

World Bank Staff Commodity Paper No. 3

An Econometric Model of The World Rubber Economy

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SUMMARY AND CONCLUSIONS

i. Rubber began to emerge as an important raw material during the 19th century. The industrialization of Western Europe and later the mass production of cars provided the main incentive for the expansion of natural rubber production. Japan's entry into World War II cut off Western Europe and the United States from East Asia, their main source of supply of natural rubber. The resulting shortage of natural rubber led to heavy investments in the production of synthetic rubbers, and with the exception of a brief period of retrenchment following the end of World War II, the synthetic rubber industry continued to expand rapidly. Under pressure from the cheaper synthetic rubbers, natural rubber prices began to decline and producers turned to other tropical tree crops, mainly oil palm.

ii. Production of natural rubber is concentrated in a few developing countries. Three of them, Malaysia, Indonesia and Thailand, account for over 80 percent of world production; another 12 percent comes from Sri Lanka, India, and two African producers, Liberia and Nigeria. Until recently the bulk of natural rubber came from estates. Today, smallholdings dominate rubber production in the major producing countries in Asia. With the exception of Nigeria, estates still produce most of the rubber in Africa.

iii. About 90 percent of the world's natural rubber production is exported. Producing countries retain only a small share of their output for domestic use. Trends in natural rubber exports have closely followed those in production: 94 percent of world rubber exports come from Asia, the remainder largely from Africa. Developed countries remain the major market for natural rubber exporters. The situation is almost the opposite for synthetic rubbers: only a fourth of its production reaches international markets, and almost three fourths of it is imported, again by developed countries. However, developing countries, as a group, have emerged as the largest net importer of synthetic rubber.

iv. Natural rubber is highly resistant to impact, abrasion and tear. However, it has a low resistance to oxidation and certain chemicals. Because of its physical and chemical properties, natural rubber is preferred in the manufacture of products that require strength but generate only little heat (e.g. airplane tires, giant truck tires, off-the-road vehicles' tires) and engineering products in which a high resistance to fatigue is required. The production of tires accounts for approximately 50 percent of total rubber consumption. The percentage of rubber used in the manufacture of tires reflects the degree of motorization; it ranges from 64 percent in the US to about 10 percent in the People's Republic of China.

v. The expansion of world rubber demand closely followed the growth of demand in automotive and other industrial uses for rubber in developed countries. At present, developed countries account for 68 percent of total world rubber consumption, centrally planned economies for 21 percent and developing countries for the remaining 11 percent. The trends in consumption of natural and synthetic rubbers after World War II closely reflected those of production: between 1948 and 1973 the use of natural rubber grew at an average rate of 3.3 percent a year,

while that of synthetic rubbers grew at 9.3 percent. Consequently, the share of natural rubber in the market for all elastomers declined from 57.3 percent in the early 1950s to 32.7 percent in the early 1970s.

vi. The market for natural rubber is highly competitive, and prices reflect even small changes in the balance between demand and supply. Since the demand for natural rubber and also its supply are highly insensitive to price changes in the short term, natural rubber prices fluctuate widely in response to changes in economic activity or variations in the flow of natural rubber supplies. As the market share of synthetic rubbers increased, their prices began to set the overall price trend, and natural rubber producers became, to a large extent, price takers.

vii. The model presented in this paper focuses on the market for natural rubber. The behavioral equations of the model can be grouped into three major blocks: supply, demand for all elastomers, and demand for natural rubber. Individual supply equations were estimated for the three major producing countries, Malaysia, Indonesia and Thailand; an additional equation captures the production of rubber in all other countries. The weighted average short-term price elasticity of supply was estimated at 0.22 percent. The demand for natural rubber was determined in two steps. First, the model determines the demand for all elastomers in six major consuming countries and regions. The demand for natural rubber is then determined with the help of a set of market share equations. It was assumed that the market share of natural rubber is largely a function of natural rubber prices relative to those of competing synthetic rubbers and technology. Because natural rubber users adjust their consumption gradually in response to changes in relative prices and technology, only a fraction of the expected use of natural rubber is realized within a certain period. A Nerlovian partial adjustment model was chosen to capture this behavior and to obtain estimates for short and long-term elasticities of the market share of natural rubber with respect to relative prices. The weighted average elasticities were 0.14 for the short term and 1.22 for the long term.

viii. The simulation results show that the model captures quite well the past behavior of the world natural rubber economy. The model was, therefore, used to gain some insight into the likely prospects for natural rubber. The growth of the economies (GNP) in the major rubber consuming countries has been traditionally the key variable for determining rubber demand. Although still important, the link between GNP and the demand for all elastomers is changing. The oil crisis and the consequent sharp increase in energy prices have altered the structure of elastomer demand. All available evidence points toward a gradual reduction of the historical income elasticity coefficients. Therefore various alternative specifications of the elastomer demand equations, each implying a gradual decline of income elasticities, were used in the model projections. In addition to the change in the specification of the demand equations, the market prospects for rubber were evaluated for two basic assumptions--a high and a low one--about the future growth path of income in major consuming countries. The model projections show that rubber producers can expect continued strong markets for their product.

I. STRUCTURE OF THE WORLD RUBBER ECONOMY

A. Natural and Synthetic Rubbers

1. Rubber 1/ began to emerge as an important raw material during the 19th century. Two technological innovations stimulated the interest in rubber: one was the masticator which made it possible to soften, mix and shape solid rubber; the other was the vulcanization process which drastically improved the physical properties of natural rubber. The industrialization of Western Europe stimulated the demand for elastomers, and recognizing the economic potential of natural rubber, planters in East Asia cleared huge tracts of land to plant rubber trees. Plantation rubber from East Asia (Ceylon, Malaysia and the Netherland East Indies) gradually replaced wild rubber from Brazil and Africa. The change in the method of production and the shift in the geographical location of natural rubber production led to a large increase in yields. Steady improvements in production practices and continuous efforts to improve the productivity of rubber trees sustained the upward trend in yields, making rubber one of the most profitable estate crops in tropical agriculture.

2. Mass production of cars provided a further boost to the demand for natural rubber in the early 20th century. The natural rubber industry responded with an enormous expansion of acreage to meet the rapidly growing demand. The worldwide recession during the 1920s and 1930s sharply reduced car production with a corresponding fall in the demand for rubber. The rubber industry was for the first time confronted with growing stocks and excess capacity. The industry established a supply regulation scheme 2/ which remained in effect until 1943. During all these years, the monopoly position of natural rubber as the only industrial elastomer remained virtually unchallenged.

3. This situation changed abruptly when Japan's entry into World War II cut off Western Europe and the United States from East Asia, their main source of natural rubber. In their search for an alternative source of supply 3/ these countries turned to their chemical industries. The United States Government launched a crash program to develop synthetic rubber, and by the end of World War II, US production of synthetic rubber had reached 1 million tons a year. Canada, Germany and the USSR had achieved large increases

1/ Throughout this paper, where not otherwise qualified, the terms "rubber" and "elastomer" imply both natural and synthetic rubbers.

2/ The International Rubber Regulation Agreement was in essence an export quota scheme, backed up by limitations on plantings and replantings. For a detailed account and evaluation of this scheme and its operations, see P.T. Bauer, The Rubber Industry: A Study in Competition and Monopoly (Cambridge, Massachusetts: Harvard University Press, 1948), pp. 88-215.

3/ The development of synthetic rubbers reaches back to the early 1930s. But before World War II synthetic rubbers accounted only for 2 percent of total world rubber consumption.

in synthetic rubber production. After a brief period of retrenchment following the end of World War II, the synthetic rubber industry continued its expansion without interruption for the next three decades. Under pressure from the cheaper synthetic rubbers, rubber prices weakened considerably and planting became less attractive in the major producing countries in relation to oil palm and other tropical tree crops. Today, synthetic rubbers account for more than two thirds of total elastomer consumption and natural rubber less than one third.

The Synthetic Rubber Industry

4. The US, Japan and the EC account for 70 percent of world synthetic rubber production; the USSR and other European centrally planned economies produce another 21 percent of the total (Table 1). Consumption is distributed in roughly the same way: about 70 percent of world output of synthetic rubber is consumed in developed countries, 21 percent in centrally planned economies, and the remainder in developing countries.

5. Within each region production of synthetic rubbers is also highly concentrated in a few companies. In the US, the four largest synthetic rubber producers account for about 65 percent of total output. In Italy, the United Kingdom, the Federal Republic of Germany, Belgium, the Netherlands and Canada, the largest firms account for 50 percent or more of total capacity. The situation is quite similar in developing countries. The main reason for this concentration of rubber production in a small number of companies is that the minimum economic size of a synthetic rubber plant is large compared to the domestic needs of most countries.

6. Backward and forward integration is another important structural characteristic of the synthetic rubber industry. The dependence of tire manufacturers on synthetic rubbers encouraged backward integration, while the similarity between the technical processes of synthetic rubber production and those of petrochemical production provided incentives for forward integration. Tire manufacturers and producers of petrochemicals dominate the synthetic rubber industry in market economies; the petrochemical industry controls slightly more than 50 percent of the existing production capacity of synthetic rubbers, and the tire manufacturing industry approximately 40 percent. The remainder is in the hands of various other industries.

7. The production of synthetic rubber is to a large extent in the hands of multinational corporations. This applies to both tire and petrochemical firms producing synthetic rubber. The influence of multinational corporations on the world market for synthetic rubbers is difficult to assess precisely. Until now, multinational corporations have shown little interest

Table 1: SYNTHETIC RUBBER - WORLD PRODUCTION VOLUMES BY MAIN COUNTRIES AND ECONOMIC REGIONS
1955-57, 1966-68 AND 1972-74 AVERAGES

	1955-57 Average		1966-68 Average		1972-74 Average		Growth Rates (% p.a.)	
	'000 m.t.	% of World Total	'000 m.t.	% of World Total	'000 m.t.	% of World Total	1955-57-1966-68	1966-68-1972-74
A. DEVELOPED COUNTRIES	<u>1,205.0</u>	<u>73.0</u>	<u>3,483.3</u>	<u>77.5</u>	<u>5,345.5</u>	<u>74.5</u>	<u>10.1</u>	<u>7.4</u>
North America /a	1,193.6	72.3	2,236.4	49.8	2,781.7	38.1	5.9	3.4
Japan	--	--	298.0	6.6	881.6	12.3	--	19.8
Western Europe	11.4	0.7	900.7	20.0	1,658.9	23.1	--	10.7
Others /b	--	--	48.2	1.1	73.3	1.0	--	7.2
B. DEVELOPING COUNTRIES	--	--	<u>110.6</u>	<u>2.5</u>	<u>261.0</u>	<u>3.6</u>	--	<u>15.4</u>
Africa /c	--	--	--	--	--	--	--	--
Asia	--	--	20.9	0.5	31.3	0.4	--	7.0
Latin America /d	--	--	89.7	2.0	229.7	3.2	--	17.0
C. CENTRALLY PLANNED ECONOMIES	<u>445.0</u>	<u>27.0</u>	<u>901.7</u>	<u>20.0</u>	<u>1,568.6</u>	<u>21.9</u>	<u>6.6</u>	<u>9.7</u>
USSR	374.2	22.7	651.0	14.5	1,162.5	16.2	5.2	10.1
Eastern Europe	70.8	4.3	224.0	5.0	359.4	5.0	11.0	8.2
China, People's Rep. of	--	--	26.7	0.5	46.7	0.7	--	9.8
D. WORLD TOTAL	<u>1,650.0</u>	<u>100.0</u>	<u>4,495.6</u>	<u>100.0</u>	<u>7,175.1</u>	<u>100.0</u>	<u>9.5</u>	<u>8.1</u>

/a Excludes Mexico.

/b Australia, New Zealand and South Africa.

/c Includes the Middle East.

/d Includes Mexico and Central America.

Source: International Rubber Study Group, Statistical Bulletin, various issues.

in establishing synthetic rubber plants in developing countries. 1/ The structure of the world market for synthetic rubbers, as it exists today, is therefore clearly oligopolistic and characterized by only a limited amount of price competition among large producers.

The Natural Rubber Industry

8. The production of natural rubber is also concentrated in a small number of countries. The three major Asian producers--Malaysia, Indonesia and Thailand--account for over 80 percent of world production. Sri Lanka, India and two African producers, Liberia and Nigeria, account together for another 12 percent of world output (Table 2).

9. Natural rubber is now mostly produced by smallholders. 2/ Although until recently the bulk of natural rubber came from estates, smallholders soon found it an attractive crop. Today, smallholdings make up the largest share of the area under rubber in the major producing countries in Asia: almost 100 percent in Thailand, about 80 percent in Indonesia, 65 percent in Malaysia and 53 percent in Sri Lanka. 3/ In these four countries smallholdings account for about 80 percent of total area under rubber. Smallholdings also dominate rubber production in India and Nigeria.

10. Neither smallholdings nor estates have a distinct economic or technical advantage over each other in the production of natural rubber. Each sector has its distinct attributes and is capable of producing rubber economically. 4/

1/ However, it could be argued that the currently available production technology--particularly for the newer types of synthetic rubber--tends to favor large existing producers. In addition, technical and economic factors place a limit on the number of synthetic rubber plants that can be established in any single market.

2/ Natural rubber is produced by well over one million smallholders and several thousand large estates. In contrast, world production of synthetic rubber is controlled by approximately 100 firms which operate about 300 plants. The differentiation between estates and smallholders is based on an arbitrary cutoff point--holdings of over 40 hectares are usually considered estates--a typical rubber smallholding rarely exceeds 5 hectares.

3/ These percentages were derived from estimates of total area under rubber in 1974-75. During the same years, production statistics--which are more reliable than area statistics--showed that smallholders accounted for 56 percent of total production in West Malaysia, 70 percent in Indonesia, and about 100 percent in Thailand. In these three countries taken together, smallholders accounted in 1974-75 for about 65 percent of total production of rubber.

4/ P. W. Allen, Natural Rubber and the Synthetics (London: Crosby Lockwood, 1972), p. 74.

Table 2: NATURAL RUBBER - WORLD PRODUCTION VOLUMES BY MAIN COUNTRIES AND ECONOMIC REGIONS
1955-57, 1966-68 AND 1972-74 AVERAGES

	1955-57 Average		1966-68 Average		1972-74 Average		Growth Rates (% p.a.)	
	'000 m.t.	% of World Total	'000 m.t.	% of World Total	'000 m.t.	% of World Total	1955-57-1966-68	1966-68-1972-74
A. DEVELOPING COUNTRIES	<u>1,823.1</u>	<u>94.9</u>	<u>2,422.0</u>	<u>96.3</u>	<u>3,252.2</u>	<u>98.4</u>	<u>2.6</u>	<u>5.0</u>
Asia								
Malaysia	691.5	36.0	1,021.2	40.6	1,473.4	44.6	3.6	6.3
Indonesia	714.0	37.3	743.8	29.6	846.5	25.6	0.4	2.2
Thailand	134.0	7.0	227.6	9.1	366.2	11.1	4.9	8.2
Sri Lanka	97.3	5.0	141.0	5.6	142.4	4.3	3.4	0.2
India	23.6	1.2	61.4	2.4	120.2	3.6	9.1	11.8
Other Asia /a	22.1	1.1	27.7	1.1	39.4	1.2	2.1	6.0
TOTAL /a	1,682.5	87.6	2,222.7	88.4	2,988.1	90.4	2.6	5.1
Africa								
Liberia	39.8	2.1	59.7	2.4	88.5	2.7	3.8	6.8
Nigeria	36.6	1.9	61.6	2.4	66.0	2.0	4.8	1.2
Zaire	31.0	1.6	30.0	1.2	41.0	1.2	-0.3	5.3
Other Africa	3.9	0.2	18.1	0.7	29.3	0.9	15.0	8.4
TOTAL	111.3	5.8	169.4	6.7	224.8	6.8	3.9	4.8
Latin America								
Brazil	23.3	1.2	22.9	0.9	22.6	0.7	-0.2	-0.2
Other Latin America	6.0	0.3	7.0	0.3	16.7	0.5	1.4	15.6
TOTAL	29.3	1.5	29.9	1.2	39.3	1.2	0.2	15.0
B. CENTRALLY PLANNED ECONOMIES	<u>99.1</u>	<u>5.1</u>	<u>91.8</u>	<u>3.7</u>	<u>52.5</u>	<u>1.6</u>	<u>-0.7</u>	<u>-8.9</u>
China, P.R.	-	-	-	-	15.0	0.5	-	-
Vietnam	68.7	3.5	39.7	1.6	21.0	0.6	-4.9	-10.0
Cambodia	30.4	1.6	52.1	2.1	16.5	0.5	5.0	-17.4
C. WORLD TOTAL (A + B)	<u>1,922.2</u>	<u>100.0</u>	<u>2,513.8</u>	<u>100.0</u>	<u>3,304.7</u>	<u>100.0</u>	<u>2.5</u>	<u>4.7</u>

/a Including Oceania.

Source: International Rubber Study Group, Statistical Bulletin, various issues; FAO, Production Yearbook, various issues; IBRD, Economic Analysis and Projections Department.

11. Originally, most rubber estates were owned by European companies, but they have now been returned to local companies or government authorities. European companies control now only about 12 percent of the world's production of natural rubber. Another 4 to 5 percent is in the hands of major US tire manufacturers. While tire manufacturers in the US and Western Europe have maintained a sizeable interest in natural rubber production, their backward integration into synthetic rubber production has limited their role as natural rubber producers.

B. Recent Trends in the World Rubber Economy

Demand for Rubber

12. The recovery of industrial production and in particular the rapid growth of the automotive industries after the end of World War II created a strong demand for elastomers and propelled the world rubber economy into a period of rapid and steady growth. From 1948 to 1973, total world rubber consumption increased steadily at an average rate of 6.3 percent per year.

13. During this period rubber utilization in developed countries grew at an average rate of about 6 percent per annum; it grew at an even faster rate--although from a smaller initial base--in developing countries (10%) and centrally planned economies (7%). Developed countries now account for 68 percent of world total rubber consumption; centrally planned economies for 21 percent and developing countries for the remaining 11 percent (Table 3).

14. Within the developed countries, since World War II the use of rubber has increased faster in Japan and Western Europe than in North America, 1/ closely reflecting the differences in the growth of the automobile industries in these regions; North America had already achieved a high level of motorization when Japan and Western Europe were still in the early stages of this process. 2/ Within the centrally planned economies, rubber utilization increased faster in Eastern Europe than in the USSR, although this trend seems to have reversed itself in recent years, following a decision of the USSR to increase automobile production for private use. Rubber consumption also increased rapidly in the People's Republic of China during the 1950s and the 1960s. But available data show that China's rubber use per capita is still lower than in other centrally planned economies. Automotive and industrial use of

1/ Throughout this paper the term "North America" refers to the US and Canada only.

2/ In 1950, for example, the number of cars per 1,000 inhabitants was 265 in the US, 139 in Canada, 21 in Western Europe, and 1 in Japan. By 1973, the number of cars per 1,000 inhabitants had grown to 481.2 in the US and 355 in Canada (at an average annual rate of 2.6 and 4.3 percent respectively), to 216 in Western Europe and 134 in Japan (an average annual rate of 10.7 and 23.5 percent respectively).

**Table 3: WORLD ELASTOMER UTILIZATION, BY MAIN COUNTRIES AND ECONOMIC REGIONS
1955-57, 1966-68 AND 1972-74 AVERAGES**

	<u>1955-57 Average</u>		<u>1966-68 Average</u>		<u>1972-74 Average</u>		<u>Growth Rates (% p.a.)</u>	
	'000 m.t.	% of World Total	'000 m.t.	% of World Total	'000 m.t.	% of World Total	1955-57 to 1966-68	1966-68 to 1972-74
A. DEVELOPED COUNTRIES	<u>2,639.6</u>	<u>75.0</u>	<u>4,895.0</u>	<u>69.5</u>	<u>7,110.7</u>	<u>68.0</u>	<u>5.8</u>	<u>6.4</u>
North America /a	1,590.1	45.2	2,460.0	34.9	3,315.6	31.7	4.0	5.6
Japan	118.2	3.4	519.0	7.4	957.4	9.2	14.4	10.7
Western Europe	837.5	23.8	1,765.0	25.1	2,618.6	25.0	7.0	6.8
Others /b	93.8	2.7	151.0	2.1	219.1	2.1	4.4	6.4
E. DEVELOPING COUNTRIES	<u>207.2</u>	<u>5.9</u>	<u>598.7</u>	<u>8.5</u>	<u>1,114.6</u>	<u>10.7</u>	<u>10.1</u>	<u>10.9</u>
Latin America /c	125.6	3.6	295.0	4.2	504.8	4.8	8.1	9.4
Asia	74.9	2.1	246.2	3.5	475.3	4.5	11.4	11.6
Africa	2.0	0.1	12.5	0.2	53.0	0.5	18.1	27.2
Middle East	4.7	0.1	45.0	0.6	81.5	0.8	22.8	10.4
C. CENTRALLY PLANNED ECONOMIES	<u>673.0</u>	<u>19.1</u>	<u>1,517.0</u>	<u>21.5</u>	<u>2,213.0</u>	<u>21.2</u>	<u>7.7</u>	<u>6.5</u>
USSR	460.0	13.1	900.0	12.8	1,348.0	12.9	6.3	7.0
Eastern Europe	156.0	4.4	410.0	5.8	585.0	5.6	9.2	6.1
China, Peoples Rep.	57.0	1.6	207.0	2.9	280.0	2.7	9.2	5.2
D. WORLD TOTAL (A+B+C)	<u>3,518.0 /d</u>	<u>100.0</u>	<u>7,044.0 /d</u>	<u>100.0</u>	<u>10,460.0 /d</u>	<u>100.0</u>	<u>6.5</u>	<u>6.8</u>

/a Excludes Mexico.

/b Australia, New Zealand and South Africa.

/c Includes Mexico and Central America.

/d Including allowance for discrepancies in available statistics.

Source: International Rubber Study Group, Statistical Bulletin, various issues; FAO, Trade Yearbook, various issues; IBRD, Economic Analysis and Projections Department.

rubber in this country is strictly controlled by the government, and rubber imports are kept to a minimum to save foreign exchange. 1/

Rubber Production

15. The world wide recession during the late 1920s and 1930s, in addition to the damage caused by World War II, had led to a sharp reduction in the number of rubber trees, and hence the production potential of the natural rubber industry was far below market needs when the motorization in Western Europe and Japan during the 1950s and 1960s generated a large additional demand for elastomers. Between 1948 and 1973 world synthetic rubber production increased more than 9 percent per annum, while natural rubber production grew at less than 3 percent per annum. The demand gap was filled by the synthetic rubber industry whose output, after some initial adjustment difficulties in the years after World War II, expanded rapidly from 1949 onwards and continued to grow at a rate of about 9 percent per annum.

16. When the outbreak of the Korean War renewed fears of a possible rubber shortage in the United States similar to the one experienced during World War II, the US government decided to provide support for a large synthetic rubber industry. This quickened the recovery of the industry from its post-war slump. Technological breakthroughs in styrene butadiene rubber (SBR) production and processing achieved in the early 1950s, such as cold polymerization and oil extension, helped to improve the quality and profitability of this type of synthetic rubber. However, the major force behind the expansion of the synthetic rubber industry throughout the 1950s was the rapid growth of world elastomer demand which natural rubber could not meet. Once launched on a large scale and supported by massive research, development and marketing efforts, the world synthetic rubber industry was able to maintain its growth momentum.

1/ China produces only about 15,000 tons of natural rubber and 45,000 tons of synthetic rubber a year. She therefore relies heavily on imports of rubbers, mainly natural rubber. Efforts are now under way to expand domestic rubber production, but in the foreseeable future demand will continue to outrun domestic production.

17. Synthetic rubber production spread quickly from the United States and Canada to Western Europe and Japan. Western Europe began to produce synthetic rubbers on a large scale in the early 1960s, while Japanese production began on a significant scale in the mid-1960s. By the late 1960s, Western Europe's share in world synthetic rubber production had climbed to 20 percent and Japan's to about 7 percent. However, North America, with its market share of about 50 percent--down from 70 percent during the mid-1950s--continued to dominate the market. These trends extended through the early 1970s. By 1972-74, North America's share of world synthetic rubber production had dropped to 38.1 percent while those of Western Europe and Japan had risen to 23.1 and 12.3 percent (Table 4). Within the centrally planned economies, which account collectively for about 22 percent of world total production, the USSR still dominates the market followed by Eastern Europe and China. Synthetic rubber production did not spread to developing countries until the late 1960s. Among the developing countries, Brazil and India were the first to establish their own synthetic rubber industries; they were followed by Argentina, Mexico and the Republic of Korea. Developing countries still account for only about 3.5 percent of world synthetic rubber production.

18. Trends in consumption of natural and synthetic rubbers in the post World War II period closely followed those of production: natural rubber use increased at an average annual rate of 3.3 percent between 1948 and 1973, while the utilization of synthetic rubbers increased at 9.3 percent per annum. Consequently the share of natural rubber in the world market for new rubbers dropped from 57.3 percent in 1951-53 to 32.7 percent in 1971-73. The market share of natural rubber declined sooner and more dramatically in the United States than in Western Europe or Japan (Chart 1). Strong markets for elastomers and a steady stream of innovations sustained the dynamic growth of the synthetic rubber industry. However, natural rubber producers succeeded in slowing down the decline in their market share by raising their productivity. The key producing countries of Asia (Malaysia, Indonesia and Thailand) began to put more emphasis on research into high-yielding clones; 1/ they also improved their cultural and processing techniques, developed chemical stimulants to improve yields, improved their external marketing arrangements and strengthened their technical assistance programs for domestic users of natural rubber. Despite the competition from synthetic rubber and a steady downward trend in natural rubber prices, these measures helped to achieve a steady growth of natural rubber output of about 3 percent a year.

1/ These countries remained the major producers of natural rubber. Asia accounted for 92.7 percent of world production in 1955-57, Africa for 5.8 percent, and Latin America for 1.5 percent. In 1972-74, the production share of Asia still was 91.5 percent, that of Africa 6.8 percent and that of Latin America 1.2 percent (see Table 1).

Table 4: NATURAL RUBBER - WORLD EXPORT AND IMPORT VOLUMES, BY MAIN COUNTRIES AND ECONOMIC REGIONS
1955-57, 1966-68 AND 1972-74 AVERAGES

	1955-57 Average		1966-68 Average		1972-74 Average		Growth Rates (% p.a.)	
	'000 m. t.	% of World Total	'000 m. t.	% of World Total	'000 m. t.	% of World Total	1955-57 to 1966-68	1966-68 to 1972-74
I. EXPORTS								
A. Developing Countries								
<u>Asia:</u>								
Malaysia	701.0	37.8	1,076.7	45.1	1,484.3	48.8	4.0	5.5
Indonesia	696.4	37.6	686.5	28.7	814.0	26.8	- 0.1	2.9
Thailand	133.2	7.2	221.9	9.3	352.6	11.6	4.7	8.0
Sri Lanka	94.2	5.1	135.0	5.6	134.8	4.4	3.3	0.0
Others	116.0	6.3	103.4	4.3	52.4	1.7	- 1.1	-10.7
<u>Total</u>	<u>1,740.8</u>	<u>93.9</u>	<u>2,223.5</u>	<u>93.0</u>	<u>2,838.1</u>	<u>93.4</u>	<u>2.2</u>	<u>4.2</u>
<u>Africa /a</u>	111.2	6.0	165.2	6.9	200.9	6.6	3.7	3.3
<u>Latin America /b</u>	2.0	0.1	1.0	--	1.0	--	- 6.1	0.0
<u>Total</u>	1,854.0	100.0	2,389.7	100.0	3,040.0	100.0	2.3	4.1
B. Developed Countries								
C. Centrally Planned Economies								
D. World Total								
	1,854.0	100.0	2,389.7	100.0	3,040.0	100.0	2.3	4.1
II. IMPORTS								
A. Developing Countries								
<u>Asia</u>								
Africa /a	26.1	1.4	78.2	3.3	129.3	4.3	10.5	8.7
Latin America /b	5.0	0.3	19.7	0.8	30.4	1.0	13.3	7.5
<u>Total</u>	<u>76.1</u>	<u>4.1</u>	<u>78.4</u>	<u>3.3</u>	<u>128.7</u>	<u>4.2</u>	<u>0.3</u>	<u>8.6</u>
<u>Total</u>	107.2	5.8	176.3	7.4	288.4	9.5	4.6	8.5
B. Developed Countries								
<u>Western Europe</u>								
North America /c	697.4	37.6	763.2	32.1	925.2	30.5	0.8	3.3
Japan	633.4	34.1	485.6	20.4	691.0	22.8	- 2.3	6.1
Others /d	112.5	6.1	243.3	10.2	321.8	10.6	7.3	4.8
<u>Total</u>	<u>72.8</u>	<u>3.9</u>	<u>71.2</u>	<u>3.0</u>	<u>102.6</u>	<u>3.4</u>	<u>- 0.2</u>	<u>6.3</u>
<u>Total</u>	1,516.1	81.7	1,563.3	65.8	2,040.6	67.3	0.3	4.5
C. Centrally Planned Economies								
<u>Eastern Europe</u>								
USSR	86.8	4.7	167.8	7.1	222.1	7.3	6.2	4.8
China, People's Rep. of	87.4	4.7	287.4	12.1	268.6	8.8	11.4	- 1.1
<u>Total</u>	<u>59.2</u>	<u>3.2</u>	<u>181.7</u>	<u>7.6</u>	<u>214.5</u>	<u>7.1</u>	<u>10.7</u>	<u>2.8</u>
<u>Total</u>	233.4	12.6	636.9	26.8	705.2	23.2	9.5	1.7
D. World Total								
	1,856.7	100.0	2,376.5	100.0	3,034.2	100.0	2.3	4.2

/a Includes the Middle East.

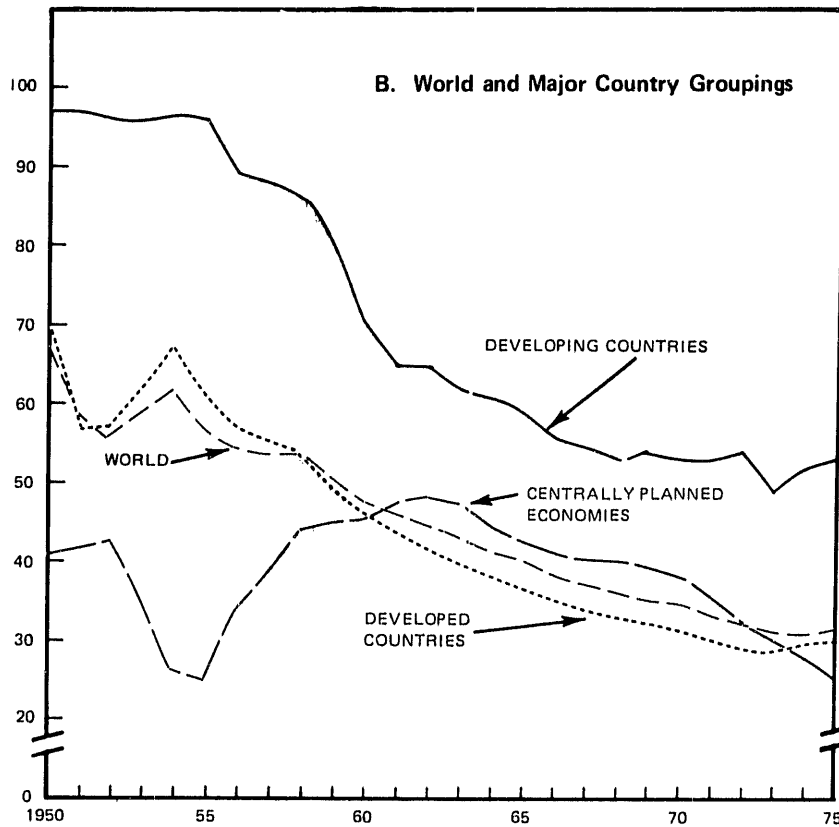
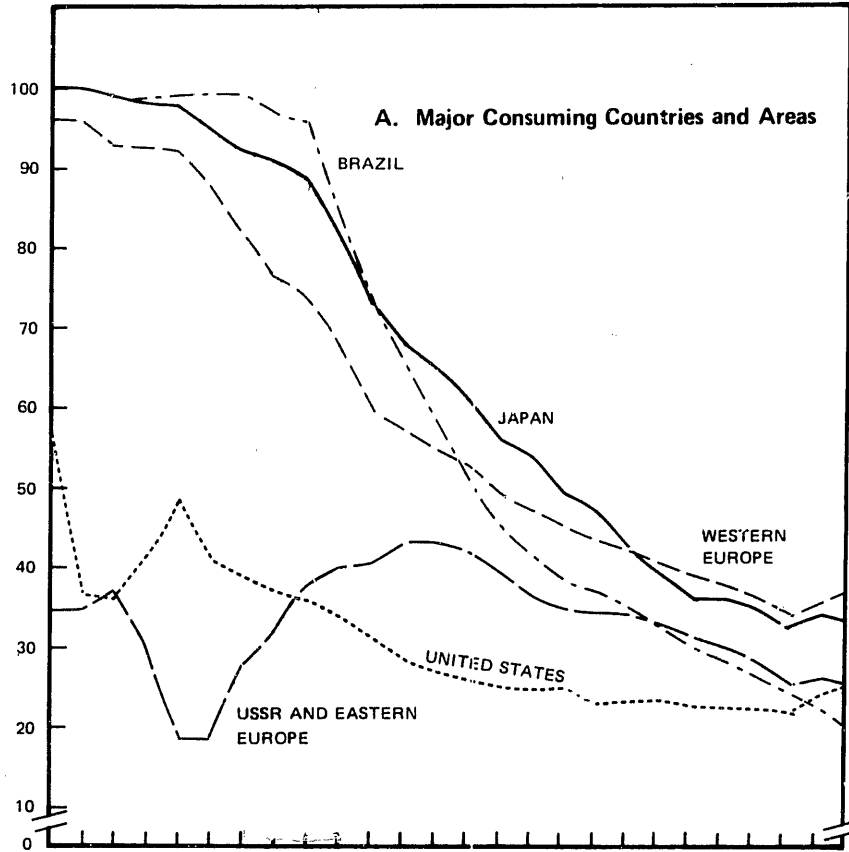
/b Includes Mexico and Central America.

/c Excludes Mexico.

/d Australia, New Zealand and South Africa.

Source: International Rubber Study Group, Statistical Bulletin, various issues.
FAO, Trade Yearbook, various issues.

CHART 1: MARKET SHARES OF NATURAL RUBBER
IN TOTAL RUBBER CONSUMPTION, 1950-1975



Trade

19. About 90 percent of the world's natural rubber production is exported. Producing countries retain only a small though growing share of their output for domestic use; this share grew from 2.5 percent in 1952-54 to 8.5 percent in 1972-74. The situation is almost the opposite in the case of synthetic rubbers: only 25 percent of world production is exported.

20. Of the major natural rubber producers and exporters, Malaysia now accounts for 49 percent of world total exports, Indonesia for 27 percent, Thailand for 12 percent and Sri Lanka for 4.5 percent. Trends in natural rubber exports have followed closely those in production: Malaysia and Thailand, whose production of natural rubber grew faster than the average, increased their export shares at the expense of Indonesia and Sri Lanka. Asia has remained the main source of natural rubber exports with 94 percent of the world total, and the remainder has largely come from Africa (Table 4).

21. The developed countries' share in total imports of natural rubber decreased significantly from 82 percent in 1955-57 to 67 percent in 1972-74, but the introduction of radial tires in North America and Japan has now checked this downward trend. 1/ At the same time, developing countries have increased their share of natural rubber imports, namely from 5.8 percent in 1955-57 to 9.5 percent in 1972-74. The share of centrally planned economies in total world imports of natural rubber doubled between the mid-1950s and the mid-1960s. However, their vigorous drive towards increased domestic production of isoprenic synthetic rubber (polyisoprene) has slowed the growth of their natural rubber imports in recent years. 2/ In 1955-57, centrally planned economies imported 12.6 percent of the natural rubber available in international markets; by 1966-68, the share of their imports had climbed to 26.8 percent; by 1972-74, this share had dropped to 23.2 percent.

22. World trade in synthetic rubbers is not only small in relation to the volume of production; most of it is among developed producers. Developed countries account for 87 percent of world exports and 74 percent of world imports. The United States has in recent years been replaced by Japan as the largest single net exporter of synthetic rubbers. Developing countries, as a group, are the largest net importer of synthetic rubber. Centrally planned economies are largely self-sufficient. The USSR and the German Democratic Republic are the two largest producers within this group of countries, and are also the main net exporters.

1/ Radial tires were first developed and commercially introduced in Western Europe in the mid-1960s. Their large-scale introduction in North America and Japan began only in the early 1970s. Radial tires require a higher percentage of natural rubber in the total rubber mix than bias belted tires.

2/ This trend seems to be particularly strong in the USSR.

Price Trends 1/

23. The market for natural rubber is highly competitive, and prices reflect even small changes in the supply and demand balance. Since the demand for natural rubber and also its supply are quite insensitive to price changes in the short term, natural rubber prices fluctuate widely whenever changes in economic activity induce demand shifts. 2/

24. The prices for natural rubber and SBR, the major synthetic rubber, are shown in Chart 2. Four major price peaks can be clearly identified in the price series for natural rubber. In the years 1950-51, 1955, 1959-60 and 1973-74, natural rubber prices rose substantially above trend. The 1950-51 and 1973-74 peaks can largely be attributed to "exogenous" factors: the Korean War and the oil crisis. 3/ The 1955 and 1959-60 price peaks, however, reflect unexpected increases in demand: world motor vehicle production increased by 34 percent in 1955, by 22 percent in 1959 and by another 18 percent in 1960.

25. As synthetic rubbers became increasingly important in world markets, their prices began to set the overall price trend, and natural rubber producers became, to a large extent, price takers. Economies of scale and technical innovations in the synthetic rubber reduced production costs and prices of synthetic rubbers, thereby depressing natural rubber prices. The oil crisis of 1973-74 and the subsequent quadrupling of crude oil prices substantially affected both the short- and the long-run cost curves of the natural and synthetic rubber industries and the interaction between the prices of natural and synthetic rubbers has now shifted to a different and higher trend level. 4/

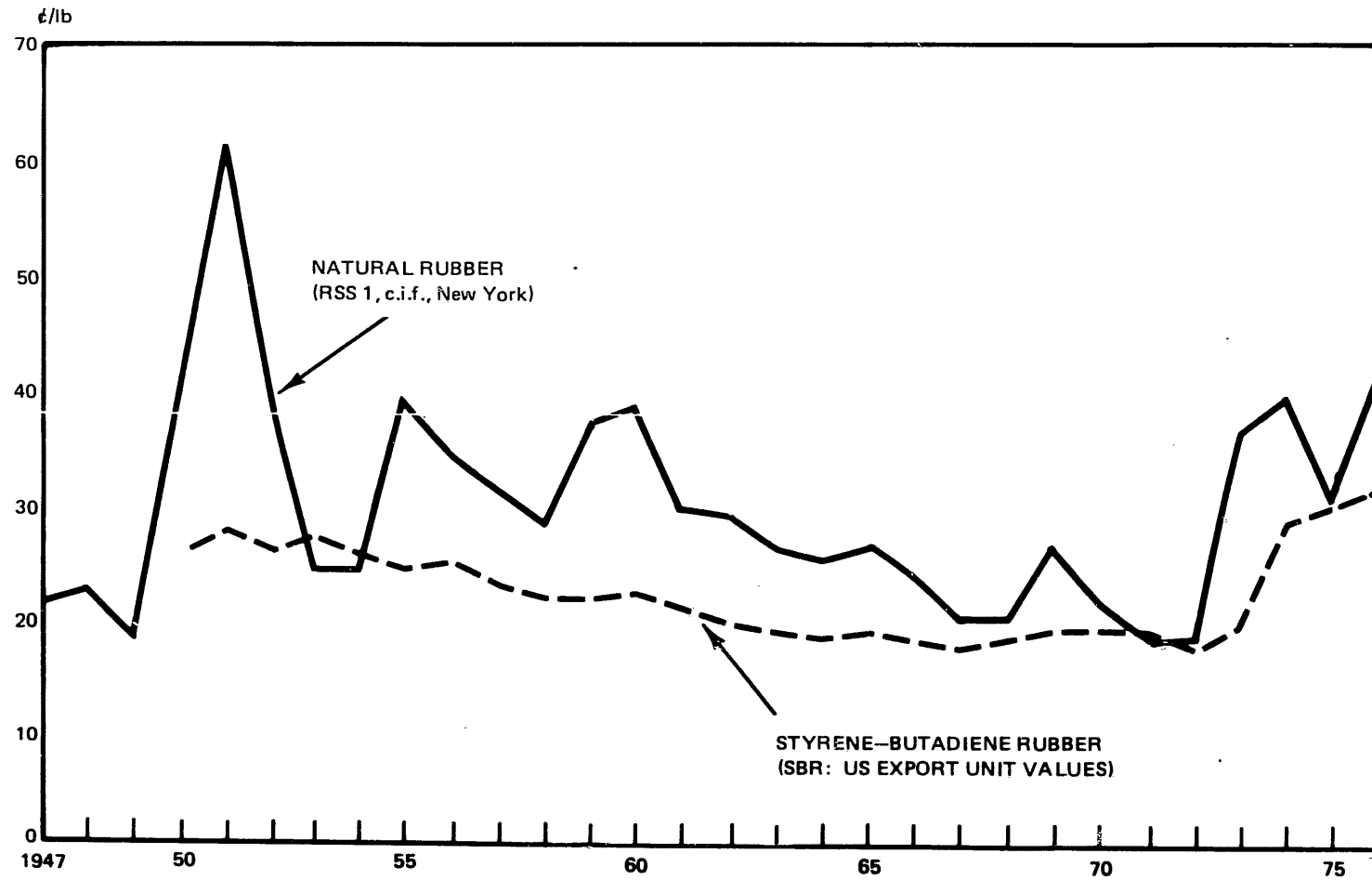
1/ The structure of the synthetic rubber industry is such that prices can be easily differentiated between markets--both regional and use-specific. For this reason, a "world price," even for a specific type of synthetic rubber, is impossible to reconstruct. For SBR, however, the long-run trend in world prices is approximated reasonably well by the trend in US export unit values.

2/ Between 1955 and 1975, the average percentage deviation from the 3 and 5 year moving average was 7.5 and 12.6 percent respectively.

3/ Import demand for natural rubber was very strong in 1973 as a consequence of a boom in industrial production which took place almost simultaneously in all the developed countries.

4/ For a detailed analysis of the changes in production costs induced by the oil crisis see: E. Grilli, B. Agostini and M. 't Hooft Welvaars, The World Rubber Economy: Structure, Changes, Prospects (Washington, D.C.: The World Bank, June 1978), p. 36-54.

CHART 2: RUBBER PRICE TRENDS, 1947-1976
(¢/lb)



II. STRUCTURE OF THE MODEL

A. Overview of the Model

26. The close, competitive relationship between natural and synthetic rubber makes the interaction between these two industries the cornerstone of any model of the world rubber economy. The optimal approach would be to model both the synthetic and natural rubber industries and to incorporate explicitly the simultaneous interaction between them. However, past attempts to model the synthetic rubber economy have not been highly successful. The structure of the synthetic rubber economy is essentially oligopolistic and it is closely integrated with other industries, and hence basic information on capacities, costs, prices and even on production have been difficult to come by. 1/ A more practical approach consists of incorporating explicitly the prices of synthetic elastomers in the demand block of the natural rubber model. This approach is followed here and synthetic rubber prices are included in the demand analysis for natural rubber as an exogenous variable. This model, however, differs in an important way from previous ones, since it first determines the joint demand for natural and synthetic rubbers and then the market share of natural rubber.

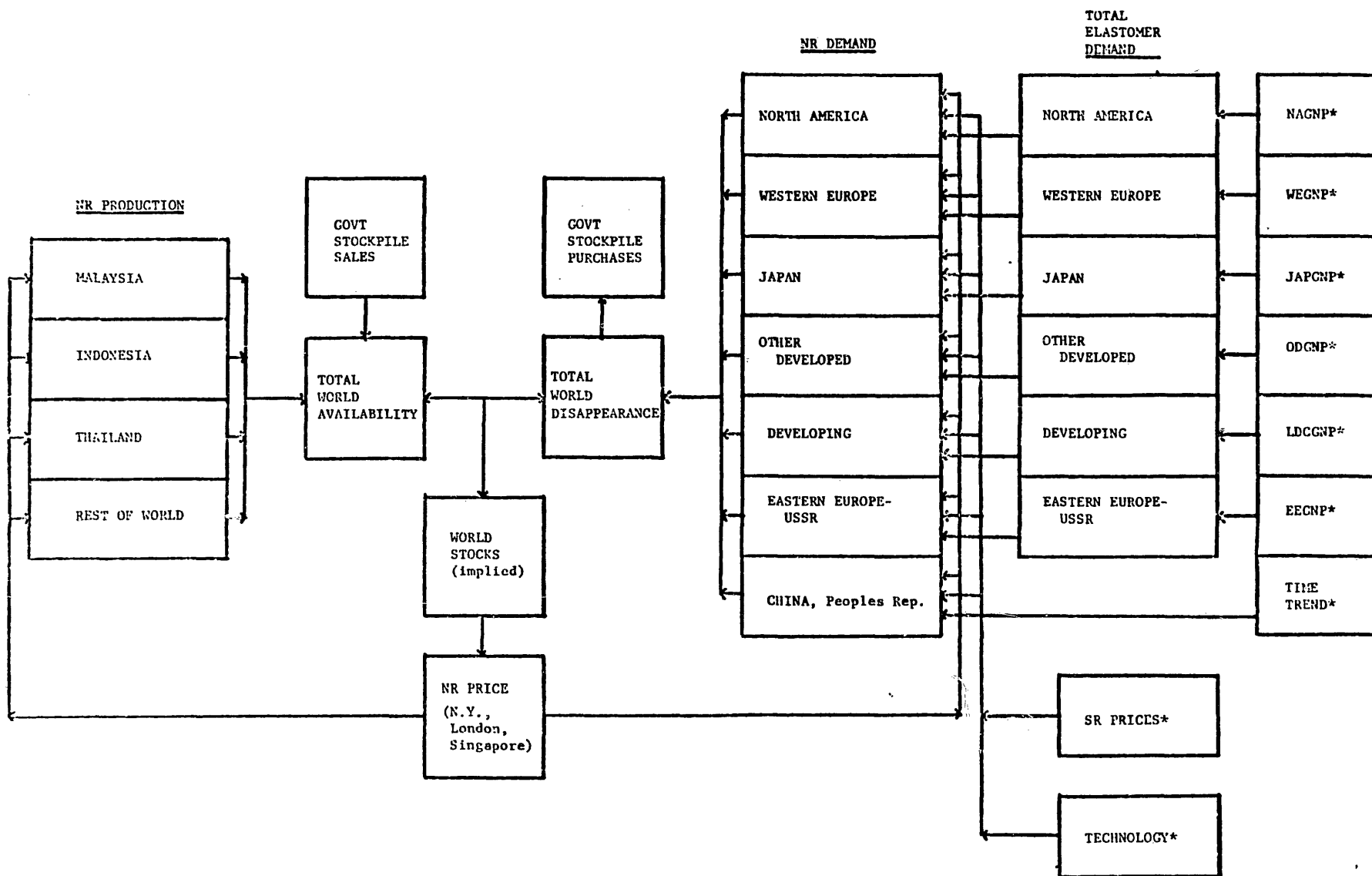
27. The model focuses on the market for natural rubber. It consists of three main blocks of equations: (i) a supply block, with supply equations for the major natural rubber producing countries; (ii) a demand block for total elastomers, containing equations for the major rubber consuming regions; and (iii) a demand block for natural rubber (Chart 3). The balance or imbalance between the supply of natural rubber and the demand for it is reflected in changes in natural rubber stocks. In competitive markets stock changes usually have a decisive impact on the short- and medium-term behavior of prices. The highly competitive nature of the world rubber economy made it possible to use this relationship between market prices and stock adjustments to link the supply block with the demand block.

28. Data from the period 1955-75 were used to estimate 17 of the 18 behavioral equations that describe supply and demand for natural rubber. 2/ The years 1973-75 were included since major structural changes--particularly on the supply side--have occurred as a consequence of the oil crisis. Information on rubber production and utilization in centrally planned economies is frequently sketchy. The inclusion of the CPEs was only possible at the cost of some drastic simplifications in the structure of the demand equations for these countries. However, the explicit inclusion of these countries gives the model a complete coverage of world consumption of natural rubber.

1/ Statistics on consumption of synthetic rubber by main types have only become available since 1973. The statistics, moreover, cover only the developed and developing countries.

2/ The only exception is the supply equations for Indonesia estimated over the 1956-75 period.

CHART 3: FLOW CHART OF THE WORLD RUBBER ECONOMY



B. Supply Equations

29. Natural rubber is a perennial crop. Production of rubber latex begins approximately 6 years after the tree has been planted and lasts on the average for 25-30 years. Yields increase rapidly in the first 10 years after the tree has reached maturity and then decline slowly, except for a temporary peak in yields around the 15th year after maturity. 1/

30. Rubber output depends, among other factors, on two types of decisions producers have to make. One is the decision to invest in rubber either by expanding the area planted or by replacing old trees; the other involves the frequency or intensity of tapping. 2/ Since the tapping intensity can be adjusted within a few weeks, rubber producers can, at least theoretically, match supplies to changing demand conditions, within the limits set by the potential output of the existing stock of trees. Therefore, separate supply equations are required to capture the investment decision and the tapping (or production) decision within a certain time interval.

31. Several theoretical models for the investment behavior of perennial crop producers have been described in the literature, 3/ and many of these models have produced good results. 4/ However, the application of these models to the rubber economy faces several difficulties. The most serious is the fact that data on plantings and replantings of rubber are only available for Malaysia. In addition, there are several conceptual problems. For example, planting is influenced not only by the relative profitability of rubber at expected future prices, but also--particularly for smallholders--

1/ This decline can now be delayed through the use of chemical stimulants.

2/ Rubber trees produce a fixed amount of rubber over their lifetime. By tapping more frequently this potential yield can be recovered more quickly. However, there are limits to how frequently a tree can be tapped without reducing future yields.

3/ For a survey of these models see: M.J. Bateman, "Supply Relations for Perennial Crops in the Less Developed Areas," in C.R. Wharton, Jr., ed., Subsistence Agriculture and Economic Development (Chicago: Aldine Pub. Co., 1969), pp. 243-253.

4/ See: P. Ady, "Supply Functions in Tropical Agriculture," Oxford University Institute of Economics and Statistics Bulletin, Vol. 30, No. 2 (May 1968), pp. 157-188 and B.C. French and J.L. Matthews, "A Supply Response for Perennial Crops," American Journal of Agricultural Economics, No. 53 (August 1971), pp. 478-490.

Indonesia: 1956-75

$$(1.2) \quad \text{INDNRS}_t = 513.628906 + 0.037292 \text{INDNRS}_{t-1} + 0.197395 \left[\frac{\text{INDNRP}}{\text{INDDFL}} \right]_t \\ - 82.085937 \text{DY63} + 13.230713 \text{TIME} \\ (0.15) \qquad \qquad \qquad (2.64) \qquad \qquad \qquad (1.79) \qquad \qquad \qquad (3.90)$$

$$R^2 = 0.83 \qquad \qquad \text{S.E.E.} = 38.568 \qquad \qquad \text{D.W.} = 2.32$$

where:

INDNRS = Supply of natural rubber from Indonesia ('000 mt)

INDNRP = Price of R.S.S. 1 in Singapore (Old Rupiahs/mt)

INDDFL = Implicit GDP deflator for Indonesia (1960=100)

DY63 = Dummy variable (set to 1 for 1963 and to 0 for all other years)

TIME = Time trend (1955=1)

Thailand: 1955-75

$$(1.3) \quad \text{THANRS}_t = 31.7031 + 0.434174 \text{THANRS}_{t-1} + 4.30957 \left[\frac{\text{THANRP}}{\text{THADFL}} \right]_t \\ + 10.191895 \text{TIME} \\ (2.12) \qquad \qquad \qquad (1.66) \qquad \qquad \qquad (2.62)$$

$$R^2 = 0.96 \qquad \qquad \text{S.E.E.} = 17.022 \qquad \qquad \text{D.W.} = 1.47$$

where:

THANRS = Supply of natural rubber from Thailand ('000 mt)

THANRP = Price of R.S.S. 3, Thailand (Malaysian ¢/mt)

THADFL = Implicit GDP deflator for Thailand (1961=100)

TIME = Time trend (1955=1)

Rest of the World: 1955-75

$$(1.4) \quad \text{ROWNRS}_t = 232.3125 + \underset{(0.93)}{0.172607} \text{ROWNRS}_{t-1} + \underset{(2.53)}{0.024487} \left[\frac{\text{SINNRP}}{\text{USWPI}} \right]_t \\ + 13.195313 \text{ TIME} \\ (5.03)$$

$$R^2 = 0.99 \qquad \text{S.E.E.} = 9.821 \qquad \text{D.W.} = 2.18$$

where:

ROWNRS = Supply of natural rubber from "Rest of the World"
('000 mt)

SINNRP = Price of R.S.S.1 in Singapore (\$/mt)

USWPI = US wholesale price index (1967=100)

TIME = Time trend (1955=1)

Total Supply: 1955-75

$$(1.5) \quad \text{TNSR}_t = \text{MALNRS}_t + \text{INDNRS}_t + \text{THANRS}_t + \text{ROWNRS}_t$$

where:

TNSR = Total world supply of natural rubber ('000 mt)

Supply Elasticities

34. Table 5 below summarizes the estimated supply price elasticities.

Table 5: NATURAL RUBBER SUPPLY ELASTICITIES

Country	Price Elasticity of Supply Short-Term /a
Malaysia	0.22*
Indonesia	0.18*
Thailand	0.25
Rest of the World	0.19*

*Significant at the 95% confidence level.

/a The elasticities were estimated at the means of production and prices using the supply equations shown above.

35. The estimated coefficients of the price variables included in the supply equations are all statistically significant, with the exception of the estimate for Thailand. The results indicate that producers adjust their production to changes in market conditions. This response is usually more pronounced in countries where the production comes mainly from small-holdings. The response, however, is small because not only does it take a long time for market information to filter down to small producers in remote areas, but also because some of these producers are forced in some cases to tap their trees more frequently in order to maintain their income level if there is a decline in natural rubber prices. The estimated supply elasticities are roughly in line with the results of other econometric studies. 1/

C. Demand Equations

36. The demand side of the model has a stronger theoretical basis than the supply side. Because natural and synthetic rubbers can be interchanged in many end-uses, the demand for all elastomers--natural and synthetic combined--became the starting point for the demand models of natural rubber.

37. The demand for all elastomers is a derived demand. Approximately half of the total supply of all elastomers is used in the manufacture of tires. Probably another 10-15% of the total is used in non-tire automotive uses, and the remainder is used for household and industrial goods. The state of the automotive industry is a key variable in the determination of the demand for elastomers. Production and use of motor vehicles is in turn closely tied to the growth of real GNP. A strong direct relationship can, therefore, be found between the total demand for elastomers and real GNP growth. 2/ Thus real was adopted as the key exogenous variable in the demand equations for all elastomers.

38. The model determines first the demand for all elastomers and then the demand for natural rubber. The step from the demand for all elastomers to that for natural rubber is somewhat complicated, and several approaches to carve out the demand for natural rubber from that for all elastomers were explored. A market share approach finally produced the best results. This approach assumes that: (i) rubber users can use either natural or synthetic rubbers; (ii) natural and synthetic rubbers are close but not perfect substitutes; and (iii) a change in the relative prices of these two types of rubber would affect the proportions in which they are used only gradually. The adjustment is assumed to be a gradual one because of the

1/ See F. Chan, "A Preliminary Study of the Supply Response of Malayan Rubber Estates Between 1948 and 1959," *Malayan Economic Review*, Vol. XLIV, No. 4 (November 1962), pp. 1021-1036; and more recently C.S. Chow, "Some Aspects of Price Elasticities of Rubber Production in Malaysia", in Proceedings of the International Rubber Conference: 1975 (Kuala Lumpur, 1975).

2/ This is reinforced by the fact that the non-automotive component of elastomer demand is also strongly related to industrial production and GNP.

uncertainty which surrounds the price prospects for natural rubber, the time and costs involved in shifting from one type of rubber to the other and the institutional constraints--in particular the backward integration of tire manufacturing into synthetic rubber production--in the market.

39. Changes in technology--particularly in the manufacturing of tires also affect the choice of rubber inputs. Whenever possible, an attempt was made to capture the effect of these changes by the use of shift variables or time trends.

40. The market share approach was used for all major consuming regions outside the centrally planned economies, namely North America, Western Europe, Japan, other developed countries and developing countries. No information was available on synthetic rubber production and rubber prices in centrally planned economies, so for Eastern Europe and the USSR the market share of natural rubber was fitted to a time trend, and for the People's Republic of China the total demand for natural rubber was fitted to a time trend. The demand equations, for the major consuming areas, all estimated by ordinary least squares (OLS), are presented below:

I. Total Elastomer Demand

North America: 1956-75

$$(2.1) \quad \ln \text{NARUBD}_t = 2.457031 + 1.186401 \ln \text{NAGNP}_t \\ (31.01)$$

$$R^2 = 0.97 \quad \text{S.E.E.} = 0.049 \quad \text{D.W.} = 1.63$$

where:

NARUBD = Total elastomer demand for North America ('000 mt)

NAGNP = Index of GNP in North America (real terms) (1970=100)

Western Europe: 1956-75

$$(2.2) \quad \ln \text{WERUBD}_t = 0.741699 + 1.511475 \ln \text{WEGNP}_t \\ (49.68)$$

$$R^2 = 0.99 \quad \text{S.E.E.} = 0.037 \quad \text{D.W.} = 0.92$$

where:

WERUBD = Total elastomer demand for Western Europe ('000 mt)

WEGNP = Index of GNP for Western Europe (real terms) (1970=100)

USSR and Eastern Europe: 1956-75

$$(2.3) \quad \ln \text{EERUBD}_t = 0.860352 + 1.426025 \ln \text{EEGNP}_t \\ (29.68)$$

$$R^2 = 0.99 \quad \text{S.E.E.} = 0.055 \quad \text{D.W.} = 0.46$$

where:

EERUBD = Total elastomer demand for the USSR and Eastern Europe ('000 mt)

EEGNP = Index of GNP for the USSR and Eastern Europe (real terms) (1970=100)

Japan: 1955-75

$$(2.4) \quad \ln \text{JAPRUBD}_t = 0.74939 + 1.27594 \ln \text{JAPGNP}_t \\ (31.82)$$

$$R^2 = 0.98 \quad \text{S.E.E.} = 0.104 \quad \text{D.W.} = 0.52$$

where:

JAPRUBD = Total elastomer demand for Japan ('000 mt)

JAPGNP = Index of GNP for Japan (real terms) (1970=100)

Other Developed: 1955-75

$$(2.5) \quad \ln \text{ODRUBD} = -0.210205 + 1.199707 \ln \text{ODGNP}_t \\ (10.622)$$

$$R^2 = 0.86 \quad \text{S.E.E.} = 0.138 \quad \text{D.W.} = 1.80$$

where:

ODRUBD = Total elastomer demand for "Other Developed Countries" (South Africa, Australia, New Zealand), ('000 mt)

ODGNP = Index of GNP for "Other Developed Countries" (real terms) (1970=100)

Developing Countries: 1955-75

$$(2.6) \quad \ln \text{LDCRUBD}_t = -0.990479 + 1.674805 \ln \text{LDCGNP}_t \\ (45.11)$$

$$R^2 = 0.99 \quad \text{S.E.E.} = 0.038 \quad \text{D.W.} = 1.79$$

where:

LDCRUBD = Total elastomer demand for developing countries ('000 mt)

LDCGNP = Index of GNP for developing countries (real terms) (1970=100)

Total Elastomer Demand: 1955-75

$$(2.7) \quad \text{TRUBD}_t = \text{NARUBD}_t + \text{WERUBD}_t + \text{EERUBD}_t + \text{JAPRUBD}_t + \text{ODRUBD}_t + \text{LDCRUBD}_t$$

where:

TRUBD_t = Total world elastomer demand ('000 mt)

II. Natural Rubber Market Share Equations

North America: 1956-75

$$(3.1) \quad \text{NANRMS}_t = 0.036846 + 0.907469 \text{NANRMS}_{t-1} - 0.016377 \left[\frac{\text{USNRP}}{\text{SRWAP}} \right]_t$$

(28.55) (2.03)

$$+ 0.020939 \text{D4345}$$

(4.06)

$$R^2 = 0.98$$

$$\text{S.E.E.} = 0.0074$$

$$\text{D.W.} = 2.11$$

where:

NANRMS = Market share of natural rubber for North America (%)

USNRP = Price of R.S.S. 1, N.Y. spot (\$/mt)

SRWAP = Weighted average price of various synthetic rubbers (\$/mt)

D4345 = Dummy variable for radial tire penetration (Set to 1 for 1973, 1974, 1975 and to 0 for all other years)

Western Europe: 1957-75

$$(3.2) \quad \text{WENRMS}_t = 0.087383 + 0.902702 \text{WENRMS}_{t-1} - 0.051464 \left[\frac{\text{WENRP}}{\text{WESRP}} \right]_t$$

(46.98) (3.18)

$$R^2 = 0.99$$

$$\text{S.E.E.} = 0.011$$

$$\text{D.W.} = 1.90$$

where:

WENRMS = Market share of natural rubber in Western Europe (%)

WENRP = Price of natural rubber in Western Europe (\$/mt)

WESRP = Price of synthetic rubber in Western Europe (\$/mt)

Japan: 1956-75

$$(3.3) \ln \text{JAPNRMS}_t = -0.1066 - 0.24222 \ln \left[\frac{\text{JAPNRP}}{\text{JAPSRP}} \right]_t - 0.000007 \text{JAPTIX}_t + 0.025705 \text{JAPRAD}_t$$

(3.79) (15.70) (8.07)

$R^2 = 0.98$ S.E.E. = 0.0496 D.W. = 1.54

where:

JAPNRMS = Market share of natural rubber in Japan (%)

JAPNRP = Index of natural rubber prices in Japan (1970=100)

JAPSRP = Index of synthetic prices in Japan (1970=100)

JAPTIX = Linear trend values of Japanese exports of tires and tubes (million units)

JAPRAD = Market share of radial tires in Japan (%)

Other Developed Countries: 1957-75

$$(3.4) \text{ODNRMS}_t = 0.108498 + 0.810257 \text{ODNRMS}_{t-1} - 0.023846 \left[\frac{\text{JAPNRP}}{\text{JAPSRP}} \right]_t$$

(14.85) (0.73)

$R^2 = 0.95$ S.E.E. = 0.021 D.W. = 2.35

where:

ODNRMS = Market share of natural rubber in "Other Developed Countries" (%)

JAPNRP = Index of natural rubber prices in Japan (1970=100)

JAPSRP = Index of synthetic rubber prices in Japan (1970=100)

Developing Countries: 1957-75

$$(3.5) \text{LDCNRMS}_t = 0.100777 + 0.894959 \text{LDCNRMS}_{t-1} - 0.43358 \left[\frac{\text{USNRP}}{\text{SRWAP}} \right]_t$$

(18.90) (1.55)

$R^2 = 0.96$ S.E.E. = 0.0263 D.W. = 1.86

where:

LDCNRMS = Market share of natural rubber in developing countries (%)

USNRP = Price of R.S.S.1, New York spot (\$/mt)

SRWAP = Weighted average price of various synthetic rubbers (\$/mt)

China: 1955-75

$$(3.6) \quad \text{CHINRD}_t = 38,599976 + 9,581318 \text{ TIME} \\ (32.36)$$

$$R^2 = 0.98$$

$$\text{S.E.E.} = 8.215$$

$$\text{D.W.} = 0.36$$

where:

CHINRD = Chinese demand for natural rubber ('000 mt)

TIME = Time trend (1955=1)

USSR and Eastern Europe: 1964-75

$$(3.7) \quad \text{EENRMS}_t = 0.061195 + 0,913544 \text{ EENRMS}_{t-1} + 0,000106 (\text{TIME})^2 - 0,005228 \text{ TIME} \\ (11.57) \quad (2.16) \quad (1.60)$$

$$R^2 = 0.99$$

$$\text{S.E.E.} = 0.009$$

$$\text{D.W.} = 1.00$$

where:

EENRMS = Market share of natural rubber in the USSR and Eastern Europe (%)

TIME = Time trend (1964=1)

Total Natural Rubber Demand

$$(3.8) \quad \text{TNRD}_t = \text{NANRMS}_t (\text{NARUBD}_t) + \text{WENRMS}_t (\text{WERUBD}_t) + \text{EENRMS}_t (\text{EERUBD}_t) \\ + \text{JAPNRMS}_t (\text{JAPRUBD}_t) + \text{ODNRMS}_t (\text{ODRUBD}_t) + \text{LDCNRMS}_t (\text{LDCRUBD}_t) \\ + \text{CHINRD}_t$$

where:

TNRD_t = Total World demand for natural rubber ('000 mt)

Demand Elasticities

41. The direct price elasticities for the market share of natural rubber implied in the coefficients of the estimated demand equations are shown in Table 6.

Table 6: PRICE ELASTICITIES FOR THE MARKET SHARE OF NATURAL RUBBER

Country/Region	Price Elasticity of Market Share	
	Short Term <u>/a</u>	Long-Term
North America	0.11*	1.17
Western Europe	0.15*	1.79
Japan	0.24*	n.a.
Other Developed	0.32	n.a.
Developing	0.44	n.a.

* Significant at the 95 percent confidence level.

/a The elasticities were estimated at the means using market share equations shown above.

42. The short- and long-term price elasticities of the natural rubber market share implicit in the estimated coefficients were computed to check the conformity of the estimates with a priori expectations. These values are quite reasonable and conform to expectations: (i) in the short term a change in relative market prices has only a marginal influence on the decision to choose one rubber over another, but this influence grows stronger in the long term; (ii) the values of the elasticities are lower in North America than in Western Europe and Japan, mainly because the North American tire industry is more vertically integrated.

D. Stock and Price Equations

43. Natural rubber prices are quoted in four major markets: New York, London, Singapore and Kuala Lumpur. The highly competitive nature of the world natural rubber economy ties these markets closely together and price movements in all four markets are highly correlated. The New York price was chosen as the representative one to conform with a long standing World Bank practice of quoting natural rubber prices, CIF New York.

44. Two major factors affect the short-term price changes of natural rubber: changes in inventories and inflation rates. The long term trend, however, is determined by the trend of synthetic rubber prices.

45. Inventories of natural rubber are kept by producers, traders and users. In the past governments also held stocks for security reasons. The US strategic stockpile was by far the most important one. It is exhausted now, although some rebuilding of strategic stocks is currently envisaged by the US Government.

46. For many commodities published information on stocks is either incomplete or highly unreliable. Rubber falls into this category, despite substantial efforts by the International Rubber Study Group to assemble a set of stock data. Since changes in the level of stocks play a key role in the determination of prices, "implied" stocks were computed, taking the stock level published for the year 1948 as a starting point. For each of the following years the total stream of rubber flowing into the market (i.e. supply plus releases from government stockpiles) was added to the level of stocks. This became the volume of rubber which was available for consumption and stockpiling in each year. To derive the level of implied stocks, actual consumption and purchases for strategic stockpiles were subtracted from the total availability.

47. These implied stock levels entered the model in the form of a ratio between stocks and consumption. It is argued that a decline in stocks relative to the level of consumption would exert an upward pressure on prices and vice versa. Prices in the model were expressed in real terms, that is, deflated by the US wholesale price index (USWPI) which is used here as a proxy for world inflation. The US price of SBR (styrene butadiene rubber), the most widely used type of synthetic rubber, is taken as the proxy for "world" SBR prices, which are not quoted. Since the United States was the first country to produce SBR on a large scale, it dominates the price determination of SBR, and hence US prices are a good indicator of prices in other markets. Natural rubber prices are directly related to those for SBR. A drop in SBR prices, caused by productivity gains in the industry or a fuller utilization of capacity, etc. would put pressure on natural rubber prices-- and vice versa. Dummy variables for 1968 and 1973 were included in the price equation to capture the short-term impact of the oil crisis and the economic recession in the United States in 1968 on the prices of natural rubber. The following price equation was estimated.

Natural Rubber Prices: 1955-75

$$(4.1) \quad \left[\frac{\text{USNRP}}{\text{USWPI}} \right]_t = 588.469971 + 0.193851 \left[\frac{\text{USNRP}}{\text{USWPI}} \right]_{t-1} - 2061.202148 \left[\frac{\text{STOCK}_t}{\text{TNRD}_t} \right] \\ + 2.826483 \left[\frac{\text{USSBRP}}{\text{USWPI}} \right]_t + 299.973999 \text{DY73} - 112.88501 \text{DY68}$$

(1.02) (3.90) (6.79) (5.82) (2.20)

$$R^2 = 0.94$$

$$\text{S.E.E.} = 45.33$$

$$\text{D.W.} = 1.44$$

where:

USNRP = Price of R.S.S. 1, New York spot (\$/mt)

USWPI = US wholesale price index (1967=100)

STOCK = Implied stocks of natural rubber ('000 mt)

USSBRP = US Price of SBR (\$/mt)

DY73 = Dummy variable for the oil crisis (set to 1 for 1973 and to 0 for all other years)

DY68 = Dummy variable for economic recession in the US and Europe (set at 1 for 1968 and to 0 for all other years)

TNRD = Total demand for natural rubber ('000 mt)

48. The following equation determines the "implied" natural rubber stocks. The equation was also used to close the model.

Natural Rubber Stocks

$$(4.2) \quad \text{STOCK}_t = \text{STOCK}_{t-1} + \text{TNRS}_t - \text{TNRD}_t + \text{STOCKSL}_t - \text{STOCKPR}_t$$

where:

STOCK = Stocks of natural rubber ('000 mt)

TNRS = Total supply of natural rubber ('000 mt)

TNRD = Total demand for natural rubber ('000 mt)

STOCKSL = Sales from stockpiles ('000 mt)

STOCKPR = Purchases for stockpiles ('000 mt)

III. MODEL SIMULATIONS AND PROJECTIONS

A. Validation of the Model

49. The estimated equations were used to simulate the behavior of the world natural rubber economy for the period 1964-75. Actual and simulated variables are presented in Chart 4 for four key endogenous variables: world supply, world consumption, stocks and prices. Some simulation statistics are summarized in Table 7 below.

Table 7: SUMMARY RESULTS OF 1964-75 SIMULATIONS FOR SELECTED VARIABLES

Variable Statistics	Supply (TNSR)	Demand (TNRD)	Price (USNRP)	Stocks (STOCK)
Mean (actual data)	2976	2929	555	1824
Mean (simulated data)	2995	3008	576	1860
RMS <u>/a</u> error	87.4	116.9	56.8	72.8
RMS error (in %)	0.028	0.043	0.129	0.042

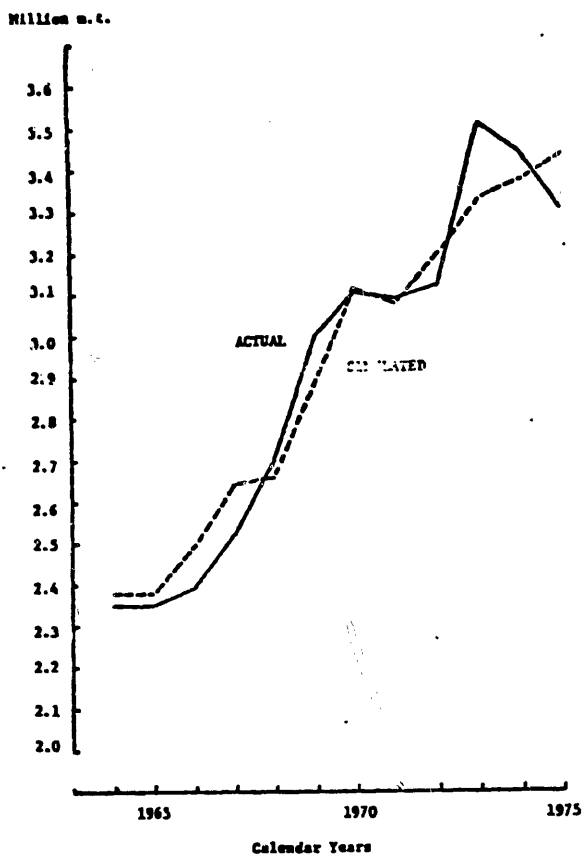
/a RMS is the Root-Mean-Square simulation error.

50. The simulation results are quite good. The model is capable of simulating satisfactorily both the trends and the turning points of world supply, demand, stocks and prices of natural rubber. Particularly remarkable is its price-tracking performance, in view of the instability of natural rubber prices over the simulation period. The model picks up both price peaks--in 1969 and 1973-74--as well as the troughs--in 1967, 1972 and 1975 (Chart 4).

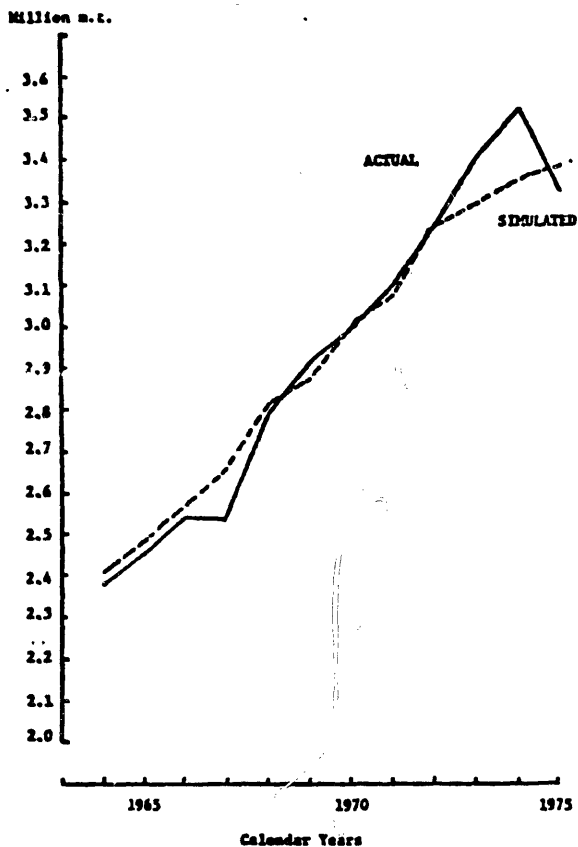
51. These results indicate that the structure of the model is sound and that the model captures most of the behavior of the world natural rubber economy.

CHART 4: HISTORICAL SIMULATIONS OF THE RUBBER MODEL - 1964-75

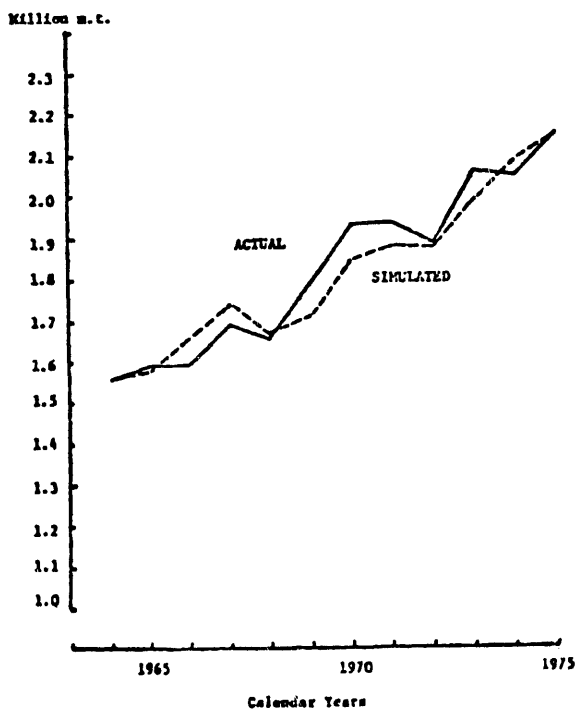
A. NATURAL RUBBER SUPPLY



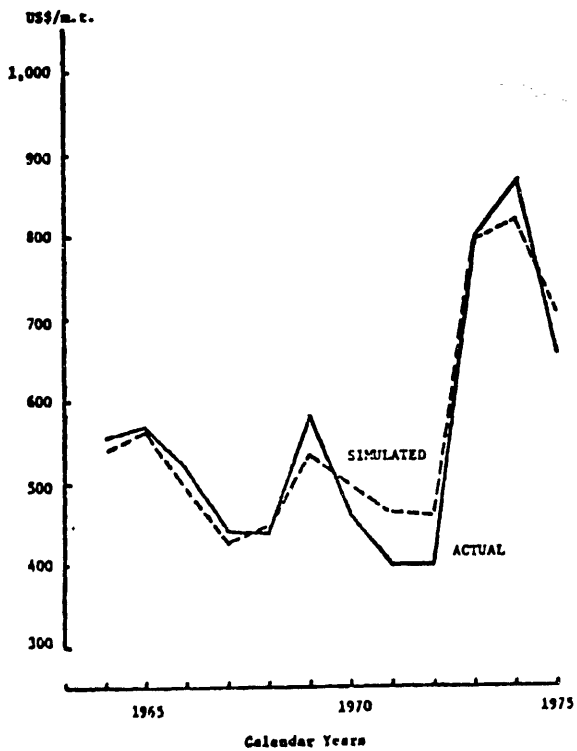
B. NATURAL RUBBER DEMAND



C. NATURAL RUBBER STOCKS



D. NATURAL RUBBER PRICES



B. Price Prospects for Rubber 1/

52. About two thirds of the world production of all elastomers is used in the manufacture of tires and other automotive products. The remaining one third is used in the production of other industrial goods. Industrial production and, in particular, the production of the automotive industries closely mirror changes in the economic situation of a country. Since the demand of rubber depends on the output of these industries, the gross national product (GNP) of a country becomes the single most important variable in determining the demand for elastomers. In the past the relationship between GNP, the production of motor-vehicles and the consumption of elastomers was so strong that it made little difference whether rubber consumption was related to the output of motor-vehicles or to GNP. This strong link between total elastomer consumption has become weaker during recent years. Several reasons account for this phenomenon. First, the rapid expansion of motorization has markedly slowed down in most developed countries; this decline in the rate of expansion will continue for the next 10 to 15 years. Second, growing maintenance costs and increasing traffic density are reducing the intensity with which motor-vehicles are used; this has particularly affected the use of private automobiles. A third factor has been the sharp rise in fuel prices in recent years. The fuel conservation policies of most major oil-importing countries aim, among other objectives, at reducing the size and weight of motor-vehicles. This lowers the rubber demand per vehicle but also the wear and tear of tires.

53. These factors would suggest that, at least, for the major market for rubber, the tire market, the historical relationship between rubber demand and GNP will become weaker. These changes in the structure of rubber demand could be captured in various ways. One possible approach would consist in gradually reducing the historical income elasticities of rubber demand. Another approach would consist in replacing the double-log specification of the demand equations for elastomers with a specification that would imply a gradually declining income elasticity as income (GNP) increases. Linear and semi-log specifications were selected from among the many specifications that possess this property, mainly because the coefficients of these two specifications can be estimated with linear regression techniques. Both specifications entail declining income elasticities. 2/ Table 8 shows the estimated coefficients. The coefficients associated with the income variable (GNP) are all statistically significant.

1/ The discussion of the price prospects for rubber in this section refers to rubber prices in current terms.

2/ The income elasticity of the linear model declines only if total elastomer consumption increases faster than income (GNP). This assumption is met in the case of natural rubber.

Table 8: ESTIMATED EQUATIONS FOR THE PROJECTION OF TOTAL ELASTOMER DEMAND /1

Specification Variable	Constant	Coefficient	Mean Elasticity	R ²	D.W.
I. Semi-log Specification /2					
North America	-9601.00	2690.41 (22.19)	1.16	.96	1.09
Western Europe	-8856.31	2409.30 (27.84)	1.42	.98	0.39
USSR & Eastern Europe	-6832.63	1860.52 (15.44)	1.42	.93	0.25
Japan	-1679.41	530.01 (19.57)	1.05	.96	0.46
Other Dev. Countries	- 702.96	196.87 (18.84)	1.23	.95	1.79
Developing Countries	-3816.11	1018.95 (21.57)	1.66	.96	1.48
II. Linear Specification /2					
North America	- 438.66	32.02 (28.40)	1.19	.98	1.64
Western Europe	- 778.52	29.99 (40.54)	1.46	.99	0.63
USSR & Eastern Europe	- 588.22	23.00 (23.19)	1.45	.97	0.34
Japan	- 72.49	8.15 (35.27)	1.14	.99	0.95
Other Dev. Countries	- 38.85	2.40 (21.31)	1.24	.96	2.21
Developing Countries	- 421.71	12.74 (49.21)	1.69	.99	1.93

/1 The estimation period for all equations is 1956-75. The values in parentheses are the t-values of the estimated coefficients.

/2 The specifications can be written in symbolic terms as follows:

(a) semi-log : $QD_i = a + b \ln GNP_i$;

(b) linear: $QD_i = a + b GNP_i$

where

QD_i = Total elastomer demand in region (i) ('000) m.t.)

GNP_i = Index of real GNP in region (i) (1970=100)

b = Coefficient

54. The linear specification of the demand equations yielded slightly higher income elasticities than the semi-log specification. The price projections (Charts 5a and 5b) reflect these results. Projected rubber prices (in current terms) raise at a substantially slower rate when the projections were based on semi-log specifications for the demand equations. The use of a linear specification yields prices that approximate more closely than any other specification the pattern of natural rubber prices in recent years. Available information about the demand prospects for natural rubber and the expansion plans of the natural rubber industry seem to support the projections results obtained by incorporating the linear demand equations into the rubber model. The semi-log specifications imply a much more decisive break in the relationship between total elastomer demand and GNP than is evident from recent trends in the natural rubber industry.

55. The projected values for the key variables of the model--supply, demand, stocks and prices--are shown in tables 9 and 10. The projections results are presented for three different specifications of the demand equations--double-log, semi-log and linear--and for two basic assumptions--a high one and a low one--about GNP growth in major rubber consuming countries. The assumptions about GNP growth follow those used by the World Bank. The values of most of the other exogenous variables were projected on the basis of past linear trends.

56. The three different specifications of the demand equations and the two basic assumptions about GNP growth provide together six scenarios of the market prospects for natural rubber. The steepest rise in natural rubber prices was obtained when double-log specifications were used for the demand equations of total elastomers; the semi-log specifications fell in between those obtained from the other two specifications. Available information on the likely market prospects of natural rubber seems to support the projections based on the linear specification. 1/ This is further supported by the model simulations for the period 1976-78 which show that the prices obtained from the linear specification of the demand equations were closest to the actual rubber prices in these years (Chart 5a). 2/ Since the projections based on the semi-log specification are clearly too low, rubber producers can look forward to a period of steadily rising prices for natural rubber.

1/ For example, the most recent price projections for natural rubber prepared by World Bank staff indicate a price of US\$1,316 per metric ton for 1982. This price is very close to the midpoint of the projected prices using the linear demand specifications and the high and low assumptions about GNP growth. See: Price Prospects for Major Primary Commodities (Washington: The World Bank, Report No. 814/78, June 1978), pp. 172.

2/ These simulations were conducted assigning the known actual values of the exogenous variables included in the model.

CHART 5a. NATURAL RUBBER PRICES: ACTUAL 1964-1978 AND PROJECTED 1978-1982, LINEAR SPECIFICATION OF DEMAND EQUATIONS

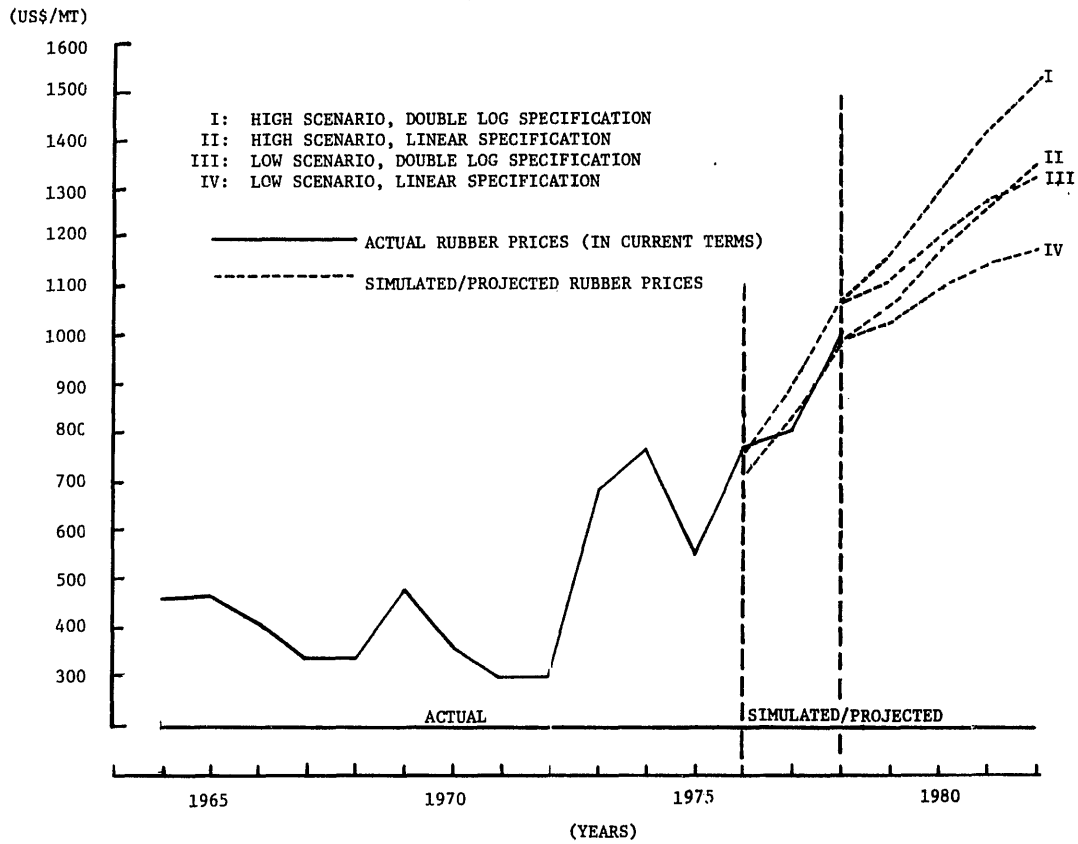


CHART 5b. NATURAL RUBBER PRICES: ACTUAL 1964-78 AND PROJECTED 1978-1982, SEMI-LOG SPECIFICATION OF DEMAND EQUATIONS

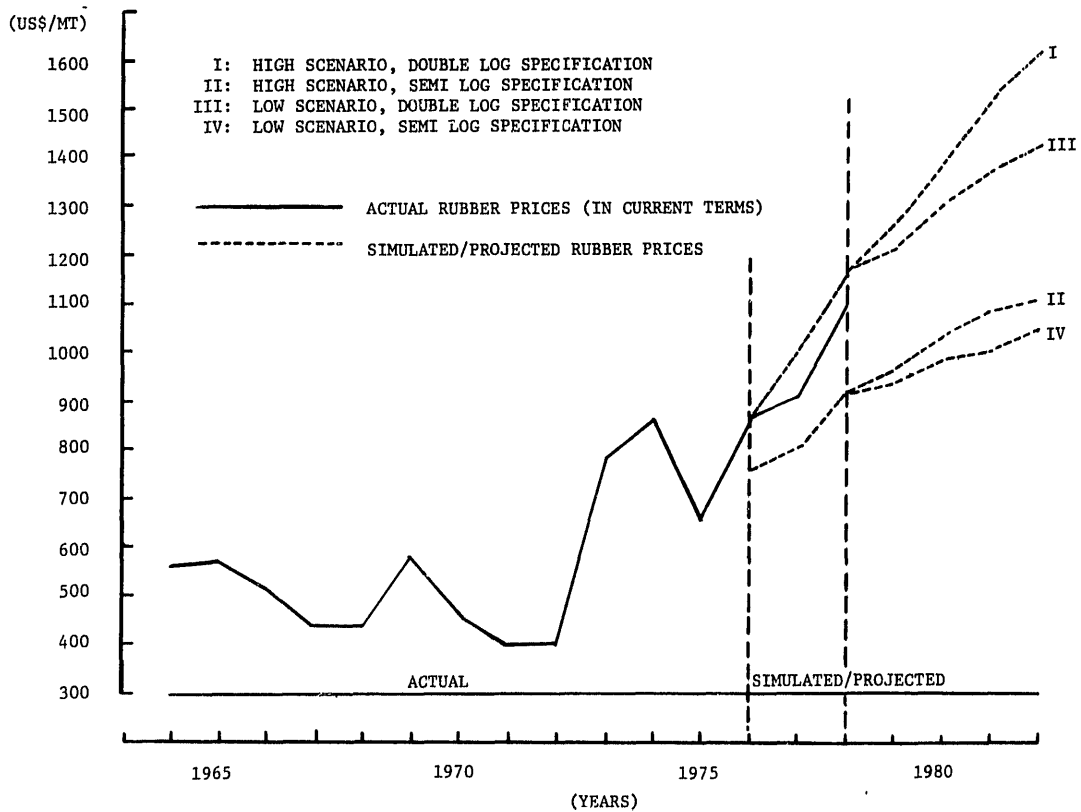


Table 9: MARKET PROSPECTS FOR NATURAL RUBBER UNDER THE ASSUMPTION OF HIGH GNP GROWTH
(Prices in US\$/m.t., Quantities in '000 m.t.)

Year	Double-log Specification				Linear Specification				Semi-log Specification			
	Price	Stocks *	Supply	Demand	Price	Stocks *	Supply	Demand	Price	Stocks*	Supply	Demand
1978	1,173	2,317	3,959	3,873	1,088	2,339	3,896	3,804	923	2,377	3,773	3,671
1979	1,268	2,464	4,145	3,997	1,165	2,490	4,069	3,918	969	2,530	3,922	3,769
1980	1,404	2,611	4,325	4,177	1,277	2,642	4,234	4,081	1,037	2,689	4,063	3,904
1981	1,527	2,780	4,497	4,327	1,374	2,815	4,392	4,218	1,068	2,868	4,195	4,015
1982	1,628	2,909	4,651	4,521	1,446	2,951	4,532	4,395	1,105	3,013	4,309	4,163

* Implied stocks.

Table 10: MARKET PROSPECTS FOR NATURAL RUBBER UNDER THE ASSUMPTION OF LOW GNP GROWTH
(Prices in US\$/m.t., Quantities in '000 m.t.)

Year	Double-log Specification				Linear Specification				Semi-log Specification			
	Price	Stocks*	Supply	Demand	Price	Stocks*	Supply	Demand	Price	Stocks*	Supply	Demand
1978	1,173	2,317	3,959	3,873	1,088	2,339	3,896	3,804	923	2,377	3,773	3,671
1979	1,223	2,479	4,119	3,962	1,131	2,496	4,048	3,891	948	2,535	3,910	3,752
1980	1,312	2,639	4,271	4,110	1,202	2,660	4,191	4,027	990	2,701	4,037	3,871
1981	1,380	2,822	4,410	4,227	1,251	2,844	4,320	4,136	1,010	2,886	4,151	3,966
1982	1,433	2,962	4,534	4,394	1,282	2,988	4,434	4,290	1,063	3,034	4,248	4,100

* Implied stocks.

54. The projected values for the key variables of the model--supply demand, stocks and prices--are shown in Annex Table I.1 for two basic assumptions--a high and a low one--of GNP growth and inflation in major rubber consuming countries. The projections based on the simulation model (with double-log demand equations for all elastomers) considerably exceed those of the projections model (with semi-log demand equations for all elastomers). In essence, each model presents a different scenario. The projections of the simulation model imply that past relationships between rubber demand and GNP in major consuming countries will remain unchanged. Under these assumptions demand for natural rubber would grow between 3.0 and 3.4 percent a year and prices would climb to between US\$1,370 and US\$1,550 per ton (Chart 5). Replacing the double-log demand equations of the simulations model with semi-log equations sharply reduces the effect of GNP growth on rubber demand. The expansion of natural rubber demand drops to about 2.3 percent a year and prices peak at US\$984 and US\$871 per ton in 1980. Available information about the world rubber economy suggests that the close relationship between rubber demand and GNP will change at a slower rate than that implied by the semi-log specification of the model. Rubber producers can, therefore, look forward to a period of steadily rising prices for natural rubber.