on the natural rubber market. After almost 20 years of virtually complete stability, the NY wholesale price of general purpose synthetic rubber increased

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* Abu Man was formerly a graduate student and David Blandford is an assistant professor in the Department of Agricultural Economics, Cornell University, Ithaca, New York. Financial support for this research was generously provided by the Center for International Studies at Cornell University and the Malaysian Government. The authors are grateful for helpful comments on an earlier draft by W. G. Tomek. They are, however, entirely responsible for any remaining errors or deficiencies.

by 38 percent in 1974. By 1977 it was 56 percent above the 1973 level. Such increases, and the likelihood that they will continue due to the escalating price of petroleum, have substantially improved the market outlook for natural rubber producers. Changes in consumption since the late 1960's, in particular the growing acceptance of radial tires, which require larger amounts of natural rubber than traditional tires, will also prove significant.

In the light of these recent developments in the natural rubber market this study has the following objectives:

(1) to describe the market structure of both natural and synthetic rubber, and the nature of the competition between them;

(2) to formulate and estimate an econometric model of the world natural rubber market which captures the effect of price competition between natural and synthetic products, and which embodies the relationship between the price of petroleum and the synthetic substitute; and

(3) to assess future supply, demand, and price prospects for natural rubber in 1985, and to determine the relative contribution of increasing petroleum prices to anticipated changes in these variables.

1. MARKET STRUCTURE

1.1 Natural Rubber

It is believed that natural rubber originated in the Amazonian area of Brazil.[1/] It was introduced to the European continent in the first half of the 18th century by a French mathematician, Charles de la Condamine (Barlow). The 'unique' characteristics of the product such as elasticity, its waterproof nature and its bounciness, stimulated the interest of other European researchers, traders, and explorers. As time went by its uses were exploited, expanded and popularized; demand increased and higher quantities had to be made available. However, at that time the only place where rubber could be obtained was the Amazon region. In the late 19th century through a combination of various factors, mostly trade-related, rubber was introduced into other parts of the world, especially into South and East Asia, where it has flourished ever since.

1/ Natural rubber is an organic product which can be obtained from many different kinds of plants (Polhamus). Hevea brasiliensis is the most commercially important variety. Throughout this study 'natural rubber' refers to the product of Hevea brasiliensis, other sources are neglected.

Production and Exports

Currently most of the world's natural rubber is produced in Asia. In 1970, production in this region accounted for 87 percent of the world total; African countries contributed a further 7 percent and South America about 1 percent. In 1975, these proportions were 92 percent, 6 percent, and 0.9 percent respectively (Table 1.1). Throughout the sixties, Malaysia was the world's leading producer; accounting for almost 39 percent of the world total in 1960. During the period 1960-75, Malaysian production grew at a compound rate of over 4 percent per year, and its share of world production increased by three percentage points. Most of this increase has been due to government replant-

Table 1.1 World Rubber Production By Region and Country, 1960 to 1975 a/

Region/country	1960	1965	1970	1975
	metric tons			
Asia	1,814,285	2,184,703	2,701,949	3,048,106
Malaysia	785,413	949,253	1,269,203	1,459,282
Indonesia	620,255	717,000	815,161	822,500
Thailand	170,875	216,486	289,663	353,304
Sri Lanka	98,939	118,312	159,[illegible]9	148,751
Vietnam	76,612	60,963	28,458	20,000
Cambodia	37,107	48,197	12,673	10,000
Philippines	na	na	17,538	46,750
Others	23,115	24,385	nr	nr
Africa	149,360	159,521	213,035	215,110
Liberia	na	na	83,403	82,753
Nigeria	na	na	65,250	67,750
Ivory Coast	na	na	10,871	14,869
Cameroon	na	na	12,229	15,448
Others	na	na	1,282	4,250
South America	30,210	36,402	31,976	30,606
World Total	2,016,674	2,380,114	3,102,500	3,445,000

a/ World totals may not equal the sum of production in each country due to allowances for discrepancies in officially reported statistics.

na = not available nr = not recorded

Source: Rubber Statistical Bulletin.

ing schemes, particularly involving smallholders, and the spread of high-yielding varieties.1/

The share of world production from Indonesia declined from 31 percent in 1960 to 24 percent in 1975, although total output increased at an average yearly rate of 1.9 percent. Unlike Malaysia, there were few replanting schemes, particularly for the smallholding sector, which generates the bulk of Indonesian production.2/

Thailand's rubber production has increased both in terms of its absolute level and its relative contribution to world production. In 1960, Thailand accounted for roughly 8 percent of world rubber production. In 1975 the figure was 10 percent, reflecting an annual rate of output growth of almost 5 percent. Like Malaysia, there has been a deliberate effort on part of the government to replant old and relatively unproductive rubber stands with high-yielding varieties. Programs begun in the late fifties have resulted in a marked increase in production since the latter part of the sixties.

Elsewhere in Asia, the output of natural rubber has also increased, with the exception of Vietnam and Cambodia where it has declined substantially, mainly due to war disruption. In 1971, Cambodian production was only about one thousand tons, compared to nearly 52 thousand tons two years before.

Rubber production in Africa is dominated by Liberia and Nigeria. In recent years a marked increase in output has occurred in Ivory Coast and Cameroon.

The bulk of the natural rubber produced in all these countries is exported, since domestic consumption is negligible (Table 1.2). The three major producers (Malaysia, Indonesia, and Thailand) exported over 90 percent of their production in 1960. This proportion remained roughly constant throughout the sixties and seventies. However, Malaysia's share of world exports increased from roughly 39 percent in 1960 to almost 49 percent in 1975 (Table 1.3). On the other hand, Indonesia's export share declined from 31 percent in 1960 to 27 percent in 1975. There has been a moderate increase in Thailand's share--from 9 percent in 1960 to over 11 percent in 1975. Total exports from Sri Lanka have shown steady growth; throughout this period its share of world exports has remained more or less constant at 5.5 percent.

1/ Rubber is derived from two different types of production units: estates or plantations, and smallholdings. In Malaysia about 50 percent of total production is from smallholdings; 65-70 percent of Indonesian production is derived from this source.

2/ Attempts are now being made to replant rubber trees in parts of Sumatra.

Table 1.2 World Rubber Exports By Region and Country, 1960 to 1975

Region/country	1960	1965	1970	1975
	metric tons			
Asia	1,724,643	1,959,719	2,556,011	2,744,151
Malaysia	737,742	998,061	1,304,082	1,424,336
Indonesia	586,522	694,665	766,231	788,292
Sri Lanka	106,416	123,926	154,051	160,874
Vietnam	73,053	61,938	22,976	7,500
Cambodia	35,053	46,171	15,000	10,000
Others	15,144	14,118	14,508	18,382
Africa	149,360	154,441	206,938	191,994
Liberia	48,384	49,220	83,403	82,753
Nigeria	69,468	68,964	59,285	52,741
Others	41,508	36,257	64,250	56,500
World Total	1,874,726	2,306,450	2,785,000	2,920,000

Source: Rubber Statistical Bulletin.

Table 1.3 Major Exporters' Shares of World Natural Rubber Exports

Country	1960	1965	1970	1975
	percent of world exports			
Malaysia	39.35	47.27	46.83	48.78
Indonesia	31.29	30.12	27.51	27.00
Thailand	9.06	9.17	10.02	11.46
Sri Lanka	5.68	5.36	5.53	5.51
Vietnam	3.94	2.69	0.82	0.26
Cambodia	1.87	2.00	0.54	0.34
Liberia	2.58	2.13	2.99	2.83
Nigeria	3.17	2.99	2.13	1.81

Source: Computed from Table 1.2.

Other significant exporters of rubber are Vietnam, Nigeria, Liberia, and Cambodia. Exports from Vietnam and Cambodia declined, both in terms of absolute magnitude and in relation to world exports, mainly due to war disruptions. Liberian rubber exports increased very slightly throughout the period, and Nigeria's have steadily declined.

Consumption

Natural rubber is primarily consumed in industrialized countries. Historically, a large proportion has been absorbed by the tire manufacturing industry. Whittlesey estimates that roughly 85 percent of all crude rubber was used in the manufacture of tire and tire sundries in the early twenties. Bauer estimates that in 1928-1929, about 75-85 percent of world rubber use was in the motor industry. Between 1938 and 1940, the U.S. used over 75 percent of all crude rubber in the manufacture of tires, inner tubes, and tire sundries (Knorr).

Table 1.4 details levels of consumption in major consuming regions/countries. The U.S. is by far the largest market, absorbing 19.8 percent of the world total in 1975. The United Kingdom used to be the second largest consumer, but its importance has declined and it has been surpassed by Japan and China.

In Japan, despite increases in the production and consumption of synthetic rubber, consumption of the natural product also has increased. In 1960 Japan used roughly 168 thousand metric tons. By 1975 had risen to 285 thousand metric tons. Japan's share of world consumption increased from 8 percent in 1960 to 9.5 percent in 1970. In 1975, because of economic recession, Japanese consumption was 1 percentage point lower than in 1970.

Consumption in China has shown a generally upward trend but in proportionate terms the picture is more variable. There was a decline in its share in 1965 compared to that of 1960, but an increase of 1 percent by 1970. By 1975 relative consumption had declined again. On the whole, China's use of natural rubber shows an upward trend.

The pattern of consumption for France, Germany, and Italy has not varied greatly since 1960. The level of consumption has increased marginally in France and Germany, and there has been a noticeable increase in Italy. Nevertheless, these three European consumers have represented a declining proportion of world natural rubber consumption, as other countries in Western Europe have increased in importance.

In the centrally-planned economies of Eastern Europe, rising production of synthetic rubber (especially in the U.S.S.R.) has contributed to reduced use of the natural product. From a level of 16.9 percent of world consumption in 1965, Eastern Europe's share declined to 15.6 percent in 1970, and 14.1 percent in 1975.

The relative decline in natural rubber consumption in 'traditional' markets has been accompanied by an increase in relative consumption in the less-industrialized countries. India, for instance, has displayed strong growth in the consumption of natural rubber. The residual 'rest of the world' category in Table 1.4, consumed nearly as much as the U.S. in 1975 (18.0 percent), a major change since 1960.

Table 1.4 Major Consuming Regions/Countries of Natural Rubber[a/]

Region/Country	1960		1965		1970		1975	
	Quantity	%	Quantity	%	Quantity	%	Quantity	%
Western Europe	677,202	32.28	737,150	30.48	902,500	30.18	907,500	26.95
United Kingdom	182,789	8.79	186,751	7.72	195,200	6.53	170,500	5.06
Germany	148,080	7.06	157,862	6.53	200,725	6.71	197,101	5.85
France	129,393	6.17	122,515	5.07	158,229	5.29	156,204	4.64
Italy	74,985	3.57	86,975	3.60	113,000	3.78	118,000	3.50
Others	142,018	6.77	183,144	7.57	235,346	7.87	265,695	7.89
North America	522,484	24.90	566,451	23.42	618,906	20.70	738,241	21.92
U.S.	486,740	23.20	522,971	21.61	568,290	19.01	655,950	19.78
Canada	35,744	1.70	43,480	1.80	50,616	1.69	72,291	2.14
Eastern Europe	322,090	15.35	408,455	16.89	465,000	15.55	475,000	14.11
Asia	336,016	16.02	402,819	16.66	576,969	19.30	639,338	18.99
China	121,673	5.80	136,660	5.65	207,500	6.94	225,000	6.68
Japan	168,412	8.03	201,484	8.33	283,000	9.46	285,200	8.47
India	45,941	2.19	64,675	2.67	86,469	2.89	129,138	3.83
Rest of the world	240,356	11.46	303,341	12.54	426,625	14.27	607,421	18.04
World consumption	2,098,158	100.00	2,481,216	100.00	2,990,000	100.00	3,367,500	100.00

a/ Quantities are in metric tons.

Source: Rubber Statistical Bulletin.

Recent figures indicate that the end-uses of natural rubber are becoming more diversified. Tire manufacturing is a relatively less important end-use now than in the first half of the century, although it is still extremely significant. Table 1.5 shows the relative proportions of use of rubber in tire and other products in major consuming countries in 1973.

Table 1.5 Uses of Natural Rubber In Tires And Other Products in Selected Countries, 1973

Country	Natural And Synthetic Rubber		Natural Rubber	
	Tires	Others	Tires	Others
	----------percent of total usage----------			
United States	64.5	35.5	74.0	26.0
Japan	53.8	46.2	64.8	35.2
Germany	44.7	55.3	52.0	48
France	63.8	36.2	73.7	26.3
United Kingdom	49.3	50.7	51.7	48.3
Canada	65.5	34.5	76.9	23.1
Brazil	57.9	42.9	75.5	24.5

Source: Barlow.

In the early 1970's it has been estimated that for the world as a whole about 68 percent of all natural rubber was used in the manufacturing of tires and tire-related products, such as covers for automobile and commercial and heavy vehicles, and in tire retreads and repairs. Mechanical goods, such as belting equipment and hoses, absorbed about 13.5 percent of world consumption. Other uses which include latex products, footwear and adhesives made up the remainder (Yusoff).

1.2 Synthetic Rubber

Synthetic rubber only began to be mass-produced during the Second World War, even though it was discovered in the 19th century (Phillips). Strategic necessity, rather than economic considerations, promoted the initial growth of the industry (Horowitz). However, economic characteristics have since sustained a continuous and vigorous growth. In a period of roughly twenty years, the production of synthetic rubber rose to a par with the natural product. By 1975, world

consumption was 67.6 percent of total rubber consumption. This compares to 59.1 percent in 1965 and 38.1 percent in 1958.1/ Currently, there are no less than twenty six countries, both developed and developing, that produce some form of synthetic rubber. (Rubber Statistical Bulletin, January 1979).

Types

Synthetic rubber comes in different forms with widely differing characteristics. Since it is man-made, flexibility exists for tailoring production to meet the requirements of particular end-uses. This partly explains its varied characteristics. Broadly, synthetic rubber can be separated into three major categories: (1) general purpose, (ii) specialty and (iii) stereo.

General-purpose synthetic rubber is made up of two principal types, styrene and butadiene (SBR). These are the cheapest and quantitatively the most important types of synthetic rubber. The major use of SBR is in the manufacture of tires for passenger cars, especially in tire fabrication. Due to low resilience, it is unsuitable for heavy-duty tires. In terms of wear resisitance, ageing resistance, groove cracking, and fast curing properties, SBR is qualitatively superior to natural rubber when properly compounded. Apart from these superior qualities, the major competitive advantage of SBR lies in two areas: first, it has typically been cheaper than natural rubber, and second, it can be readily adapted to the modern fabricating requirements of customers.

There are at least nine kinds of special-purpose synthetic rubber, but only three are prominent.2/ As the name suggests, these possess special properties suitable for specific kinds of usage.

Butyl rubber is a quantitatively significant special-purpose rubber. It is highly impermeable to air and grease, and is mainly employed in making inner tubes or as an inner lining for tubeless tires. Due to its ability to resist deterioration by heat, ozone and other outdoor weathering, butyl rubber is also used for electrical insulation.

A second important special-purpose rubber is neoprene, which has outstanding properties for resistance to oil and low temperatures.

1/ These percentages are with respect to the sum of natural plus synthetic rubber. Reclaimed rubber is not included.

2/ The nine types are butyl, neoprene, nitrile, polysulfide, silicone, acrylic, hypalon, urethane and fluroelastomers. The first three are the most important.

Hence, its major use is as a protective covering for materials that are exposed to oil, heat, weather and hydrocarbon fuel, such as gaskets in motor mounts.

A third special-purpose rubber is nitrile, which has marked ability to withstand contact with oil, gasoline, and common solvents. Because of this, nitrile is used in products where resistance to the deteriorating effects of fuels is important, as in gasoline hose and tank linings.

There are two component types that make up the group known as stereo rubber: polyisoprene and polybutadiene. Stereo rubber has properties similar to natural rubber and has been claimed to duplicate its molecular structure. It therefore finds uses where natural rubber has an advantage, such as in the manufacture of heavy-duty tires. Polybutadiene, on the other hand, is only used as a partial substitute for natural rubber. It does not possess the same characteristics of low heat build-up, but is superior in resistance to oxidation. Its toughness increases if properly blended with natural rubber.

Industry Structure

Due to the prominence of a few large companies or firms manufacturing and selling the product, the synthetic rubber industry can be characterized as an oligopolistic industry. It also exhibits some tendency towards integration, particularly forward integration in which fabricators of rubber products are at the same time major producers of synthetic rubber.

Table 1.6 illustrates the pattern of ownership of synthetic rubber capacity in major developed countries for 1964 and 1970. In the U.S., about half of the total capacity is owned by rubber fabricators, who are prominent in the production of general-purpose rubber. In 1964, fabricators produced 960.4 thousand metric tons of this rubber, representing 52 percent of total capacity. By January 1970, their share had increased by approximately 15 percentage points to 66.8 percent of the total.

The largest synthetic rubber manufacturers are the tire producers. The big two U.S. tire companies, Goodyear and Firestone, owned SBR capacity of 643 thousand metric tons in 1970, more than one-third of all U.S. SBR capacity and an amount in excess of U.S. imports of natural rubber in that year (567,400 metric tons). More than 50 percent of SBR, and about 69 percent of polybutadiene and isoprene capacity, are owned by the 5 major tire companies (Goodyear, Firestone, General Tire, Uniroyal and B.F. Goodrich). These same companies account for roughly 95 percent of U.S. tire production (Ch'ng).

In the United Kingdom almost 91 percent of SBR in 1970 was produced by a single company, the International Synthetic Rubber Company, a consortium of tire manufacturers, which are also the major suppliers

Table 1.6 Distribution of Synthetic Rubber Capacity in Selected Developed Countries, 1964 and 1970[a]

	October 1964			January 1970		
	Total	Rubber Fabricators' Share		Total	Rubber Fabricators' Share	
		Total	Percent		Total	Percent
U.S.						
GP rubber	1853.5	960.4	51.8	2254.6	1506.2	66.8
SBR	1594.9	813.4	51.0	1720.2	1136.3	66.1
BR	176.3	118.6	67.3	392.2	265.7	67.8
IR	82.3	28.4	34.6	142.3	104.3	73.3
Others	448.1	98.0	21.9	577.1	114.8	19.9
Total	2301.6	1058.5	46.0	2831.8	1621.0	57.2
U.K.						
GP rubber	128.0	114.8	89.7	301.8	274.3	90.9
SBR	117.9	104.7	88.7			
BR	10.2	10.2	100.0	301.8	274.3	90.9
Others	67.1	-	0.0	90.4	20.8	23.0
Total	195.1	114.8	58.9	392.2	295.2	75.3
France						
GP rubber	159.5	39.6	24.8	256.0	63.0	24.6
SBR	103.6	4.1	4.0	181.9	9.1	5.0
BR	55.9	35.6	63.6	74.2	53.9	72.6
Others	20.3	-	0.0	87.4	9.1	10.5
Total	179.8	39.6	23.0	343.4	72.1	21.0
Japan						
GP rubber	209.9	187.5	89.4	641.1	517.7	80.7
SBR	179.4	167.2	93.2			
BR	30.5	20.3	66.7	641.1	517.7	80.7
Others	22.8	6.5	28.6	112.8	40.6	36.0
Total	232.7	194.1	83.4	753.9	557.8	74.1

Note: Detail may not add to total due to rounding.

a/ Quantities in thousand metric tons.
SBR = styrene butadiene
BR = polybutadiene
IR = isoprene
GP = general-purpose

Source: Ch'ng.

of tires in the U.K. (Dunlop, Goodyear, Michelin, Pirelli, and Uniroyal). More than 95 percent of the synthetic rubber capacity in Germany is owned by two companies (Huls Group and Farben Fabrication Bayer Ag). In Italy, a subsidiary of the state-run company, ENI, owns about 90 percent of capacity. In France, three important tire manufacturers, Michelin, Firestone, and Goodyear, accounted for 20 percent of synthetic rubber capacity.

The Japanese industry is dominated by only two companies, accounting for 91.4 percent, 46.7 percent and 74.1 percent of SBR, polybutadiene, and total synthetic rubber capacities respectively, in 1970. These companies are Japanese Synthetic Rubber and Japan Geon, with a 46.9 percent holding by rubber fabricators in the former company and 58.0 percent in the latter.

The market structure of the synthetic rubber industry is a close-knit intra-conglomerate business in which the major buyers and sellers are under the same organizational umbrella. Internalized transactions insulate supply from many of the exogenous factors which cause fluctuations in availability of the natural product. The pattern of transactions and market insulation allow more flexibility for cost control, and hence price stability. On the demand side, the existence of a 'captive' market detaches the industry from the instabilities of world markets, which are characteristic of natural rubber and other agricultural raw materials. Such peculiarities of the synthetic rubber market are of particular interest from the viewpoint of natural rubber, as they influence competition between the two products.

1.3 Competition Between Natural and Synthetic Rubber

Much has been written on the competition between synthetic and natural rubber, since the former became a major commercial commodity. However, not all types of synthetic rubber compete with natural rubber. About 5 percent of synthetic rubber production is non-competitive. This includes costly specialty rubber tailored for specialized products for which the natural product cannot be used, for example, silicone, acrylics, and nitrile butadiene. Therefore, roughly 95 percent of synthetic rubber production is actually in competition with natural rubber (Allen et al.)

UNCTAD has identified three major factors influencing the competition between the natural and synthetic products: (1) the structure of the synthetic rubber industry; (2) research and development; and (3) cost and price relationships.

Market Structure

The market structures for synthetic and natural rubber are completely different, both in terms of production and consumption. Being

an agricultural commodity, the production of natural rubber is influenced by factors outside the control of producers, most importantly weather. Due to biological infexibility, there is a production lag of five to seven years which generates short-run unresponsiveness to changing market conditions. The combined effect of these factors is production rigidity, a major characteristic of most tree crops. In contrast, synthetic rubber is a manufactured good which allows producers production flexibility, both in terms of quantity and quality. Production can be controlled in response to peaks and troughs in demand.

The structure of ownership and control in the synthetic rubber market, discussed above, is an important factor in the competition between the two products. The internalized and intra-firm transactions in the production and consumption of synthetic rubber, form a 'captive' market which guarantees demand, and shields the industry from cyclical changes and stochastic shocks. In marked contrast is the open and loosely structured market for natural rubber, dominated on the demand side by the producers of the synthetic substitute. Under these circumstances, UNCTAD concluded that synthetic rubber might always tend to have a competitive 'edge' over natural rubber. Though the extent of the 'edge' varies from one consumer and country to another, it is undoubtedly an important competitive factor.

Research and Development

Research into the development of synthetic rubber has been extensive and successful. Early synthetic rubber was qualitatively inferior to the natural product and was expensive to produce (Phillips). As the result of research, production costs have decreased and new types of polymers have been developed. The synthetic rubber industry has been able to develop products that not only closely resemble natural rubber, but in some cases are superior in meeting the requirements of end-users. Recognizing the need for product improvement, producers of natural rubber have taken steps to maintain and improve its competitiveness by improving productivity per acre and quality.

Extensive plant breeding programs have been carried out by research institutions in major producing countries, notably the Rubber Research Institute of Malaysia (RRIM). Promising results have been obtained from these efforts. Production of nearly 10 thousand kg. per hectare per year is reportedly possible (Sekhar and Thomas) compared to the 3360 kg. currently being realized. This points to future opportunities for increased productivity and cost reductions.

One of the problems facing natural rubber is the long period from planting to the commencement of economic production about five to seven years. One of the research objectives is to reduce this time lag, and this has resulted in the development of what is known as the 'Three-Part-Tree', which involves successive grafting. A high-yielding trunk

is first grafted onto a vigorous root-stock and later a new 'top' is added from a variety with good growth habit, and high disease and wind resistance. The 'Three-Part-Tree' reduces the production lag to about three years. Research also is being carried out to increase the yield of mature trees by using chemicals to stimulate production under reduced tapping frequency.

In order to win customers for natural rubber, the product has to be processed, graded, and presented in such a way that it meets their requirements. New methods of processing have been developed such that natural rubber can be consistently graded according to measurable technical specifications. Most rubber producers have introduced their own standards to improve processing and grading. Malaysia was the first to do so, by introducing Standard Malaysian Rubber in 1965. This was followed by similar action by Indonesia and Thailand. These actions have improved the ability of natural rubber to satisfy customer requirements for an industrial raw material of relatively standard quality.

Cost-Price Relationships

Over the last three decades, the price of natural rubber has generally been above the price of general-purpose synthetic rubber. The basic reason for this has been the technical superiority of the former over the latter in major end-uses where the two types are substitutable. SBR has always been quantitatively more important than other types of synthetic rubber in competition with natural rubber, though they are not perfect substitutes. However, the advent of new stereo rubbers (especially polyisoprene) in the late fifties added a new competitive dimension, and it was generally concluded at the time, that natural rubber would have to compete more on the basis of price (Phillips; UNCTAD).

The actual extent of price competition is difficult to determine. In 1962, it was estimated that a price of 24 cents per pound and 20 cents per pound for natural rubber would discourage the construction of all new synthetic rubber plants and polybutadiene plants respectively, in the U.S. (Bateman, L.). Bateman also estimated that if (1962) natural rubber prices lay between 12.2 cents and 15.8 cents per pound, SBR production would discontinue. If natural rubber prices were in the 14.5 to 15.8 cents per pound range, the current production (1962) of BR would discontinue. In order for natural rubber to maintain its share of the market, Corden estimated in 1963 that its price could go no higher than 20 cents per pound, and for it to expand its market share, its price would have to be lower than 17 cents. All these estimates reflect the accepted view in the industry in the early sixties that it would be prudent to aim to produce at a selling price of 18 cents per pound (UNCTAD).

Table 1.7 illustrates prices and the relative share of natural rubber in total consumption since 1958. Prices declined steadily from

1960 until 1972, and then rose abruptly. More marked is the declining trend in natural rubber's share of total consumption. On the basis of these facts, Ch'ng suggested that for natural rubber to stabilize its long-run market share, it would have to be more price competitive.

Table 1.7 Prices and Market Share of Natural Rubber

Year	Prices		Price Ratio	Market Share a/
	Natural Rubber	SBR		
	----cents/pound----		-------percent---------	
1958	28.12	23.9	117.66	61.92
1959	36.61	23.9	153.18	57.35
1960	38.10	23.9	159.41	53.39
1961	29.48	23.9	123.35	52.66
1962	28.62	22.9	124.98	44.77
1963	26.22	23.0	114.00	42.87
1964	25.31	23.0	110.04	41.24
1965	25.72	23.0	111.83	40.88
1966	23.59	23.0	102.57	38.45
1967	19.91	22.9	86.94	37.31
1968	19.84	22.8	86.02	36.33
1969	26.22	22.9	114.50	35.21
1970	21.00	23.0	91.30	34.67
1971	18.10	23.0	78.70	33.33
1972	18.23	23.0	79.26	32.43
1973	35.61	23.0	154.83	31.00
1974	39.37	31.7	124.20	32.07
1975	29.89	34.9	85.64	32.40
1976	39.60	35.5	111.55	30.96
1977	41.59	35.9	115.85	30.43

a/ Natural rubber usage as proportion of total rubber usage.

Source: Rubber Statistical Bulletin.

Competition between natural and synthetic rubber is affected by relative price levels and stability. This is clearly illustrated by the experience of 1972, when natural rubber prices fluctuated at extremely low levels. The FAO pointed out that during this period SBR was being sold at an exceptionally large discount, possibly even below cost, in order to prevent consumers from shifting to natural rubber (FAO, Commodity Review And Outlook 1972/73). It is therefore clear that the future market prospects for natural rubber will be closely influenced by its overall supply and demand situation, and that the latter will be dependent to a large extent on relative prices.

2. AN ECONOMETRIC MODEL OF THE NATURAL RUBBER MARKET

This study employs an annual equilibrium market model to analyze future prospects for natural rubber. The model is composed of three sets of equations which explain production, consumption, and inventories and prices of both natural and synthetic rubber. These components are discussed in turn below.

2.1 Supply

The supply relationship for tree crops has received relatively less attention than that for annual crops. Due to the long period of immaturity and productive life, complexities arise in estimating perennial supply response. In particular, there is the question of distinguishing short and long-run price responses. Wharton, in his study of Malaysian rubber, defined the short-run as that period of time during which the producer is unable to change the number of productive trees, and the long-run as a sufficiently long period to allow new trees to come into production. Due to continuous planting, replanting, and abandonment of tree crops, annual production data reflect both short and long-run factors.

Among the first to estimate a supply function for a perennial crop was Peter Ady (1949). Her work on cocoa paved the way for later studies, such as those by Bateman (1965 and 1968), Behrman (1968), and Stern (1965b). Cocoa is the perennial crop that has received the most attention, but others analyzed have been coffee, palm oil, tea, lauric oil, olive oil, and lemon (Labys, 1973a).

As for natural rubber, Bauer, Chan, Stern (1965a), and Wharton were early contributors to the formulation and development of a supply function. Recent studies include the work of Behrman (1971), Reuten, Teken, and Yusoff. These are broader in scope in that demand and price functions are also considered, in addition to supply.

Theoretical Development

Theoretically, the basic factors affecting the supply of perennial crops are the same. Divergences arise primarily because of agronomic differences, such as the length of lag between planting and first yield, and responses to environmental conditions. In their analysis of the supply response of perennial crops, French and Matthews stipulated five components: (i) a pair of functions to explain the quantity of production and bearing acreage desired by producers; (ii) a function that explains new plantings; (iii) a function to explain acreage removed each year; (iv) relationships that explain unobservable expectation variables; and (v) a relationship that explains yearly variation in yields. M. J. Bateman (1969), in a simplification of this approach, identified two basic components of a perennial supply model (i) a planting relationship and (ii) an output

relationship. Bateman did not implicitly include a relationship to explain yield variations, and a limitation is the necessary assumption that trees have an infinite life.

Wharton developed the following formulation for the supply response of natural rubber

$$Q_s = f(P, A_m, C, p, T, W), \tag{2.1}$$

where Q_s = quantity of natural rubber supplied,
P = price of rubber,
A_m = mature acreage,
C = prices of inputs,
p = prices of products competing for inputs used in rubber,
T = technology
W = weather.

Then for any given level of A_m, quantity supplied is

$$Q = A_t \cdot Y, \tag{2.2}$$

where A_t = acreage being tapped,
Y = yield per acre of tapped acreage,
$A_t = < A_m$.

Yearly change in mature acreage (A_m) is the net result of three major activities: new planting (N_t), replanting (R_t), and net loss of acreage of rubber between t and t-1 (L_t)

$$A_m = N_{t-7} + R_{t-7} + L_t. \tag{2.3}$$

Equation (2.3) states that the change in mature acreage is a function of both past and current decisions, i.e. lagged decisions affect the current productive capacity of rubber.

For any given level of A_t, yields per acre are determined by the following function

$$Y = f\ (F,\ I,\ B,\ V,\ O,\ D,\ E,\ X,\ H) \tag{2.4}$$

where F = frequency of tapping
I = intensity of tapping,
B = number of trees tapped,
V = varietal composition of the stand,
O = age composition of the stand,
D = density of the stand,
E = soil quality and elevation,
X = use of chemical stimulants,
H = condition of trees and holdings.

Unfortunately, in order to apply Wharton's model, one must have considerable statistical information, much of which is usually unavailable. To overcome this problem an alternative model is constructed, a model that is less demanding in terms of data and yet sound enough to reflect the basic characteristics of rubber production.

Theoretical Specification

In this study the supply function for natural rubber is developed using a theory of capital stock formation. Ady (1968) applied this approach to the specification of supply functions for cocoa and coffee, and later Labys (1973b) used the same approach for lauric oils.

Potential output is defined by assuming that trees cease production after N years, their "normal" maximum age

$$Q_t^* = \sum_{i=k}^{N} (Y_i S_{t-i}). \tag{2.5}$$

Actual output differs from potential output due to climatic, economic, and institutional rigidities which affect the extraction of potential output. Climatic factors, such as rain, may inhibit harvesting activities. Prolonged drought affects the agronomic structure of the trees, which in turn affects yields. Economic factors and institutional rigidities affect expected returns, and are a major factor in determining whether existing bearing plants are to be harvested, abandoned, removed or replanted, or whether new planting is worthwhile.

Actual output can therefore be represented by

$$Q_t = Q_t^* + dE_t + cW_t\ , \tag{2.6}$$

where E_t = economic factors,

W_t = climatic factors.

In any given year, the existing stock of trees is the net result of new plantings and replantings (PL_t), less abandonment and removal (AR_t). It is also equal to the change in acreage from year t-1 to year t

$$S_t = PL_t - AR_t = A_t - A_{t-1} , \tag{2.7}$$

where A_t = existing acreage (stock).

Planting and replanting decisions are hypothesized to depend on expected relative future returns, which in turn depend on the balance between product and factor prices for rubber and other alternative crops or investments. Assuming that expected product prices relative to those of other crops are an indicator of expected profitability, then planting and replanting decisions can take the following relationship

$$PL_t = a_{11} + a_{12}P_t^* - a_{13}A_{t-1} , \tag{2.8}$$

where P_t^* = expected relative price in year t (which will subsequently be referred to as expected price).

The inclusion of last period's acreage implies that planting and replanting decisions in the current period depend on the existing stock. The higher the stock currently in existence, the lower the acreage planted or replanted.

Decisions to abandon and remove the trees are also hypothesized to depend on expected returns, as reflected by expected future prices. Trees are abandoned when expected future prices are too low to cover variable costs, and are removed when expected future prices are too low to cover fixed costs. In addition, the age composition of the stand enters into consideration. Removal and abandonment decisions are expected to depend negatively on expected prices and positively on the proportion of the acreage which is old

$$AR_t = a_{21} - a_{22}P_t^* + a_{23}K_t , \tag{2.9}$$

where K_t = proportion of acreage composed of old stands.

By combining equations (2.8) and (2.9), the following stock equation is obtained .

$$S_t = b_0 + b_1P_t^* - b_2A_{t-1} - b_3K_t , \tag{2.10}$$

where $b_0 = a_{11} - a_{21}$,

$b_1 = a_{12} + a_{22}$,
$b_2 = a_{13}$,
$b_3 = a_{23}$.

In order to simplify the analysis it is assumed that future prize expectations are based on actual price lagged one period ($P_t^* = P_{t-1}$). This assumption was made by Ady (1968) and Bateman (1968) in their studies of cocoa supply, and also by Labys (1973b) for lauric oil. Thus

$$S_t = b_o + b_1 P_{t-1} - b_2 A_{t-1} - b_3 K_t. \tag{2.11}$$

Actual output is specified to be a modification of potential output. For this function to be computationally tractable an assumption of constant yield is made. Yield is assumed to remain at a plateau ($\bar{Y}$) after the first year of full bearing. Substituting equation (2.5) into (2.6) and incorporating the single yield assumption gives

$$Q_t = \sum_{i=k}^{N} (\bar{Y}.S_{t-i}) + dE_t + cW_t \ , \tag{2.12}$$

and by using (2.7) this can be simplified to

$$Q_t = \bar{Y}.A_{t-k} + dE_t + cW_t \ . \tag{2.13}$$

Forming a first-order differnce equation from (2.12) and expressing it in terms of S_{t-k} gives

$$\bar{Y}.S_{t-k} = \Delta Q_t - c\,\Delta W_t - d\,\Delta E_t. \tag{2.14}$$

From (2.11)

$$S_{t-k} = b_o + b_1 P_{t-k-1} - b_2 A_{t-k-1} - b_3 K_{t-k}, \tag{2.15}$$

which can be substituted into (2.14) to yield

$$\Delta Q_t = \bar{Y}b_o + \bar{Y}b_1 P_{t-k-1} - \bar{Y}b_2 A_{t-k-1} - \bar{Y}b_3 K_{t-k} + c\Delta W_t + d\,\Delta E_t. \tag{2.16}$$

By lagging (2.13) one period and substituting an (2.16), on equation which does not include acreage as an explanatory variable can be derived

$$\Delta Q_t = \bar{Y}b_0 + \bar{Y}b_1 P_{t-k-1} + c\Delta W_t + d\Delta E_t - b_2 Q_{t-1} + b_2 c W_{t-1} + b_2 d E_{t-1} - \bar{Y}b_3 K_{t-k} \,. \tag{2.17}$$

Empirical Specification

For the purposes of empirical estimation, supply equations based on the theoretical formulation (2.17) are derived for Malaysia, Indonesia, Thailand, and the 'rest of the world'. Because there are no available data regarding the proportion of old acreage, the variable K has to be omitted in each case.

The principal economic factor (E) influencing current production response is price, and the principal weather factor (W) is rainfall. Thus the basic form of (2.17) used in the estimation of a supply equation for each of the counties/regions is

$$\Delta Q_t^i = \beta_0 + \beta_1 P_{t-k-1}^i + \beta_2 \Delta RN_t^i + \beta_3 \Delta P_t^i - \beta_4 Q_{t-1}^i + \beta_5 RN_{t-1}^i + \beta_6 P_{t-1}^i \,, \tag{2.18}$$

where i denotes the ith region/country, $(i = 1,4)$
Q is supply (production),
P is price,
RN is rainfall.

2.2 Demand

The demand for natural rubber is derived largely from the demand for its end-products. Since a large portion of natural rubber is used in tire manufacturing, the demand for tires exerts a strong influence on rubber demand. The demand for tires is affected by the demand for automobiles, which in turn is influenced by the general level of economic activity. Since the price of tires is a small proportion of the price of automobiles, an increase in the price of rubber has little effect on the price of its principal final product. A priori, one would expect the demand for natural rubber to be price inelastic, and to be strongly affected by cycles of industrial activity in consuming countries.

Earlier studies have assumed that the major factors determining the demand for natural rubber are industrial production and gross national product. Wharton specified demand symbolically as

$$Q_d = f(P, Y_n, T, P_s, I, S, G, W) , \tag{2.19}$$

where P = price of natural rubber,
Y_n = income or industrial production,
T = tastes or preferences,
P_s = prices of substitutes,
I = inventory,
S = stockpiles,
G = speculation,
W = shock variables such as wars and political tension.

He further assumed that I and S are functions of expectational variables. Studies by Teken, Swan, Yusoff, and Behrman (1971) used basically the same approach as Wharton. All these models have the advantage of simplicity, but do not account for the division of the consumption of natural rubber into two major categories: automobile production and general uses. An attempt is made in this study to disaggregate demand for natural rubber according to these two categories. Response elasticities in the two uses are likely to differ and should be determined separately (Grilli et al.).

Theoretical Development

The demand for natural rubber is specified through a dynamic formulation. Natural rubber is a raw material used as an input in industrial processes. Given the state of the art of the manufacturing process at any given time, technological rigidity exists which limits short-run consumption response. Thus response to changes in such factors as income and price is spread over a period of time.

Desired demand for natural rubber is the sum of desired demand in tire and non-tire uses

$$TC_t^* = C_t^{T*} + C_t^{NT*} , \tag{2.20}$$

where TC_t = total desired consumption of natural rubber,

C_t^{T*} = desired consumption in the tire sector,

C_t^{NT*} = desired consumption in the non-tire sector.

In the tire sector total desired consumption can be broken down into two categories of use: for original equipment and replacement

$$C_{ti}^{T*} = f(TA_{oe}, TA_r) , \tag{2.21}$$

where TA_{oe} = consumption of natural rubber for original equipment tires,

TA_r = consumption for replacement tires.

The demand for original equipment tires depends on the production of vehicles (APRO) and the demand for replacement tires depends on the number of vehicles in use (AUSE)

$$TA_{oe} = f(APRO_t) \quad , \tag{2.22}$$

$$TA_r = f(AUSE_t) \quad . \tag{2.23}$$

To account for substitution between natural and synthetic rubber, their price ratio enters the demand functions. Thus desired demand for natural rubber in the tire sector can be represented by

$$C_t^{T*} = c_0 + c_1R_t + c_2APRO_t + c_3AUSE_t \quad , \tag{2.24}$$

where R_t = the price of natural rubber relative to the price of synthetic rubber.

It is assumed that changes in current consumption vary in proportion to the difference between long-run desired consumption and actual consumption in the previous period

$$C_t^T - C_{t-1}^T = \beta(C_t^{T*} - C_{t-1}^T) \quad , \tag{2.25}$$

where β = the coefficient of adjustment ($0<\beta<1$).

The expectation variable in (2.25) can be eliminated by using equation (2.24) to give

$$C_t^T = \beta c_0 + \beta c_1R_t + \beta c_2APRO_t + \beta c_3AUSE_t + (1 - \beta)C_{t-1}^T \quad . \tag{2.26}$$

The second major category of use of natural rubber is in the manufacture of hoses and belting equipment, boots, and insulators etc. The demand for these products is likely to follow the state of the economies of consuming countries/regions. Thus the level of industrial activity is assumed to be the major factor determining the level of consumption.

Following the dynamic theory adopted for the tire sector, long-run demand for natural rubber in non-tire uses can be represented as

$$C_t^{NT*} = e_0 + e_1IP_t + e_2R_t \quad , \tag{2.27}$$

where IP = industrial production.

It is assumed that the long-run consumption variable C^{NT*} can be used in an equation similar to (2.25)

$$C_t^{NT} - C_{t-1}^{NT} = \gamma(C_t^{NT*} - C_{t-1}^{NT}) \quad . \tag{2.28}$$

C^{NT*} can be substituted out by using (2.27) to give

$$C_t^{NT} = \gamma g_0 + \gamma g_1 IP_t + \gamma g_2 R_t + (1 - \gamma)C_{t-1}^{NT} \quad . \tag{2.29}$$

Empirical Specification

Demand equations for tire and non-tire uses based upon (2.26) and (2.29) are derived for Western Europe, the United States, and Japan. The basic forms used in estimation are

$$\text{Tire Use} \quad : C_t^{Tj} = \gamma_0 + \gamma_1 R_t + \gamma_2 APRO^j + \gamma_3 AUSE_t^j + \gamma_4 C_{t-1}^{Tj} \tag{2.30}$$

$$\text{Non-tire Use: } C_t^{NTj} = \delta_0 + \delta_1 R_t + \delta_2 IP_t^j + \delta_3 C_{t-1}^{NTj} \tag{2.31}$$

where j denotes the jth consuming region/country (j = 1,3),

C^T is demand for natural rubber for tire use,
C^{NT} is the demand for non-tire use,
R is the ratio of the price of natural rubber to synthetic rubber,
APRO is vehicle production,
AUSE is number of vehicles in use,
IP is industrial production.

Since natural rubber is largely sold on a contractual basis, current consumption will depend on lagged rather than current prices. Due to the lack of disaggregated data, a single equation based upon (2.30) was estimated for Eastern Europe, and a single equation based on (2.31) was estimated for the 'rest of the world'.

2.3. Inventories and Prices

Stockholding behavior is likely to vary depending upon whether the stocks are held by natural rubber producers or consumers. Each of these groups holds inventories for different reasons, and may be expected to behave differently in the market.

Theoretical Development

Producers' Stocks

It is probable that stockholding by natural rubber producers is primarily determined by the annual supply/demand balance and by transactional motives. In a given year there may be an excess of production over consumption, while in another year the reverse situation may prevail. Stocking activity therefore reflects the annual production/consumption balance. It is also common practice for producing countries to hold stocks in order to meet their contractual commitments to consumers. However, stockholding is not costless and producers will seek to avoid a large inventory, particularly when market prices are high.

In order to incorporate these factors, producers are assumed to partially adjust the actual level of stocks in each period (S^P) towards a desired or equilibrium level (S^{P*})

$$S_t^P - S_{t-1}^P = \delta(S_t^{P*} - S_{t-1}^P) \quad , \tag{2.32}$$

where δ is the coefficient of adjustment ($0 < \delta < 1$).

Desired stocks are assumed to be positively related to production (representing supply/demand balance) and negatively related to current price (reflecting cost considerations)

$$S_t^{P*} = h_0 + h_1 Q_t - h_2 P_t \quad . \tag{2.33}$$

Substitution of (2.33) in (2.32) yields

$$S_t^P = \delta h_0 + \delta h_1 Q_t - \delta h_2 P_t + (1 - \delta) S_{t-1}^P \quad . \tag{2.34}$$

Consumers' Stocks

In order to deal with consumers' stockholding behavior a parallel assumption to that employed in (2.32) is used. Consumers are assumed to desire a certain level of inventory which is 'optimal' in the long-run. Actual stocks in each period (S^C) are adjusted by some fraction of the difference between actual stocks in the previous period and the desired long-run level (S^{C*})

$$S_t^C - S_{t-1}^C = \varepsilon(S_t^{C*} - S_{t-1}^C) \quad , \tag{2.35}$$

where ε is the coefficient of adjustment ($0 < \varepsilon < 1$).

Two factors are considered to influence consumers' desired demand for stocks: transactional motives and speculation. As demand for the product increases, consumers must carry a larger inventory to meet delivery dates and guard against shortages. Thus transactional demand will be primarily determined by existing levels of consumption. A second factor is price speculation. Consumers will tend to purchase more of a commodity if prices are expected to rise, and to drawdown stocks if they are expected to fall. It is assumed that consumers base their expectations of future prices on current prices. Thus the desired level of inventory can be represented by

$$S_t^{c*} = j_0 + j_1 C_t + j_2 P_t \quad . \tag{2.36}$$

Substituting (2.36) into (2.35) yields

$$S_t^c = \varepsilon j_0 + \varepsilon j_1 C_t + \varepsilon j_2 P_t + (1 - \varepsilon) S_{t-1}^c \quad . \tag{2.37}$$

Synthetic Rubber Price

The price of synthetic rubber is an important variable in the demand equations for natural rubber (2.30 and 2.31) specified above. It is assumed that the price of synthetic rubber (P^{sr}), which is largely institutionally established, follows a partial adjustment framework in which its long-run equilibrium is determined by the price of petroleum (P^{oil}). Thus

$$P_t^{sr} - P_{t-1}^{sr} = \eta(P_t^{sr*} - P_{t-1}^{sr}) \ , \ (0 < \eta < 1) \tag{2.38}$$

and

$$P_t^{sr*} = k_0 + k_1 P_t^{oil} \quad . \tag{2.39}$$

By substitution of (2.39) in (2.38)

$$P_t^{sr} = \eta k_0 + \eta k_1 P_t^{oil} + (1 - \eta) P_{t-1}^{sr} \ . \tag{2.40}$$

Natural Rubber Price

The world price of natural rubber is determined through a model-closing identity which enforces equilibrium in supply and demand

$$Q_t^w \equiv C_t^w - \Delta S_t^w \quad , \tag{2.41}$$

where Q^W is world production,

C^W is world consumption, and

S^W is the change in world stocks.

The model therefore assumes that the world price of natural rubber is the market-clearing price.

Empirical Specification

Producer stock equations based on (2.34) are derived for Malaysia and the residual 'other producing countries'. The basic form used in estimation is

$$\text{Producers' Stocks:} \quad S_t^k = \lambda_0 + \lambda_1 Q_t^k - \lambda_2 P_t + \lambda_3 S_{t-1}^k , \qquad (2.42)$$

where k denotes the kth producing country/region (k = 1,2),
S is the stock of natural rubber,
Q is the production of natural rubber,
P is the price of natural rubber.

A single stock equation based on (2.37) was estimated for all consuming countries

$$\text{Consumers' Stocks:} \quad S_t^c = \pi_0 + \pi_1 C_t^W + \pi_2 P_t + \pi_3 S_{t-1}^c \qquad (2.43)$$

where S^c is the stock of natural rubber in consuming countries.
C^W is world consumption.

The synthetic rubber price equation estimated based on (2.40) is

$$\text{Synthetic Rubber Price:} \quad P_t^{sr} = \phi_0 + \phi_1 P_t^{oil} + \phi_2 P_{t-1}^{sr} \qquad (2.43)$$

where P^{sr} is the price of synthetic rubber,
P^{oil} is the price of oil.

Natural rubber price is determined through a modified version of the closing identity (2.41). Certain statistical discrepancies are encountered in applying equation (2.41) directly. Total computed world rubber production does not balance with the net of recorded world consumption and changes in stocks. There are two reasons for this. First, government strategic stockpiles are not included in the model because they are viewed to be exogenous, and because of their insignificant amount in recent years. Second, there are quantities of rubber which are unrecorded because they are in transit. Unrecorded quantities of rubber (S_t^{res}) were calculated from the following equation.

$$S_t^{res} = Q_t^w - C_t^w - \Delta S_t^w \tag{2.44}$$

S_t^{res} was then assumed to be exogenous to the model ($\bar{S}_t^{res}$), and the following closing identity used to determine price

$$Q_t^w \equiv C_t^w + \Delta S_t^w + \bar{S}_t^{res} \tag{2.45}$$

3. ESTIMATION AND MODEL VALIDATION

3.1 Data Sources and Treatment

Data sources employed in the estimation of the model are listed in Table 3.1. A complete listing of data is given in the Appendix. All quantities of rubber (production, consumption, and inventories) are expressed in thousand metric tons. Automobile production and use are in hundred thousand units, and rainfall is in millimeters per annum.

The price of natural rubber is the New York "spot" market price for Ribbed Smoked Sheet (RSS) grade 1 in U.S. cents per pound. In the estimation of supply functions for the three major producers, current New York rubber prices are converted into the domestic currencies of the three countries, and deflated by their respective consumer price indices. In estimating a supply function for the 'rest of the world' category, the deflator used is the c.i.f. unit value of developed countries' manufactured exports to developing countries, as given by the World Bank. All these indices have a 1970 base year.

Deflation by the consumer price index reflects the relative attractiveness of prices (in this case rubber prices) to producers over and above the rate of inflation. In addition, the index is an indirect indicator of alternative opportunities, both in terms of production and also in terms of hiring one's labor in other occupations. Consumer price indices in the three producing countries are dominated by food items, such as rice and coffee, and other goods considered as 'necessities'. In most cases, the food items are also production alternatives for rubber, especially for smallholders. Direct incorporation of the price of alternative products in the supply function, as suggested by Bateman (1969), is theoretically desirable but involves substantial practical difficulties. Detailed statistical information on alternatives is not available. Furthermore, it is frequently difficult to choose the most appropriate alternative(s). There exist a large number, given the diversified distribution of soil structure and fertility, climate and topography of rubber-producing localities. This is a particular problem in view of the level of aggregation used in this study. To incorporate a wage rate in other

Table 3.1 Data Sources

1. Rubber Statistical Bulletin, The Secretariat of the International Rubber Study Group: London. (various issues).

2. UN, Monthly Bulletin of Statistics (various issues)

   a. Indonesian exchange rates.

   b. Indian industrial production index.

   c. Exchange rates for Bulgaria, Czechoslovakia, Hungary, Poland, and the U.S.S.R.

   d. Consumer price indices for Czechoslovakia, Hungary, Poland, and the U.S.S.R.

   e. Automobile production for the Eastern European countries.

3. The Automobile Industry of Great Britain (1968 and 1978).

   a. Automobile production and use for the U.S., Western Europe, and Japan.

4. The World Automobile Markets, 1979

   a. Automobile production and use for 1977 for the U.S., Western Europe, and Japan.

5. US Bureau of Labor Statistics, Wholesale Prices and Price Indices.

   a. Price of synthetic rubber.

6. IMF, International Financial Statistics. (various issues).

   a. Consumer price indices for Malaysia, Thailand, Indonesia, Canada, and Australia.

   b. Exchange rates for Malaysia, Thailand, and India.

7. OECD, Main Economic Indicators.

   a. Industrial production indices for OECD European countries (Western Europe), the U.S., Japan, Canada, and Australia.

8. OECD, National Accounts of OECD Countries

   a. Gross National Products for Western Europe, the U.S., Canada, and Australia.

Table 3.1. cont'd.

9. UN, Yearbook of National Accounts Statistics, (1976 and 1977)

   a. Net Material Product for Bulgaria, Czechoslovakia, Hungary, Poland, and the U.S.S.R.

10. World Bank, Commodity Trade and Price Trends, Report No. EC-166/79.

   a. Price of natural rubber.

   b. Price of oil.

11. Data on rainfall are obtained from the following sources.

Indonesia

   a. Indonesia Rain Observation: Monthly Rainfall and Monthly Number of Rainy Days. Department of Communication, Indonesia (yearly).

   b. US Department of Commerce, Monthly Climatic Data of the World, Washington DC.

Thailand

   a. Sternstein, Lawrence. The Rainfall of Thailand, Indiana University Foundation Research Division: Bloomington.

   b. Metereological Department, Monthly Metereological Bulletin, Office of the Prime Minister, Bangkok.

   c. Ministry of Communication, Weekly Weather Reports, Metereological Reports, Bangkok.

   d. US Department of Commerce, Monthly Climatic Data of the World, Washington DC.

Malaysia

   a. Malaysian Metereological Service, Climatological Division, as reported by Lanagan, K.L. The Palm Oil Industry In West Malaysia, Foreign Agriculture Service, USDA, FASM 276, June 1977.

   b. US Department of Commerce, Monthly Climatic Data of the World, Washington DC.

occupations to account for alternative earning opportunities is also not easy, because there is no simple way to identify such earnings. The use of the consumer price index in the supply equations overcomes these difficulties. It acts as a proxy for production and earning alternatives for natural rubber producers.

The price of synthetic rubber used is the current wholesale price of SBR in the U.S., quoted on the New York market. This is expressed in U.S. cents per pound. SBR is chosen because it is quantitatively more significant than other types of synthetic rubber. Thus it can be assumed that SBR is representative of all types of synthetic rubber in competition with the natural product.

The choice of prices, both for synthetic and natural rubber, in the New York market reflects the following implicit assumptions. First, these prices reflect those at both consumer and producer levels. For natural rubber, there are three principal markets: Singapore, London, and New York. An examination of the pattern of natural rubber prices in these markets indicates that they move very closely together. Thus the use of the prices in one market will adequately reflect prices in other markets. Second, producers are assumed to respond to changes in prices in the New York market, when allowances are made for exchange rates and domestic inflationary pressures.

During the period of this study the major rubber producing countries levied various forms of export taxes. Malaysia for instance imposed research and replanting taxes in addition to a direct export duty (Lim Chong Yah; McHale). In the case of Indonesia, duties have been imposed on exports of rubber (Teken). In Thailand ad valorem taxes were levied for each form of rubber exported when prices were below minimum specified levels. When prices were above these minimum levels, flat deduction rates were charged in addition to ad valorem rates. Before 1967, rubber producers were required to pay business and municipality taxes and also production taxes (Bisco). The use of rubber prices in a single market, especially in a consuming country such as the United States, fails to fully reflect the actual prices received by producers. New York prices are inclusive of these taxes, shipping costs, and other expenses normally encountered in import-export transactions. They are higher than prices at the producer level. The use of these prices in the analysis was necessitated by data availability.

In estimating demand functions, the ratio of the natural rubber price to that of SBR, expressed as a percentage, is used. This is consistent with the earlier discussion that relative price is the factor determining the degree of substitution between them. The price of petroleum used is the f.o.b. Saudi Arabian posted price of light crude oil.

Industrial production indices employed are aggregated indices for all sectors. For Western Europe, the index is that given by the OECD

for European countries. The production index for the 'rest of the world' group is the weighted average of indices for Australia, Canada, and India; the weights being their proportionate share of their combined natural rubber consumption.

3.2. Estimated Equations

The model was estimated over the period 1960-1977. Equations having only exogenous or lagged endogenous variables on the right-hand side were estimated using ordinary least squares (OLS). Those having current endogenous variables on the right-hand side were estimated using two-stage least squares (TSLS), in which principal components were used as instrumental variables in the first stage. This method was adopted to economize on degrees of freedom.[1/] The equations finally derived are based on the theoretical forms specified above, but include modifications to allow for differences in production/consumption environments between countries. Variables which proved to have unacceptably large standard errors were omitted, and only equations displaying satisfactory statistical properties, in terms of overall 'goodness-of-fit', maintained. The equations are presented below with standard errors in parentheses, the adjusted multiple correlation coefficient ($\bar{R}^2$), and the Durbin-Watson 'd' statistic (DW). For equations estimated using TSLS the latter two statistics are derived from the corresponding OLS regression.

Production

Malaysia:

$$\Delta Q_t^M = \underset{(137.7)}{-37.69} + \underset{(1.107)}{4.598}\,\Delta P_t^M + \underset{(0.043)}{0.082}RN_t^M + \underset{(0.551)}{0.844}\,\Delta P_{t-6}^M$$

$$+\underset{(43.36)}{77.08}D1 - \underset{(0.076)}{0.121}Q_{t-1}^M$$

Estimator: TSLS $\bar{R}^2 = 0.68$, DW = 2.28

1/ Eight principal components derived from all the predetermined variables in the model (lagged endogenous plus exogenous) were employed. These components explained 98 percent of the variation in the predetermined variables.

Indonesia:

$$\Delta Q_t^I = \underset{(83.6)}{176.78} + \underset{(0.387)}{0.898P_{t-2}^I} + \underset{(0.027)}{0.065\Delta RN_t^I} + \underset{(0.396)}{0.417P_{t-7}^I}$$

$$- \underset{(29.61)}{100.09D2} - \underset{(0.101)}{0.336Q_{t-1}^I}$$

Estimator: OLS $\bar{R}^2 = 0.68$
DW = 2.37

Thailand:

$$\Delta Q_t^{TH} = \underset{(19.4)}{90.70} + \underset{(0.069)}{0.326\Delta P_t^{TH}} - \underset{(0.011)}{0.041\Delta RN_t^{TH}} + \underset{(0.058)}{0.203\Delta P_{t-6}^{TH}}$$

$$+ \underset{(0.035)}{0.134\Delta P_{t-7}^{TH}} + \underset{(13.01)}{47.85D1} - \underset{(0.086)}{0.331Q_{t-1}^{TH}}$$

Estimator: TSLS $\bar{R}^2 = 0.63$
DW = 2.20

Rest of the World:

$$\Delta Q_t^{RW} = \underset{(71.5)}{392.55} + \underset{(1.808)}{3.672\Delta P_{t-1}^{RW}} + \underset{(1.087)}{1.642\Delta P_{t-7}^{RW}} + \underset{(33.684)}{173.01D3}$$

$$- \underset{(29.22)}{111.90D4} - \underset{(0.154)}{0.816Q_{t-1}^{RW}}$$

Estimator: OLS $\bar{R}^2 = 0.71$
DW = 1.89

Malaysian and Thai production are functions of the change in current domestic price, and in price lagged six or seven periods. For Indonesia, prices are lagged two and seven periods, indicating that production is not responsive to current prices. Likewise production from the 'rest of the world' is not responsive to current prices; the change in prices lagged one period is more important.

The dummy variable (D1) in the Malaysian and Thai supply functions is included to account for technological improvements in production that are visable since 1968, as the result of replanting with high-

yielding varieties in the early sixties. For Indonesia, a dummy variable (D2) is included to account for the political instability and uncertainty during 1959/60 and again in 1963, when a political confrontation existed with Malaysia and Singapore, which were then the major trading centers for Indonesian rubber. The variable D3 in the rest of the world supply function is included to account for general technological improvement in other producing countries since 1967, and D4 for production shocks in 1968 and 1969 due to the substantial reduction in production in Vietnam because of war.

All variables in the production equations have appropriate signs. Prices have a positive relationship with production; an increase in current or recent price will stimulate production (tapping) and encourages further investment in the natural rubber industry, which is subsequently reflected in output in six or seven years. Malaysian and Indonesian rainfall exerts a positive effect on production. However, in the case of Thailand, the effect is negative. This is probably due to the locality where rainfall was recorded (Haadyai), an area with exceptional variation in rainfall and also susceptible to monsoon storms.

Consumption

A. Tire Sector

Japan:

$$C_t^{JAPT} = \underset{(11.3)}{68.33} - \underset{(0.071)}{0.184}R_{t-2} + \underset{(0.217)}{0.830}APRO_t^{JAP} + \underset{(0.127)}{0.406}C_{t-1}^{JAPT} + \underset{(6.74)}{18.46}D6$$

Estimator: OLS $\bar{R}^2 = 0.99$, DW = 1.67

Western Europe:

$$C_t^{WET} = \underset{(17.0)}{238.89} + \underset{(0.280)}{0.073}APRO_t^{WE} + \underset{(0.032)}{0.111}AUSE_t^{WE} + \underset{(9.56)}{53.74}D5$$

Estimator: OLS $\bar{R}^2 = 0.97$, DW = 2.08

United States:

$$C_t^{UST} = \underset{(128.7)}{35.29} - \underset{(0.386)}{0.518}R_{t-2} + \underset{(0.653)}{1.946}APRO_t^{US} + \underset{(0.576)}{0.576}C_{t-1}^{UST} + \underset{(32.10)}{36.52}D6$$

Estimator: OLS $\bar{R}^2 = 0.90$
DW = 2.51

The signs of coefficients in the estimated demand functions conform to theoretical expectations; prices are negatively related and demand shifters, such as automobile production and use, are positively related to current consumption. The standard errors of the coefficients on these variables are mostly smaller than the values of the coefficients themselves. The values of $\bar{R}^2$ are generally high, indicating that the fit of the equations is acceptable.

With the exception of Western Europe, lagged price ratios enter the functions. This reflects the existence of contractual agreements in purchases of the bulk of natural rubber. Price was dropped from the function for Western Europe because it was not possible to derive an acceptable sign. The estimated equations for Japan and the United States do not have automobiles in use as an explanatory variable. This was omitted because of high collinearity with automobile production. The lagged consumption variable reflects, to a large extent, rubber used for replacement equipment.

In the late sixties, radial tires were developed and introduced, first in Europe and later in the U.S. and Japan. Increasing consumer acceptance of these new types of tires has encouraged a larger volume of consumption in these countries/regions. Radial tires require a greater proportion of natural rubber than traditional ply tires. D5 and D6 are variables included to capture the effects of increased production of radial tires in Western Europe (since 1970) and in Japan and the U.S. (since 1972).

B. Non-tire Sector

Japan:

$$C_t^{JAPN} = \underset{(11.0)}{74.61} - \underset{(0.047)}{0.275R_t} + \underset{(0.073)}{0.578C_{t-1}^{JAPN}} + \underset{(0.155)}{1.038\ \Delta IP_t^{JAP}} - \underset{(0.176)}{0.441T}$$

Estimator: TSLS $\bar{R}^2 = 0.99$
DW = 1.67

Western Europe:

$$C_t^{WEN} = \underset{(59.5)}{160.31} - \underset{(0.158)}{0.297R_{t-1}} - \underset{(0.651)}{0.726IP_t^{WE}} + \underset{(0.247)}{0.598C_{t-1}^{WE}}$$

Estimator: OLS $\bar{R}^2 = 0.93$
Dw = 2.14

United States:

$$C_t^{USN} = \underset{(19.6)}{145.97} - \underset{(0.097)}{0.127}R_{t-1} + \underset{(0.120)}{0.419}IP_t^{US}$$

Estimator: OLS $\bar{R}^2 = 0.58$
DW = 2.22

As in the case of the tire sector equations, the signs of coefficients conform to theoretical expectations. Current or near-term prices are significant in determining demand. This is consistent with the fact that greater substitution possibilities exist between natural and synthetic rubber in this category of uses. The level of industrial activity also exerts a positive influence on consumption.

The lagged consumption variable was omitted from the U.S. equation due to poor statistical performance. Overall the goodness of fit for the U.S. equation is not as good as for other equations. The negative trend variable included in the Japanese equation reflects the increasing inroads of synthetic rubber into non-tire uses during the period. This was due to non-price factors, such as market structure and security of supply objectives, which resulted in a rapid expansion in the domestic production and use of synthetic rubber.

C. Total Consumption

Eastern Europe:

$$C_t^{EE} = \underset{(48.5)}{445.15} - \underset{(0.214)}{0.614}R_{t-3} + \underset{(1.968)}{3.707}APRO_t^{EE} + \underset{(0.110)}{0.220}C_{t-1}^{EE}$$

$$- \underset{(15.94)}{130.16}D7 - \underset{(3.733)}{7.463}T$$

Estimator: OLS $\bar{R}^2 = 0.86$
DW = 2.44

Rest of the World:

$$C_t^{RW} = \underset{(102.4)}{-6.30} - \underset{(0.452)}{0.461}R_{t-2} + \underset{(2.389)}{2.010}IP_t^{RW} + \underset{(0.253)}{0.877}C_{t-1}^{RW}$$

Estimator: OLS $\bar{R}^2 = 0.98$
DW = 2.14

The total consumption equations are 'hybrid' functions reflecting both tire and non-tire uses. Automobile production is used as the main demand shifter in the Eastern European equation, and industrial production in the 'rest of the world' equation. The time trend variable in the former equation reflects the rapid expansion of the production of synthetic rubber, and its effects on the consumption of natural rubber. The dummy variable D7 represents exceptionally low purchases of natural rubber in 1960 and 1964, during which time requirements were met by heavy releases from stocks (FAO, Commodity Review and Outlook, 1964 and 1965).

Inventories and Prices

Malaysian Stocks:

$$S_t^M = \underset{(32.3)}{48.17} - \underset{(0.202)}{0.447}P_t^M + \underset{(0.157)}{0.551}S_{t-1}^M + \underset{(0.032)}{0.054}Q_t^M - \underset{(8.84)}{20.80}D8 - \underset{(7.91)}{42.05}D9$$

Estimator: TSLS $\bar{R}^2 = 0.95$, DW = 2.22

Stocks in Other Producing Countries:

$$S_t^{OP} = \underset{(15.3)}{186.56} - \underset{(0.112)}{0.055}P_t^I + \underset{(0.070)}{0.155}S_{t-1}^{OP} + \underset{(7.60)}{89.82}D10 - \underset{(10.57)}{50.24}D11$$

Estimator: TSLS $\bar{R}^2 = 0.96$, DW = 2.15

Stocks in Consuming Countries:

$$S_t^{CON} = \underset{(129.8)}{367.06} + \underset{(2.183)}{5.383}P_t^{RW} + \underset{(0.156)}{0.564}S_{t-1}^{CON} + \underset{(0.049)}{0.185}C_t^W$$

Estimator: TSLS $\bar{R}^2 = 0.94$, DW = 1.27

Price of Synthetic Rubber:

$$P_t^{SR} = \underset{(0.1)}{1.49} + \underset{(0.056)}{0.882}P_t^{OIL} + \underset{(0.058)}{0.280}P_{t-1}^{SR}$$

Estimator: OLS $\bar{R}^2 = 0.99$, DW = 1.35

Stocks depend on current domestic prices and other variables as specified. Indonesian prices are assumed to be a representative of those facing other rubber producers. This is because of the difficulty of finding an alternative single price, and also due to the fact that stocks in Indonesia are substantially larger than for other producers (excluding Malaysia).

Since stockholding performs a balancing function between production and consumption, the level of stocks is particularly sensitive to market shocks and disturbances. These are captured through the use of dummy variables. The variable D8 in the Malysian function captures the effect of the confrontation with Indonesia in 1963-65. The variable D9 represents unusual release of stocks in 1968-69 associated with the Vietnam war, and in 1977 during which government price-propping purchases of 1975-76 were disposed of.

In the other producing countries equation, D10 captures a series of events in 1964-67 that led to exceptional stock accumulation: (1) the release of government stockpiles in the United States and United Kingdom; (2) the U.S. rubber manufacturing strike in 1967; and (3) slow purchases by the U.S.S.R., due to its own increased production of synthetic rubber (FAO, Commodity Review and Outlook, 1967 and 1968). The variable D11 captures the reduction in stocks due to low wartime production in Indochinese countries and the effect of substantial purchases by China.

The stock equations and the price equation for synthetic rubber have signs which conform to a priori expectations. Statistical properties, in terms of precision of estimated coefficients and overall goodness of fit, are acceptable.

3.3. Elasticities

Price elasticities for production, consumption, and stock functions are presented in Table 3.2. For production, Thailand is more responsive to price changes than Malaysia, while Indonesia is the least responsive. These results differ from those found by Behrman (1971). He found that the short-run elasticity (variation in tapping rates) for Indonesia was 0.473 (1951-1960), Malaysia 0.141 (for Peninsula only from 1949-1963) and Thailand 0.409 (1947-1965). The structure of production in these countries has changed significantly since the early 1960's. Therefore, there is reason to believe that the degree of responsiveness of production to price changes will also have changed.

As might be expected, long-run supply elasticities are higher than those in the short-run, because investment in the industry in response to price becomes important. Long-run elasticity of production response in Thailand is particularly high. This reflects the aggressive promotion of replanting and new varieties in Thailand over the sample period. On the other hand, Indonesia's low long-run response reflects its limited achievements in the area of production expansion.

Table 3.2 Price Elasticities[a/]

	Short-run	Long-run
Production[b/]		
Malaysia	0.294	0.358
Indonesia	0.086	0.125
Thailand	0.644	1.452
Rest of the World	0.162	0.249
Consumption		
Tire		
Japan	-0.143	-0.240
Western Europe	0.0	0.0
United States	-0.141	-0.332
Non-tire		
Japan	-0.275	-0.653
Western Europe	-0.070	-0.175
United States	-0.083	-0.083
Total		
Eastern Europe	-0.157	-0.202
Rest of the World	-0.069	-0.566
Stock		
Malaysia	-0.238	-0.530
Other producers	-0.016	-0.019
Consumers	0.206	0.471
Synthetic rubber prices[c/]	0.147	0.204

a/ Defined at the mean of the observations.

b/ Long-run elasticities are calculated by summing all the price elasticities derived from an equation.

c/ With respect to the price of oil.

As for consumption, Japan is the most price responsive in both tire and non-tire uses in the short-run. Long-run elasticity in the non-tire sector is also greatest in Japan, but is highest in the nontire sector in the U.S. Total consumption is more price responsive

in Eastern Europe in the short-run than in the 'rest of the world', but in the long-run the reverse is true. In terms of the demand for stocks Malaysia and consuming countries are relatively responsive in both the short and long-run. Other producers' stocks are basically unresponsive to price.

Synthetic rubber prices are 'inelastic' to changes in oil prices. However, the relationship indicates that as oil prices increase, synthetic rubber prics will also increase, and if the price of oil doubles, synthetic rubber prices will increase almost 15 percent in the short-run and over 20 percent in the long-run. The long-run 'elasticity' is higher because of the delay in altering production processes as oil prices increase. Elasticities of demand with respect to shift variables such as automobile production/use or industrial production are given in Table 3.3. Short-run elasticity is relatively high only in the case of the U.S. tire sector. However, the long-run elasticity in both the U.S. and the "rest of the world" are both in excess of unity. In the latter case the high long-run elasticity reflects the influence of a low coefficient of adjustment in the demand equation.

Table 3.3. Elasticities with Respect to Demand-Shift Variables

	Short-run	Long-run
Tire use		
Japan	0.245	0.412
Western Europe	0.223	0.223
United States	0.470	1.109
Non-tire use		
Japan	0.055	0.137
Western Europe	0.141	0.350
United States	0.233	0.233
Total consumption		
Eastern Europe	0.137	0.176
Rest of the World	0.258	2.106

3.4 Sample Period Validation

In order to evaluate the dynamic properties of the model it was simulated over the sample period (1960-77). Table 3.4 gives the root mean square percentage error (RMSPE) for each of the endogenous variables.[1/] Figure 3.1 graphs actual and predicted values for three key aggregates (production, consumption, and stocks), and the NY spot price. The average RMSPE of the 20 endogenous variables is 6.5 percent. In general, the errors are not unreasonable when compared to the results of other commodity models with similar levels of aggregation (e.g. Labys 1973a). However, two variables--Thailand production and the NY spot price--have relatively large average errors of roughly 20 percent. The error of the former is closely related to the latter, through high short-run elasticity of price response in Thailand's production equation.

The degree of error demonstrated by price is unfortunate but perhaps not surprising. Price is derived implicitly by the model through a market-clearing identity, linking production, consumption, and stocks.[2/] It is assumed that only the real market position (balance between production, consumption, and stocks) is the determinant of the average NY spot price. This in itself may only be partially correct. Since price also performs a "balancing" function in the model, any non-price-related errors of prediction in other equations will tend to be reflected in price. In many of the equations, considerable rigidity exists with respect to current prices, thus they cannot help to 'absorb' some of the predictive error from other equations. For these reasons, the pattern displayed by predicted prices in Figure 3.1, in particular their greater instability, is not surprising.

If the objective of the model were to provide a good representation of short-term market price movements, for example, in order to analyze stabilization through a buffer stock, this property of exaggerated short-term price instability would be a serious problem. However, for longer-run predictions of trends, in which short-run disturbances are considerably reduced by the smooth growth assumptions applied to exogenous variables, this characteristic is much less damaging. There are strong reasons to believe that structurally the

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1/ Root mean square percentage error is defined as

$$100 \sum_{t=1}^{n} \sqrt{\frac{((P_t - A_t)/A_t)^2}{n}}$$

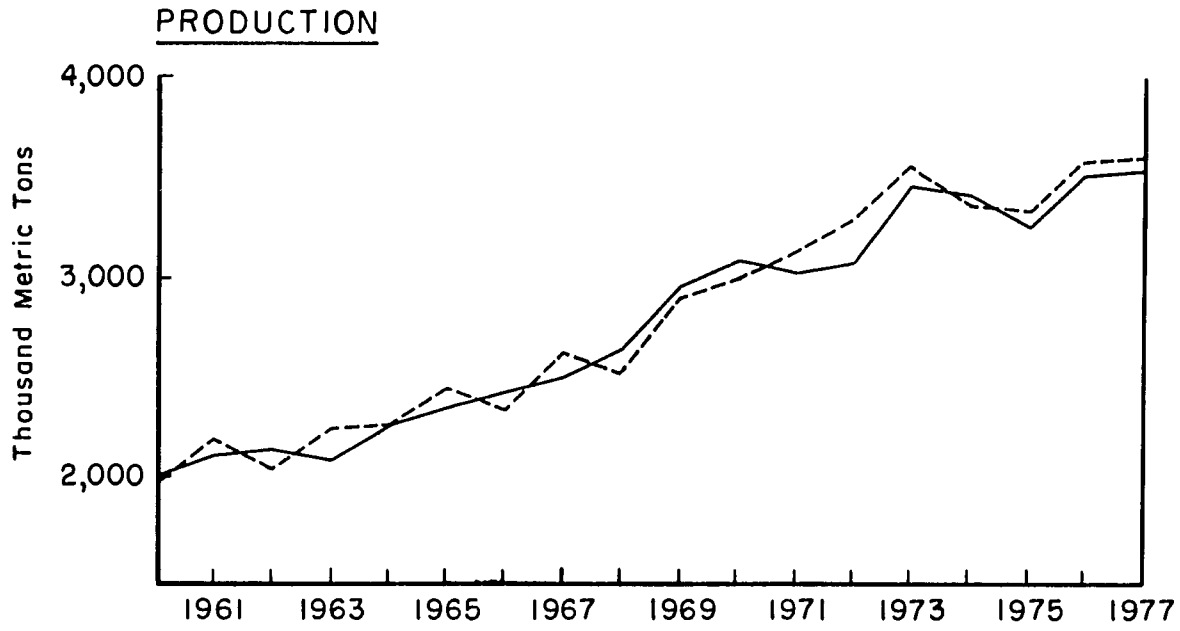
where P and A are predicted and actual values, respectively.

2/ Also included is a residual, reflecting rubber in transit.

Table 3.4. Root Mean Square Percentage Errors of Simulated Endogenous Variables over the Sample Period

Variable	Error %
Malaysian production	7.1
Indonesia production	3.3
Thailand production	19.5
Rest of the world production	6.3
World production	3.5
Japanese tire use	4.0
Western European tire use	2.4
U.S. tire use	5.8
Japanese non-tire use	7.2
Western European non-tire use	3.2
U.S. non-tire use	5.3
Eastern European consumption	4.4
Rest of the world consumption	5.0
World consumption	1.7
Malaysian stocks	7.5
Other producers' stocks	3.5
Consumers' stocks	10.4
World stocks	6.5
Natural rubber price	21.5
Synthetic rubber price	2.1

FIGURE 3.1. ACTUAL AND SIMULATED VALUES OF CONSUMPTION, PRODUCTION, STOCKS AND PRICE OVER THE SAMPLE PERIOD, 1960-77



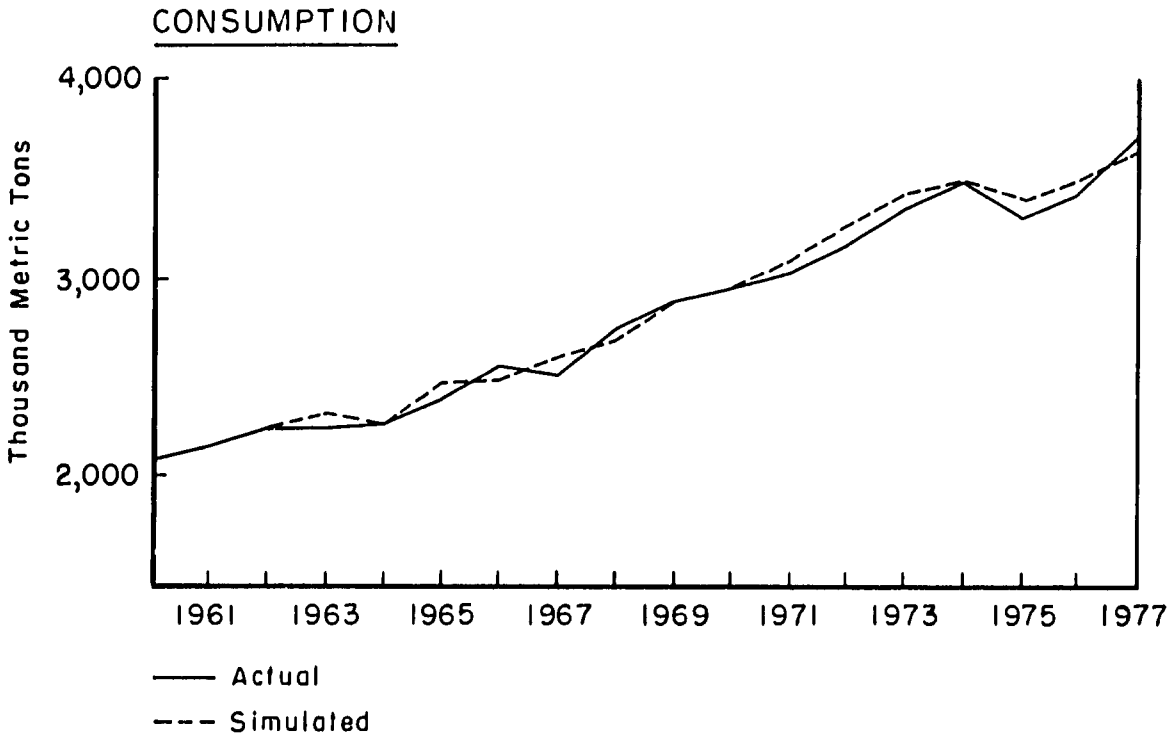
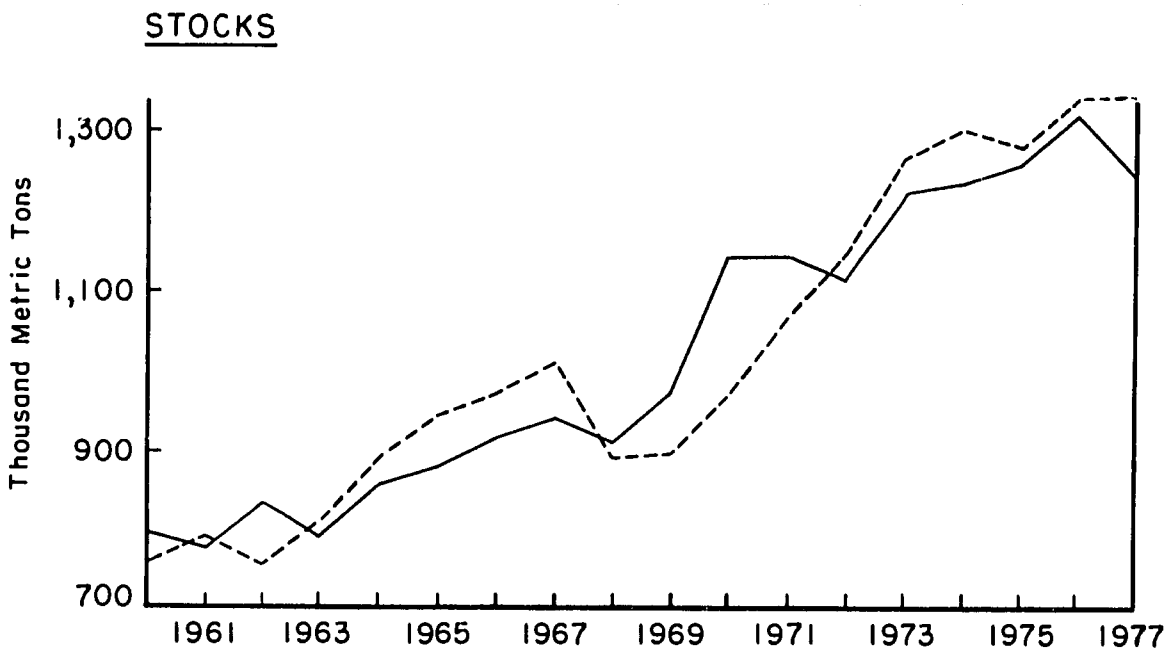
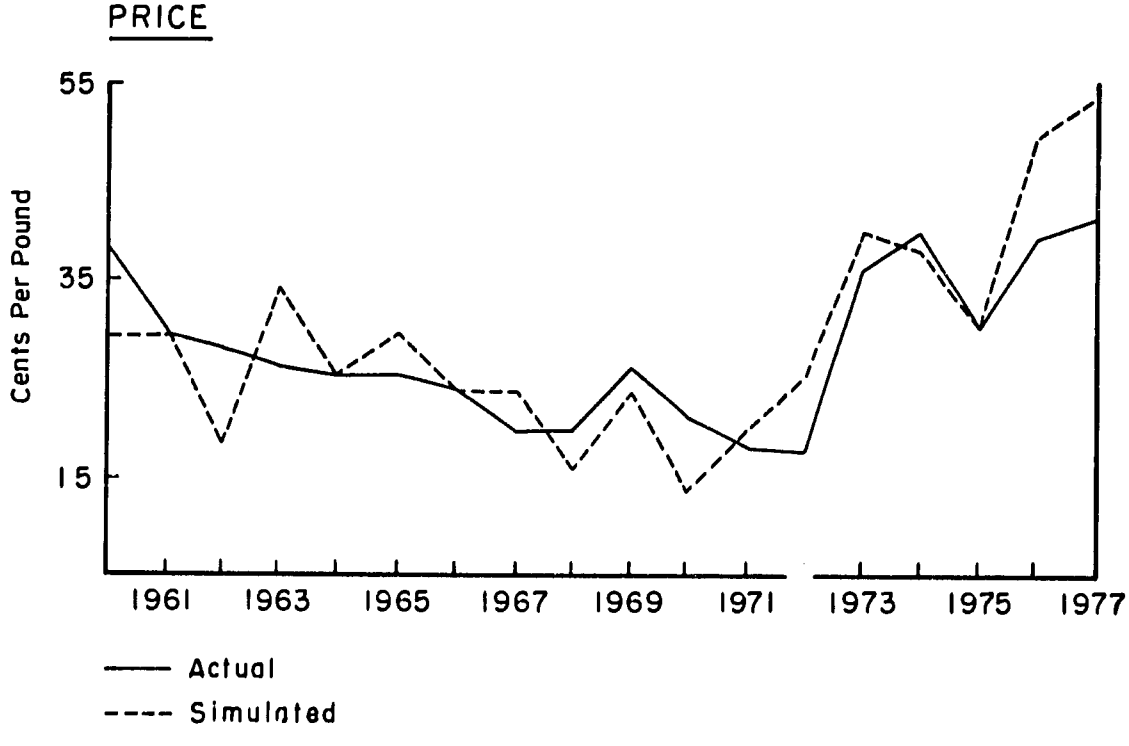


FIGURE 3.1. (Cont.)





world rubber market is characterized by considerable rigidity. Such rigidity, on both the consumption and production sides, is adequately captured by the model. As Figure 3.1 and Table 3.4 demonstrate, actual and predicted values of production and consumption are relatively close.1/ The path of prices generated by the model is stable; there is no evidence of sustained divergence of predicted from actual values, and the trend in actual prices is clearly capcaptured. For these reasons, the performance of the model is judged to be acceptable for the purposes of long-run trend projections.

4. MARKET PROJECTIONS FOR 1985

The econometric model is used to make projections of quantities and price in 1985. This year was chosen because it is not too far (8 years) outside the sample period employed to estimate the model. Since it is necessary to assume that market structure of the estimation period will remain essentially unchanged, projections further into the future become progressively less reliable.

It must be stressed that the results obtained in this analysis are not forecasts. They are strictly projections--illustrations of the effects of a particular set of assumptions under 'average' conditions. They are intended to illustrate the impact of two factors--economic growth and the price of petroleum on the market for natural rubber.

4.1 Methodology

In order to make the projections, assumptions are made about the levels of exogenous variables in the model. On the supply side, the following four sets of exogenous variables exist: (1) exchange rates; (2) consumer price indices; (3) rainfall; (4) dummy variables. On the demand side, in addition to the price of petroleum, a further four sets of exogenous variables exist: (1) automobile production; (2) automobile use; (3) industrial production; (4) dummy variables.

It is assumed that changes in exchange rates and consumer price indices (CPIs) effectively offset one another during the projection period, such that the ratios existing in 1977 are maintained. For any given change in the price level, as reflected by the CPI, there is a corresponding depreciation or appreciation of the domestic currency

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1/ The performance for stocks is not quite so good. To some extent, as in the case of Thailand production, this is due to the effects of errors in predicted prices. It is also due to the poor quality of available data. In many cases stock data are based on estimates whose reliability is questionable.

against the dollar. Changes in the levels of domestic prices of natural rubber after 1977 are therefore solely attributable to changes in 'world' rubber prices in 1977 dollars. In the 'rest of the world' supply equation, the index of the developed countries' manufactured exports to developing countries, used as a price deflator, is held constant at its 1977 value. As a result of these assumptions, the level of world rubber prices generated by the model from 1978 onwards are in real 1977 values.

With regard to rainfall, the average level during the sample period (1960-77) is used in the Malaysian supply equation, since the rainfall variable employed is the absolute amount. However, in the case of Indonesia and Thailand, rainfall enters in terms of the change from one period to another. It is assumed to fluctuate normally around the mean or normal level, and therefore that the expected change is zero.

One of the difficult problems in making projections is the estimation of a reasonable (realistic) rate of increase in the price of petroleum. Changes in the price of petroleum influence the price of synthetic rubber, and thus its relative competitiveness with the natural product. The experience of the last few years has forceably demonstrated the difficulty of projecting the future price of petroleum. However, the former Secretary of Energy, James Schlesinger, recently estimated that the real price of petroleum in 1990 is likely to be in the region of $40 per barrel.[1/] This would imply a real growth rate of roughly 8.8 percent per annum, based on the price in 1977 ($13.33 per barrel, Saudi Arabian posted price of light crude). The impact of a slightly lower growth rate of 8 percent per annum is evaluated in this study. It is recognized that past increases in petroleum prices have not followed a smooth curve, and are probably unlikely to do so in the future. Since the aim is to generate projections rather than predictions it is reasonable to assume such a smooth profile of price increases.

It is difficult and cumbersome to separately derive sets of projected values for automobile production, automobiles in use, and industrial production. The first two in particular are a problem in the absence of a model of the automobile sector in each of the countries concerned. Since ultimately, each one of these variables is closely linked to national income, they were related, through OLS regression equations, to actual GDP during the period 1960-76. These equations, whose explanatory power was generally high, were then used to examine the impact of alternative rates of growth of GDP on the rubber market. The equations are presented in Table 4.1.

1/ Quoted in the New York Times, August 6, 1979.

Table 4.1 Equations Relating Principal Demand-Shift Variables to Gross Domestic Product

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Japanese automobile production

$$APRO_t^{JAP} = -\ 3.2 + 0.118JAPGDP_t + 0.647APRO_{t-1}^{JAP}$$
$$(3.2)\ (0.046) \qquad (0.146)$$

$$\bar{R}^2 = 0.98$$

Japanese index of industrial production

$$IP_t^{JAP} = 3.7 + 0.119JAPGDP_t + 0.735IP_{t-1}^{JAP} + 9.28JAPDUM1$$
$$(2.4)\ (0.039) \qquad (0.086) \qquad (2.47)$$

$$-\ 13.94JAPDUM2$$
$$(4.21)$$

$$\bar{R}^2 = 0.99$$

Automobile production in Western Europe

$$APRO_t^{WE} = 10.4 + 0.054WEGDP_t + 0.567APRO_{t-1}^{WE}$$
$$(10.5)\ (0.029) \qquad (0.186)$$

$$\bar{R}^2 = 0.86$$

Automobiles in use in Western Europe

$$AUSE_t^{WE} = 35.6 + 0.019WEGDP_t + 0.984AUSE_{t-1}^{WE}$$
$$(15.5)\ (0.051) \qquad (0.040)$$

$$\bar{R}^2 = 0.99$$

Industrial production index for Western Europe

$$IP_t^{WE} = 3.4 + 0.035WEGDP_t + 0.713IP_{t-1}^{WE}$$
$$(4.4)\ (0.273) \qquad (0.725)$$

$$\bar{R}^2 = 0.97$$

U.S. automobile production

$$APRO_t^{US} = 25.1 + 0.063USGDP_t + 0.209APRO_{t-1}^{US} -.22.1USDUM$$
$$(7.6)\ (0.010) \qquad (0.101) \qquad (2.4)$$

$$\bar{R}^2 = 0.92$$

Table 4.1. cont.

U.S. industrial production index

$$IP_t^{US} = -19.1 + 0.121USGDP_t$$
$$(3.7) \quad (0.004)$$

$$\bar{R}^2 = 0.98$$

Automobile production in Eastern Europe

$$APRO_t^{EE} = -11.01 + 0.051EEGDP_t$$
$$(2.0) \quad (0.004)$$

$$\bar{R}^2 = 0.92$$

Index of industrial production in the rest of the world

$$IP_t^{RW} = -3.3 + 0.608RWGDP_t$$
$$(5.4) \quad (0.033)$$

$$\bar{R}^2 = 0.96$$

Notes:

(a) JAPDUM1 is a dummy variable for above-average industrial activity in 1969, 1970 and 1973. JAPDUM2 is a dummy for the impact of low industrial activity due to world-wide recession in 1975.

(b) USDUM is a dummy for low automobile production in 1960, 1970, 1974 and 1975 because of recession or strikes.

(c) Variables ending in 'GDP' generally relate to gross domestic product in US $ at 1970 market prices. In the case of Eastern Europe it is the sum of the net material products of Bulgaria, Czechoslovakia, Hungary, Poland, and the U.S.S.R. converted into U. S. $ at 1970 exchange rates and deflated by the Polish CPI (1970 100). For the rest of the world category the GDP used is a weighted average of those in Canada, Australia, and India where the weights are the respective shares of their combined consumption of natural rubber. Sources of data were O.E.C.D. Natural Accounts of OECD Countries Vol. 1, 1977 and U.N. Yearbook of National Accounts Statistics, 1976 and 1977.

(d) All other variables are as defined in the text.

Three sets of growth rates were adopted: 'high', 'medium' and 'low' (Table 4.2). Compared to actual rates of growth during the period 1960-76 these rates are generally conservative. In no case does any of the highest rates assumed, exceed those actually experienced during this historical period. The choice of conservative estimates of future income growth is important, particularly in the light of recent experiences with the effects of higher oil prices. It is likely that an 8 percent real annual increase in annual petroleum prices would significantly reduce economic growth world-wide.

Table 4.2 Assumed Growth Rates in Real GDP

Country/Region	Actual a/ 1969-76	High	Medium	Low
	----------percent per year----------			
U.S.	3.5	3.5	2.5	2.0
Japan	10.2	7.0	5.0	4.0
Western Europe	5.1	4.0	3.0	2.5
Eastern Europe	5.4	4.5	4.0	3.0
Rest of the World	4.0	4.0	3.0	2.5

a/ Computed from the data used in Table 4.1.

Although it is impossible in the current study to determine exactly what the impact of increasing oil prices would be, the rates chosen probably reflect a reasonable range of more to less- optimistic assessments of future economic growth with higher-priced petroleum.

All dummy variables used to capture unusual events, such as war or strikes, were omitted in making projections. Those used in supply equations to capture the impact of technological improvement were maintained (assigned the value of unity in each year). Similarly, dummy or trend variables used to capture changes in demand 'preferences' were also maintained.

The variable S^{res}, the exogenous residual reflecting rubber in transit, was assumed to be determined endogenously at two percent of world consumption, the average during the sample period. This implies that as world consumption changes the amount of rubber in transit increases by a constant proportion of that change.

4.2 Results

Under the assumptions employed, world natural rubber consumption in 1985 is projected to increase from a minimum of 9 percent above the 1977 level under low income growth, to a maximum of 13 percent under high income growth (Table 4.3).[1/] The largest relative increases occur in the Japanese tire sector (27-43 percent), but the largest absolute increases occur in the 'rest of the world' group's consumption. Demand in Japanese non-tire uses is projected to decline sharply, relecting a continued shift away from the material in this sector. Consumption in the U.S. tire sector declines under both low and medium income growth, such that aggregate U.S. demand for both tire and non-tire uses is basically stagnant. There is a slight increase with high income growth.

Perhaps unsurprisingly, the largest absolute increase in production is projected for the largest producer, Malaysia. However, this country also generally experiences the highest relative rates of increase. Of the overall increase in world production, from 74 percent (high income growth) to 82 percent (low income growth) of the total occurs in Malaysia. The only other country in which a large relative expansion takes place is Thailand. In the 'rest of the world' group production declines under all income growth scenarios. These results seem to be realistic. Both Thailand and Malaysia have embarked on extensive replanting programs and the improvement of credit and advisory services in order to increase production. Other producers, particularly in Asia and South America, continue to neglect or de-emphasize rubber production for social or other reasons.

Accompanying the increases in quantity are large increases in real prices. Even under low income growth real price more than doubles, from 42 to 86 cents per pound. Under the high growth assumption the increase is 150 percent. Although these numbers may appear unduly large it is worth noting that recent NY spot prices of natural rubber (80 cents per pound, late January 1980) reflects a nominal increase of over 90 percent from 1977, or a real (inflation adjusted) increase of roughly 65-70 percent.

The combined effect of the increases in production and prices is a major increase in the value of rubber produced in exporting countries.[2/] As Table 4.4 demonstrates, all producers experience

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1/ The results obtained are not unduly sensitive to the choice of year. Checks showed that averages for 1984-86 correspond closely with the figures presented for 1985.

2/ Value of production closely parallels export revenue, although they are not equal. Some rubber moves into producers' stocks and some is consumed domestically. Due to the importance of exports, the magnitude of the increase in the value of production is a good indicator of the effects upon export revenue.

Table 4.3 Projections of Price and Quantity of Natural Rubber in 1985 Under Alternative Income Growth Assumptions

	1977 Actual	Low Income Growth 1985 Projected	Change 1977-85	Percentage Change	Medium Income Growth 1985 Projected	Change 1977-85	Percentage Change	High Income Growth 1985 Projected	Change 1977-85	Percentage Change
World Price (US cents per pound)	42	86	+ 44	+105	93	+ 51	+121	106	+ 64	+152
Production (Metric tons)										
Malaysia	1,613	2,019	+406	+ 25	2,054	+441	+ 27	2,121	+508	+ 31
Indonesia	835	866	+ 31	+ 4	879	+ 44	+ 5	903	+ 68	+ 8
Thailand	423	510	+ 87	+ 21	525	+102	+ 24	554	+131	+ 31
Rest of the world	721	696	- 25	- 3	698	- 23	- 3	703	- 18	- 2
World Production	3,593	4,090	+497	+ 14	4,157	+564	+ 16	4,281	+688	+ 19
Consumption (Metric tons)										
Japan										
Tire	223	284	+ 61	+ 27	295	+ 72	+ 32	318	95	+ 43
Non-tire	97	75	- 22	- 23	72	- 25	- 26	69	- 28	- 29
Total	320	359	+ 39	+ 12	367	+ 47	+ 15	387	+ 67	+ 21
United States										
Tire	623	604	- 19	- 3	611	- 12	- 2	629	+ 6	+ 1
Non-tire	181	189	+ 8	+ 4	191	+ 10	+ 6	195	+ 14	+ 8
Total	803	794	- 9	- 1	802	- 1	0	824	+ 21	+ 3
Western Europe										
Tire	418	449	+ 31	+ 7	450	+ 32	+ 8	452	+ 34	+ 8
Non-tire	516	565	+ 49	+ 9	565	+ 49	+ 9	566	+ 50	+ 10
Total	934	1,015	+ 81	+ 9	1,015	+ 81	+ 9	1,018	+ 84	+ 9
Eastern Europe	435	463	+ 28	+ 6	476	+ 41	+ 9	474	+ 39	+ 9
Rest of the world	1,305	1,491	+186	+ 14	1,522	+217	+ 17	1,591	+286	+ 22
World Consumption	3,798	4,122	+324	+ 9	4,182	+384	+ 10	4,294	+496	+ 13

Table 4.4 Value of Rubber to Producers in 1985 under Alternative Income Growth Assumptions

	Actual 1977	Projected			Projected/1977 Actual		
		Low Growth	Medium Growth	High Growth	Low Growth	Medium Growth	High Growth
	Million 1977 dollars						
Malaysia	1,479	3,842	4,227	4,979	2.60	2.86	3.37
Indonesia	766	1,648	1,809	2,120	2.15	2.36	2.77
Thailand	388	970	1,060	1,301	2.50	2.78	3.35
Rest of the World	661	1,324	1,436	1,650	2.00	2.17	2.50
World Total	3,294	7,782	8,554	10,050	2.36	2.60	3.05

Note: Value computed as production x NY spot price.

substantial rise in the real value of their output. The greatest relative increase naturally occurs in those countries in which production response is the most marked, Malysia and Thailand. Even under low consumer income growth, Malaysian production is projected to increase in value from roughly $1.5 billion to $3.8 billion in real terms by 1985.

These results are indicative of the combined importance of increasing income and petroleum prices for the natural rubber market. In order to specifically highlight the role played by oil prices, a second set of projections was made in which the price of oil was held constant at its 1977 level. By combining the two sets of results the incremental effect of increased petroleum prices under the three income growth scenarios can be determined (Table 4.5). For example, under low income growth and constant petroleum price, world consumption of natural rubber in 1985 is projected to be 6 percent above that in 1977. Rising oil prices add an additional 3 percent, for a total increase of 9 percent. Similarly, world price under low income growth and constant oil price is 76 percent above that in 1977. Rising oil prices add an additional 29 percent. The relative importance of the increase in the price of petroleum is greatest under low income growth.

It would be extremely interesting to determine whether the producers of natural rubber would be better off in terms of the value of their production under higher oil prices, even if such oil prices lower the rate of economic growth in consuming countries. Unfortunately, due to the lack of direct linkage between oil prices and economic growth in the model this is not possible. However, Table 4.5 demonstrates that if the low income growth/increasing oil price scenario is assumed to be the most reasonable assessment of the future, both prices and production exceed those for the medium growth assumption/constant oil price scenario, and are not far below those of the high income growth/constant oil price scenario. If it were argued that even under constant oil prices high income growth would probably be difficult to achieve in the 1980's, then the balance of evidence seems to suggest that rubber producers may be better-off with increasing oil prices than without them.1/

1/ It should be stressed that this conclusion only considers the value of rubber production. Those rubber producers who have to pay the higher cost of imported oil may not be better-off overall.

Table 4.5 The Effect of Increasing Oil Prices on Price, Production, and Consumption of Natural Rubber

	Low Growth		Medium Growth		High Growth	
	Change Under Constant Oil Price	Additional Effect of Increased Oil Price	Change Under Constant Oil Price	Additional Effect of Increased Oil Price	Change Under Constant Oil Price	Additional Effect of Increased Oil Price
	----------percent of 1977----------					
World Price	+76	+29	+93	+28	+119	+33
Production						
Malaysia	+21	+ 4	+23	+ 4	+ 27	+ 4
Indonesia	+ 2	+ 2	+ 3	+ 2	+ 6	+ 2
Thailand	+15	+ 6	+18	+ 6	+ 24	+ 7
Rest of the world	- 4	+ 1	- 3	0	- 3	+ 1
World Production	+11	+ 3	+12	+ 4	+ 15	+ 4
Consumption						
Japan						
Tire	+25	+ 2	+30	+ 2	+ 40	+ 3
Non-tire	-52	+29	-57	+31	- 64	+35
Total	+ 2	+10	+ 3	+12	+ 8	+13
United States						
Tire	- 6	+ 3	- 5	+ 3	- 3	+ 4
Non-tire	+ 3	+ 1	+ 4	+ 2	+ 6	+ 2
Total	- 4	+ 3	- 3	+ 3	- 1	+ 4
Western Europe						
Tire	+ 7	0	+ 8	0	+ 8	0
Non-tire	+ 7	+ 2	+ 7	+ 2	+ 7	+ 3
Total	+ 7	+ 2	+ 7	+ 2	+ 7	+ 2
Eastern Europe	+ 3	+ 3	+ 6	+ 3	+ 5	+ 4
Rest of the world	+12	+ 2	+14	+ 3	+ 19	+ 3
World Consumption	+ 6	+ 3	+ 7	+ 3	+ 10	+ 3

SUMMARY AND CONCLUSIONS

During the 1950's and 1960's natural rubber was a classic example of an agricultural commodity whose market price was depressed by competition from synthetic substitutes. Relatively low and stable petroleum prices resulted in low and stable oil-based synthetic rubber prices. From a postwar high of 61 cents per pound in 1951 the price of natural rubber on the New York market declined to just over 18 cents in 1971.

Since the OPEC oil embargo of 1973 and the subsequent increase in petroleum prices, the situation in the world rubber market has changed dramatically. Higher oil prices have resulted in higher synthetic rubber prices and increased competitiveness of the natural product. The growing use of radial tires, which require larger amounts of natural rubber than traditional ply tires, has also contributed to increased demand.

In this study the interaction of supply, demand, inventories, and price in the world natural rubber market are determined through an econometric model estimated for the period 1960-77. The influence of petroleum prices on the competitiveness of natural rubber is also reflected. Projections for 1985 based upon the model indicate that, even with modest economic growth in consuming countries, the real price of natural rubber in 1985 can be expected to be double that of 1977. Roughly 28 percent of the increase is due to the impact of anticipated higher-priced petroleum. The implication of the projections is that the value of production in exporting countries will more than double in most cases. For countries, such as Malaysia, who obtain a significant proportion of their foreign exchange earnings from rubber, the outlook for rubber exports is significantly improved from the depressed conditions of the early 1970's.

APPENDIX: DATA USED IN THE ANALYSIS

Production of Natural Rubber

Year	Malaysia	Indonesia	Thailand	Others
	----------metric tons----------			
1959	772,083	704,623	174,006	422,046
1960	784,413	620,255	170,865	441,341
1961	814,696	682,180	186,113	443,111
1962	818,353	681,580	195,388	458,721
1963	865,124	582,299	189,841	463,435
1964	904,167	648,705	221,666	496,350
1965	949,253	716,998	216,486	497,377
1966	998,292	715,698	207,176	514,831
1967	990,446	700,834	216,119	615,101
1968	1,100,284	793,910	264,221	526,582
1969	1,268,014	880,426	283,381	563,179
1970	1,269,203	815,161	289,663	728,473
1971	1,318,518	819,311	318,823	628,348
1972	1,304,147	773,655	336,919	705,279
1973	1,542,323	885,802	386,953	689,921
1974	1,524,673	854,964	379,188	686,175
1975	1,459,282	822,500	353,304	679,914
1976	1,639,760	847,500	404,849	672,891
1977	1,613,193	835,000	422,681	721,446

Tire and Nontire Consumption of Natural Rubber

	Tire			Non-tire		
	Western Europe	Japan	U.S.	Western Europe	Japan	U.S.
	metric tons					
1960	282,084	76,936	328,804	395,118	91,465	157,936
1961	278,519	86,406	282,621	380,902	92,400	151,582
1962	281,815	90,145	309,499	395,133	102,855	160,690
1963	291,085	93,802	299,745	412,027	102,687	164,825
1964	293,381	98,304	318,525	428,202	107,702	170,707
1965	301,679	94,697	361,013	435,471	106,788	161,958
1966	300,245	101,250	393,245	449,859	114,713	161,195
1967	296,052	117,100	340,702	443,948	125,900	155,991
1968	316,655	125,000	402,576	478,345	130,000	188,625
1969	352,277	139,500	435,670	497,723	128,500	172,202
1970	381,431	154,000	393,024	521,069	129,000	175,266
1971	399,364	165,800	425,407	513,136	129,200	161,673
1972	388,833	188,300	469,414	513,667	123,700	181,464
1973	388,980	217,100	515,209	546,020	117,900	196,768
1974	399,143	218,200	561,083	530,857	93,800	177,279
1975	387,949	197,100	489,508	519,551	88,100	176,442
1976	412,804	207,460	490,994	502,196	94,540	195,685
1977	417,687	223,000	622,786	516,313	97,000	180,703

Total Consumption

Year	Eastern Europe	Rest of the world
	----------metric tons----------	
1960	322,090	443,714
1961	483,643	405,589
1962	466,370	449,139
1963	436,397	465,919
1964	337,077	542,574
1965	408,455	548,156
1966	459,004	606,355
1967	445,000	617,807
1968	460,000	678,799
1969	465,000	724,128
1970	465,000	771,210
1971	475,000	822,920
1972	485,000	879,622
1973	490,000	930,523
1974	500,000	1,037,138
1975	475,000	1,033,850
1976	460,000	1,141,321
1977	435,000	1,305,011

Stocks of Natural Rubber

Year	Malaysia	Other Producers	Consuming Countries
	----------metric tons----------		
1960	76,339	210,697	509,347
1961	77,550	201,866	498,262
1962	104,573	227,929	500,000
1963	88,509	223,996	480,000
1964	91,775	315,726	445,000
1965	89,540	325,460	462,500
1966	101,851	313,149	505,000
1967	133,801	316,199	487,500
1968	109,949	245,051	555,000
1969	101,063	168,937	702,500
1970	152,526	219,974	765,000
1971	163,873	213,727	765,000
1972	195,551	206,949	702,500
1973	188,566	223,924	807,500
1974	201,091	211,409	840,000
1975	230,541	214,459	830,000
1976	239,077	210,923	867,500
1977	194,398	204,352	838,750

Automobile Production And In Use

Year	Production				In Use		
	Western Europe	Japan	U.S.	Eastern Europe	Western Europe	Japan	U.S.
	1,000 units						
1960	6,616	757	7,879	740	26,845	1,354	73,769
1961	6,282	1,039	6,677	789	30,158	1,964	75,827
1962	7,420	1,137	8,173	820	34,048	2,729	79,170
1963	9,054	1,401	9,100	855	38,658	3,762	82,748
1964	9,341	1,784	9,292	879	43,282	4,988	86,193
1965	8,903	1,921	10,329	958	47,931	6,300	90,358
1966	10,568	2,320	10,329	1,135	52,612	7,921	93,950
1967	9,954	3,173	9,974	1,160	56,617	10,029	96,906
1968	10,566	4,108	10,718	1,296	60,392	12,908	100,898
1969	11,765	4,692	10,147	1,408	64,485	15,127	105,097
1970	12,448	5,304	8,140	1,566	68,980	17,582	108,418
1971	13,082	5,823	10,558	1,764	73,446	19,664	112,986
1972	13,631	6,297	11,271	2,027	78,066	22,576	118,797
1973	14,215	7,086	12,647	2,434	82,382	24,999	125,754
1974	12,596	6,553	10,052	2,763	85,106	26,781	129,934
1975	11,860	6,944	8,999	2,960	88,223	28,091	132,962
1976	13,511	7,842	11,762	3,116	92,337	30,069	138,549
1977	13,676	8,515	13,904	3,211	95,608	32,008	143,835

Rainfall

Year	Malaysia	Indonesia	Thailand
	----------millimeters----------		
1959	5,280	2,183	2,217
1960	2,473	2,061	1,831
1961	2,481	1,588	2,650
1962	2,321	1,868	1,813
1963	1,934	1,508	1,725
1964	2,375	1,781	1,439
1965	2,533	2,101	2,496
1966	2,756	2,031	3,649
1967	2,764	2,057	2,129
1968	2,315	1,817	1,554
1969	2,374	2,397	2,741
1970	2,580	2,343	2,567
1971	2,532	2,222	2,419
1972	2,125	1,748	1,834
1973	2,686	2,440	2,581
1974	2,000	1,956	1,935
1975	1,744	2,048	2,293
1976	2,405	2,148	2,462
1977	2,094	1,945	1,512

Prices and Exchange Rates

	Prices			Exchange Rates		
	Natural Rubber (¢/lb)	Synthetic Rubber (¢/lb)	Oil ($/barrel)	Malaysia ($M/$US)	Thailand (Bahts/$US)	Indonesia (Rup/$US)
1952	38.78	-	-	3.05	16.76	.01136
1953	24.22	-	-	3.05	21.16	.01136
1954	23.59	-	-	3.08	20.88	.01136
1955	39.19	23.9	-	3.06	20.91	.01136
1956	24.21	23.9	-	3.08	20.66	.01136
1957	31.21	23.9	-	3.05	20.90	.0227
1958	28.12	23.9	-	3.06	21.10	.0303
1959	36.31	23.9	-	3.06	21.19	.036
1960	38.10	23.9	1.86	3.06	21.14	.045
1961	29.48	23.9	1.80	3.05	20.99	.045
1962	28.62	22.9	1.80	3.06	20.84	.048
1963	26.22	23.0	1.80	3.06	20.84	.315
1964	25.31	23.0	1.80	3.07	20.83	.520
1965	25.72	23.0	1.80	3.06	20.83	2.2
1966	23.59	23.0	1.80	3.08	20.75	78
1967	19.91	22.9	1.80	3.08	20.80	176
1968	19.84	22.8	1.80	3.07	20.85	277
1969	26.22	22.9	1.80	3.08	21.00	340
1970	21.00	23.0	1.80	3.07	21.00	378
1971	18.10	23.0	2.21	2.89	21.00	415
1972	18.23	23.0	2.47	2.82	21.00	415
1973	35.61	23.0	3.30	2.45	20.45	415
1974	39.37	31.7	11.59	2.31	20.38	415
1975	29.89	34.9	11.59	2.59	20.40	415
1976	39.60	35.5	12.38	2.54	20.40	415
1977	41.59	35.9	13.33	2.37	20.40	415

Price Indices

Year	Malaysian CPI	Thailand CPI	Indonesian CPI	Export Index
	----------1970 = 100----------			
1952	109.9	62.3	.00422	85.0
1953	99.0	69.2	.00449	81.0
1954	93.0	68.6	.00476	79.0
1955	90.0	72.7	.00633	80.0
1956	91.0	76.9	.00723	83.0
1957	95.0	81.7	.00795	86.0
1958	94.0	86.6	.01159	86.0
1959	91.0	82.4	.01460	87.0
1960	90.0	81.7	.01959	89.0
1961	91.2	83.1	.02422	89.0
1962	91.2	84.8	.06745	88.0
1963	94.0	85.7	.14533	89.0
1964	93.0	87.4	.29793	90.0
1965	93.5	88.3	1.20627	93.0
1966	94.8	90.8	13.8096	94.0
1967	98.7	95.1	37.22	95.0
1968	98.5	97.2	83.88	89.0
1969	98.1	99.1	89.02	90.0
1970	100.0	100.0	100.0	100.0
1971	101.6	102.0	104.9	109.0
1972	105.0	106.0	111.2	120.0
1973	115.9	118.4	146.3	145.0
1974	136.0	146.0	205.8	181.0
1975	142.2	152.0	245.0	209.0
1976	145.7	159.4	293.5	211.0
1977	152.9	173.0	325.9	231.0

Industrial Production Indices

	Western Europe	Japan	U.S.	Rest of the world
	----------1970 = 100----------			
1960	59	28	62	70.44
1961	62	33	63	69.95
1962	65	36	68	71.08
1963	68	40	72	71.89
1964	73	46	77	76.74
1965	76	48	84	80.78
1966	79	54	92	86.27
1967	80	65	94	91.28
1968	86	76	99	93.54
1969	94	89	104	95.64
1970	100	100	100	100.00
1971	107	108	100	104.04
1972	115	110	108	109.85
1973	117	127	118	123.26
1974	118	122	120	148.30
1975	110	110	109	161.55
1976	117	122	120	163.17
1977	120	127	127	176.74

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