THE INFLUENCE OF PRICE FACTORS IN THE COMPETITION BETWEEN NATURAL AND SYNTHETIC RUBBER IN THE U.S. MARKET: AN ECONOMETRIC ANALYSIS*

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The United States market has today become the scene of an epic struggle between the synthetic and natural rubber industries. Until recently synthetic and natural rubber had well defined zones of use where each excelled the other, while there remained a zone where there was competition between the two according to considerations of cost, availabilities of supply, etc. During the last few years, however, research in certain fields of the synthetic industry has led to a break-through of synthetic products into the last bastion of the natural rubber industry — the field of heavy duty truck and aircraft tyres, thus widening greatly the zone of competition between synthetic and natural rubber. The pattern of competition is shown most clearly in the United States which, in 1957 produced well over 90% of the world's synthetic rubber (excluding Russia) and consumed nearly 30% of the total world exports of natural rubber. Thus it has become a matter of importance for the natural rubber industry to estimate the relative strength of the competition offered by the synthetic industry. In assessing this we shall in this survey attempt to determine those factors which influenced the variations in the consumption respectively of synthetic, natural, and reclaimed rubber in the United States during the years 1947-57.

*** Symbols used in this study**

R^t = Total rubber consumed in the U.S.A.
R^s = Total synthetic rubber consumed in the U.S.A.
R^n = Total natural rubber consumed in the U.S.A.
R^r = Total reclaimed rubber consumed in the U.S.A.
P^n = Price of natural rubber
P^s = Price of synthetic rubber
U = Index of manufactured rubber products in the U.S.A.
A = Number of automobiles produced in the U.S.A.
T = Number of trucks and buses produced in the U.S.A.
Z = Profits before taxes of American Corporations
Y = National income of the U.S.A.

U.S. Consumption of Rubber, 1947—1957 (Thousands of Long Tons)

Year	*Natural*	*Synthetic*	*Reclaimed*	*Total*
1947	563	560	288	1411
1948	627	442	261	1330
1949	575	414	223	1212
1950	720	538	304	1562
1951	454	760	346	1560
1952	454	807	280	1541
1953	553	785	285	1623
1954	596	637	249	1482
1955	635	895	312	1842
1956	562	874	271	1707
1957	540	929	267	1736

Source: Percy W. Bidwell — *Raw Materials, A Study of American Policy.*

As will be evident the figures exhibit wide fluctuations in consumption during this period. We shall attempt in the first instance, to explain the factors which determine the major components of variation in each series. In our estimation we shall make use of the methods of correlation analysis.

The demand for all varieties of rubber (R_t) as measured by the total of rubber consumed in the United States by all industries taken together is determined by the quantity of manufactured rubber products (U) in the same time interval.

$$R_t = 128.71 + 11.92\,U \qquad R = .99$$

Year	Index of Manufactured *Rubber Products*
1947	106
1948	102
1949	92
1950	119
1951	119
1952	116
1953	128
1954	115
1955	143
1956	133
1957	135

Source: *Statistical Abstracts* (U.S.A.).

Since we are interested in estimating the relative competitive strength of synthetic and natural rubber as measured by their use in industry, we shall restrict our analysis to the figures of rubber consumed without using the figures on the one hand, of total imports of natural rubber and on the other, the figures of the production of synthetic rubber in the U.S.A., since these series do not always reflect accurately the demands of industry, in as much as a part of this goes abroad as exports and a part into the strategic stockpile of the U.S. government. We found above that total rubber consumed appeared to move in close correspondence with the index of manufactured rubber products (U). The next step, therefore, was to investigate whether each of the components which made up the total of rubber consumed also moved closely with the index (U).

An examination of the relationship between synthetic rubber consumed (R_S) and manufactured rubber products (U) indicated a very high correlation between these two variables of the form

$$R_S = 599.03 + 10.88\ U \qquad R = .90$$

A similar analysis of the relation between natural rubber consumed (R_n) and (U), as well as that between reclaimed rubber (R_r) and (U) did not yield significant correlations. Thus variations in the quantity of manufactured rubber products seemed to have had repercussions on the demand for synthetic rubber only. Expansion and contraction in the demand for rubber by industrial firms was met by corresponding expansion and contraction in the level of synthetic rubber production. It is to be noted, however, that the years 1947-50 during which the synthetic rubber industry continued for the most part, to be owned by the United States government did not reflect this tendency to expansion of synthetics at the expense of natural rubber which was so marked a feature of the subsequent years. The percentage figures of consumption of synthetic to consumption of total new rubber illustrates well this situation.

Year	*Percentage of Synthetic to Total New Rubber*
1947	49·9
1948	41·3
1949	41·9
1950	42·8
1951	62·6
1952	64·0
1953	58·7
1954	51·7
1955	58·5
1956	60·9
1957	63·2

The average percentage of synthetic used, to Total New Rubber, for the years 1947-50 was 44% while there was a sharp increase in this percentage from 1951 onwards giving an average of 59.9% for the period 1951-57, the particularly sharp rise in 1951 and 1952 being due to the need of meeting the urgent military demands of the Korean War. Thus synthetic production rose from 538,000 tons in 1950 to 760,000 tons in 1951 from which level it seldom looked back reaching the record level of 929,000 tons, in 1957. Even at this level of production the industry could not be said to have been working at full capacity since, in 1945, the government owned synthetic rubber industry had a capacity of 1,100,000 tons. One of the chief reasons for the increase in the percentage of synthetic to total new rubber consumed after 1951 was the spate of technical innovations which caused the synthetic product to be substituted for natural rubber in many branches of industry. These innovations made it possible for synthetics to be sold at prices very much lower than those obtaining for the natural product. An investigation of the effect of the price of natural rubber on the consumption of synthetic rubber yielded a significant positive correlation between the price of natural rubber (P^n) with a half-year lag, and the consumption of synthetic rubber:—

$$R_S = 352.19 + 10.82\ P^n_{-\frac{1}{2}} \qquad R = .62$$

It must also be remembered that during the years 46-50 synthetic production failed to expand partly because of the concern of the United States government lest the process of social revolution then going on in the rubber producing countries, especially Malaya and Indonesia, should be accelerated by a fall in the price of natural rubber. All these considerations were swept aside in 1951 when for military and strategic reasons, synthetic production was greatly accelerated, and the growing control of the industry by private enterprise between 1945 and 1955 (by which year all synthetic rubber plants were in private hands), made such an increase in the production of synthetic much more feasible politically.

Finally synthetic rubber by virtue of certain properties which it possessed enjoyed a near monopoly of being the sole supplier of rubber to the automobile tyre industry. An investigation of the variations of (R_S) as determined by the variations in the output of automobiles (A) in the United States produced a highly significant lagged relationship

$$R_S = 143.53 + 110.23A_{-2} \qquad R = .87$$

An explanation for this lag in the relationship would be that the variable A_{-2} indicates replacement demand arising from used automobiles — the variation in A_{-2} seems to explain the variation in R_S much more than the variable A the current output of automobiles which yielded a correlation of only R = .50 with R_S. Although we shall not explicitly make use of A as a determinant of R_S it comes in as an explaning variable since it is included in U the quantity of manufactured rubber products. As the synthetic rubber producers were working well below capacity they could respond immediately to any increase of demand by the manufacturers of rubber products. Similarly production could be expanded during periods when the price of natural rubber was tending to rise. A combined investigation of the influence of these factors on the demand for synthetic rubber yielded the highly significant relation

$$R_S = 447.55 + 6.54\,U + 3.01P^n_{-\frac{1}{4}} + 52.62\,A_{-2} \qquad R = .97$$

Unlike the synthetic product, natural rubber did not move in correspondence with fluctuations in the quantity of manufactured rubber products. The reason for this will become apparent later when we analyse the factors which were leading to variations in the manufacture of rubber products. Although the range in the quantities of natural rubber demanded was not large as that in the synthetic product, the price fluctuations were such as to make it difficult for natural rubber producing countries to make the proceeds of such sales the basis for the financing of a planned programme of investment. Also the relatively high cost of natural rubber due to the rise in wages in producing countries caused by a spate of social welfare legislation passed by the newly independent states made for price differentials between the natural and synthetic product.

U.S. Wholesale Price of Rubber (U.S. Cents per Pound)

Year	*Natural Rubber Price*	*Synthetic Rubber Price*
1947	20·8	18·5
1948	21·9	18·5
1949	17·6	18·5
1950	41·3	19·0
1951	60·9	25·0
1952	38·6	23·5
1953	24·1	23·0
1954	23·4	23·0
1955	39·0	23·0
1956	34·3	23·0
1957	31·1	23·0

Source: *Statistical Abstracts (U.S.A.)*

This gap was widened by the fact that during the period when the U.S. government was in control of the synthetic producing plants strategic considerations had kept the price of the product at a low level as an incentive to the encouragement of its use. This policy cost the U.S. government a sum of nearly 122 million dollars between the years 1943 and 1955, when it decided to give up all proprietary rights in the synthetic industry. Further, when the industry was transferred to private enterprise, the easy terms of transfer made it possible to sell the synthetic product at prices which were very much less than they would have been if the industry had to be constructed entirely from the resources of private enterprise, for in that case the heavy capital investment made in the early and difficult phases of the industry would have had to be recovered in later years a step which would naturally have led to an increase in the price of synthetic rubber. The net result of the existing situation was that synthetic rubber prices did not entirely reflect the costs which had been incurred in its production. Thus there is the possibility that at some future date these price differentials may be narrowed when the cost of producing synthetic rubber is accurately reflected in its market price. This is all the more likely if the costs of producing natural rubber are held down or even reduced below their present level — a prospect which is far from improbable in view of the extensive replanting with high yielding trees which has begun in many of the natural rubber producing areas. As it is, at the present moment the existing price differential has had an adverse effect on the quantity of natural rubber consumed. The relation between the quantity of natural rubber consumed (R_n) and its one year lagged price yields a significant negative correlation.

$$R_n = 739.31 - 5.21P^n_{-1} \qquad R = -.85$$

An even stronger relation was found to exist between the quantity of natural rubber consumed and the lagged price relative between natural and synthetic rubber.

$$R_n = 784.02 - 143.53 \left(\frac{P_n}{P_s}\right)_{-1} \qquad R = -.90$$

There is thus very little room to doubt that the price differential did appreciably affect the quantity of natural rubber consumed in the United States. But a high price of natural rubber in any year would make its effect felt in a falling off of

consumption only in the year following and the decline would be substituted for by the stepping up of production of synthetic rubber. This sequence of events was fairly clearly indicated in the relation which was found between the consumption of synthetic rubber and the half year lagged price of natural rubber

$$R^s = 352.19 + 10.82P^n_{-\frac{1}{2}} \qquad R = .62$$

A point of particular interest is that by contrast synthetic rubber consumption was quicker to respond to the effects of variations in price in the market for natural rubber. This was seen in the shorter lagged price effect on the consumption of synthetic rubber, and is probably attributable to the existence of excess capacity in the synthetic rubber industry with the result that production could be readily expanded in times of rising demand.

What is of even greater interest, is the existence of a lag in the price effect in the relation determining the consumption of natural rubber. This means that the current price of natural rubber does not exert an immediate effect on its consumption. We shall try to explain this phenomenon in the discussion which follows. The price of natural rubber, in common with most other raw materials, is not a major determinant of demand during periods of economic boom. Price considerations affect demand mostly during the downswing of the trade cycle. Thus an investigation of the relation between total world exports of natural rubber and the price paid for natural rubber in the U.S.A. gave a high positive correlation of R=.67 indicating that it was possible to export more rubber during periods of high prices. The rise in price was thus the result of the increase in demand. Thus although we did not obtain a satisfactory relation connecting the total of natural rubber consumed in the United States and its price, it is possible that we might have obtained such a relation expressing the demand for natural rubber as a negative function of its price if we had restricted our observations of the two variables to the years when the conditions prevailing were not those of a seller's market. Unfortunately this was not possible owing to the shortness of the period we had chosen for investigation. Hence it was not possible to determine the demand schedule for natural rubber by investigating the relationship between current consumption and current price, but a very close substitute for the demand schedule was available in the highly significant lagged relationship we had already found between consumption of natural rubber and its price lagged by one year:

$$R^n = 739.31 - 5.21P^n_{-1} \qquad R = -.85$$

We have already analysed the effects of the price of natural rubber on the demand for new rubber. We shall now examine its effect on the reclaimed rubber industry. An investigation of the relationship between the consumption of reclaimed rubber R^r and the current price of natural rubber yielded a highly significant positive correlation

$$R^r = 210.2 + 2.19P^n \qquad R = .82$$

From this we may conclude that a high price of natural rubber led to an immediate increase in the quantity of reclaimed rubber consumed. This was the only sector of the rubber industry which reacted immediately to a change in natural

rubber prices. This is understandable, since the cost to the consumer of manufactured rubber products would have depended at least partly on the price of natural rubber. The wholesale price of rubber and rubber products was found to have a significant positive correlation of R=.70 with the price of natural rubber, thus in periods of high natural rubber prices reclaimed rubber would have been used as a substitute for natural rubber.

We have so far attempted to determine the factors which influence the variations in the demand for rubber. Those which were found to be significant were the output of manufactured rubber products and the prices of natural and synthetic rubber. In order, however, to obtain a more complete view of the variations in the demand for rubber it will be necessary to determine the factors which caused the variations in the last named variables.

In analysing the variations in the output of manufactured rubber products (U) it is necessary to remember that nearly 60% of manufactured rubber products in 1957 went into the motor industry. During the period 1947 to 1957 the demand for rubber products arose mainly from two branches of this industry, namely the automobile and the heavy vehicle tyre (trucks, buses) industries. The demand arising from these two sectors have to be carefully distinguished, since they have different effects on the rubber industry. Automobile tyre manufacturers have, on the whole, been accustomed to use a very high proportion of synthetic rubber in their products, while the heavy vehicle tyres during this period were as yet made mainly out of natural rubber because it possessed certain qualities which were necessary for heavy duty work, and which were absent in the synthetic product as known at the time. An examination of the relationship between the demand for rubber products (U) and the output of automobiles (A) in a year yielded an extremely significant lagged relationship.

$$U = 49.5 + 12.56\, A_{-\frac{1}{4}} \qquad R = .81$$

This would seem to be reasonable since automobiles emerging from the assembly lines would have had to be equipped with a set of new tyres, but the relation does not take into account demand for rubber products arising from the production of heavy duty vehicles. An investigation of the hypothesis that the output of heavy duty vehicles as measured by the production of trucks and buses would explain a part of the variations in the output of manufactured rubber products did not yield any significant result.

Output (Millions)

Year	*Automobiles*	*Trucks and Buses*
1947	3·56	1·24
1948	3·91	1·38
1949	5·12	1·13
1950	6·67	1·34
1951	5·34	1·43
1952	4·32	1·22
1953	6·12	1·21
1954	5·56	1·04
1955	7·92	1·25
1956	5·82	1·11
1957	6·11	1·11

Source: *Statistical Abstracts (U.S.A.)*

As will be seen from the above figures the output of trucks and buses in sharp contrast to the output of automobiles remained fairly constant throughout the period and as such did not greatly influence the variations in the demand for rubber as a whole. In the above analysis we did not take into consideration the replacement demand arising from used vehicles. One method of making allowance for this factor would have been to examine whether there was any significant correlation between (U) and the number of old automobiles in use in a particular year. Such a procedure would have assumed that the replacement demand for tyres from automobiles of different age groups would arise during the same time interval. This was too unrealistic a hypothesis to accept. An alternative method of analysis which suggested itself was to make an estimate of the most significant segment of the replacement demand.

Support for the adoption of this approach was found from the presence of a strong correlation of R=.87 between the consumption of synthetic rubber and the two year lagged sales of automobiles. Since automobile tyres were predominantly made of synthetic rubber, this suggested a two year lagged effect of automobile sales on (U) since U was extremely sensitive to variations in the consumption of synthetic rubber. The correlation obtained between U and A_{-2} was R=.65

We have so far not attempted to explain the variation in the output of manufactured rubber products (U) arising from fluctuations in demand in other sectors of industry. As will be seen from the accompanying table, a not insignificant proportion of the total rubber used in industry came from sectors other than the motor industry.

Uses of New Rubber (%) 1955

Tyres and Tubes	62
Mechanical goods	10
Latex foam products	6
Shoe products	4
Athletic goods, toys, Stationers' goods, sponge rubber	4
Insulated wire and cable	3
Footwear	2
Miscellaneous	9

Source: P.W. Bidwell : *Raw Materials.*

But none of them, taken singly, accounted for more than a very small part of the total demand for rubber products. Thus it did not seem necessary or useful to examine in detail the relation between the fluctuations in production in each of these sectors and their effects on the rubber industry. However, we have not wholly neglected this aspect of the problem in view of the fact that the demand for rubber from these sectors has its origin in a large range of industries in the United States economy, the fluctuations of production in which can be measured by an index of the change in the national income of the U.S.A. (see Appendix). An investigation of the relationship between (U) the index of manufactured rubber products and (Y) the national income of the United States, yielded a significant correlation

$$U = -1205.52 + 3.94\,Y \qquad R = .86$$

Which indicated that the demand for rubber is to a great extent tied to prosperity and depression in the American economy.

An investigation of the effect of price on the demand for rubber products (U) was made difficult by the fact that there was no separate index of the price of rubber products. The only available index was a wholesale price index of rubber and rubber products which did not have a significant correlation with the quantity of manufactured rubber products. Thus a combined investigation of those factors which we found to have significantly explained the variations in demand for manufactured rubber products gave the relation

$$U = 13.19 + 10.83\, A_{-\frac{1}{4}} + .07\, Y + 3.89\, A_{-2} \qquad R = .97$$

It remains to consider the factors which have caused the variations in natural rubber prices. The price of natural rubber is made of two components V and W:

$$P = V + W$$

The variable V depends on supply factors, such as the wage rate and the yield per acre of planted area. The variable W on demand factors, and as such depends on economic conditions in the industrialized countries. We shall first consider the determinants of the value of W.

As is the case with most other raw materials which are not within the monopolistic control of a single producing country the price of natural rubber has not at any time been within the arbitrary control of the producer countries. Thus, except for a brief period during the early 'fifties in the trade between the People's Republic of China and Ceylon, when the price paid for Ceylon rubber was well over that obtaining in the world market, the price for natural rubber has shown a tendency to vary according to economic conditions in the capitalist world. The time series of profits before taxation (Z) of American corporations, is a representative indicator of economic activity in the American economy (see Appendix). This time series has a correlation of R = .65 with the series of prices of natural rubber, but this relation does not explain much of the variation that has occurred in the price series. Since the production of heavy duty tyres accounts for a major proportion of natural rubber consumed, we have used the series of the output of trucks and buses (T) as a factor to explain the variation in natural rubber prices. This estimation yielded a correlation of R = .53 with natural rubber prices.

A combined investigation of the effects of these two factors on the prices of natural rubber yielded the relation

$$P_n = -79.91 + 53.64\, T + 1.29\, Z \qquad R^2 = .69 \qquad R = .83$$

It will be seen that this relationship explains only about 70% of the variations in the price series. An important contributory factor which we have not so far taken into account and which influences the price of natural rubber is the release for sale from time to time of natural rubber from its stockpile by the United States government. Heavy disposal of such stocks has always tended to depress the price of natural rubber. For the particular period of our study,

however, this has not been a factor of major importance. Finally, as we have shown above, the price relative between synthetic and natural rubber determines to an appreciable extent the quantity of natural rubber consumed. Thus, although the price of synthetic rubber will necessarily have a restraining influence on the price of natural rubber, it is not possible to estimate the exact nature of the relationship between these two price series owing to the fact that the synthetic rubber price series in contrast to the natural rubber price series shows a remarkable constancy free from the violent fluctuations which have beset natural rubber prices. One of the important factors which determines the component (V) of price is the cost of production of rubber on the plantations of Malaya and Indonesia. A major proportion of this cost goes as wages of labour, but it is doubtful whether wage rate alone, which has been exhibiting a steady trend in recent years, can explain the wide fluctuations in the price of natural rubber.

Thus, we now have the basis of a model for explaining the variations in the market for rubber in the United States.

$$R^s = -447.55 + 6.54\,U + 3.01\,P^n_{-\frac{1}{2}} + 52.62\,A_{-2} \qquad R = .97$$

$$R^n = 784.01 - 143.53\left(\frac{P^n}{P^s}\right)_{-1} \qquad R = -.90$$

$$R^r = 210.2 + 2.19\,P^n \qquad R = .82$$

$$U = 13.19 + 10.83\,A_{-\frac{1}{4}} + .07\,Y + 3.89\,A_{-2} \qquad R = .97$$

$$P^n = -79.91 + 53.64\,T + 1.29\,Z \qquad R = .83$$

The assumption that the residuals of these estimated relations were serially uncorrelated was fundamental to the method of estimation of these structural equations. A test of this assumption was carried out for each of the structural equations by means of Von Neumans' Statistic.[6]

The test did not indicate the presence of any serial correlation among the residuals.

Equation for	Von Neumans' Statistic	N (Sample size)
R^s	2·91	9
R^n	3·34	10
R	2·50	11
U	2·48	9

The next stage of our analysis was to test the validity of the model as a means of extrapolating for extra sample data. For this purpose we have compared the error in the estimated value of each of the explained variables for the extra sample year 1958 with the errors prevalent in the model for the sample period. The testing procedure adopted was that proposed by Carl F. Christ [4] — A tolerance interval was constructed for the disturbances in each structural equation, and it was examined whether the error in the estimate for the extra sample year fell within this tolerance interval. If the error fell within this estimated

interval then the inference was that there was no significant evidence to suspect a change in the structure of each of the equations so investigated.

Equation For	Real Value	Estimated Value	Error of Est.	Tolerance Int.
R^s	880	766	114	± 270
R^n	485	590	105	± 190
R^r	248	272	24	± 95
U	125	118	7	± 29

Each tolerance interval was constructed so that 99% of the residual errors generated by the estimated structural equation would be included within its limits with a probability equal to .99. As is shown in the above table since the errors fell within the tolerance interval the test did not indicate any structural change in any of the estimated equations, but a comparison of the predictions made for the extra sample year 1958 with the actual value obtaining for that year indicates the presence of a considerable degree of error in many of our estimates.

Equation for	*Percentage Error in Estimate for* 1958
R^s	12·9
R^n	21·6
R^r	9·6
U	5·6

Now these percentage errors can be used to give an estimate of the losses resulting from the use of a structural equation for the purpose of prediction, but they can in no sense be used as a measure of the reliability of each estimated structural equation. In this connection Milton Friedman commenting on Carl F. Christ's "test of an econometric model of the United States of America 1921-1947", says:

> But how shall we assess the adequacy of prediction? Obviously we need not require perfect prediction; so the question is when are the errors sufficiently small to regard the prediction as unsuccessful? We cannot judge by the absolute size of the error; on what grounds are we to say that an error of, say, $ 1 billion is either small or large? Nor do percentage errors help much, even though they seem intuitively more relevant. An error of 2 per cent means one thing if the variable being predicted never varies by more than 3 per cent and quite a different thing if it usually varies by 50 per cent. Moreover, the percentage error is itself really arbitrary. For example, suppose we know income and seek to predict savings and consumption expenditures. Since consumption expenditures will be something like 10 times as large as savings, a 20 per cent error in savings will be approximately a 2 per cent error in consumption. Which is the appropriate number for judging the adequacy of the prediction? The 2 per cent or the 20 per cent error?"[4]

Thus according to the test procedure based on the method of tolerance intervals we have no basis for suspecting a change in the structure. But we have reason to suspect that our model is not sufficiently precise because other simple tests seem to indicate a very marked structural change in the market for rubber

in the United States. An examination of year to year movements of the quantity of natural rubber (R^n) consumed in relation to the one year lagged price ratio $\frac{P^n}{P^s}$

Year	R^n	$\left(\frac{P^n}{P^s}\right)_{-1}$	
1948	627	1·12	
1949	575	1·18	
1950	720	·95	
1951	454	2·17	
1952	454	2·44	
1953	553	1·64	
1954	596	1·05	
1955	635	1·02	
1956	562	1·70	
1957	540	1·49	contrary movements
1958	485	1·35	

indicated that for the first 9 of the 11 years of the sample of values from which the structural equation was estimated the quantity of natural rubber consumed rose in relation to a fall in the one year lagged price ratio of natural to synthetic rubber, the estimated structure being

$$R^n = 784.02 - 143.53 \left(\frac{P^n}{P^s}\right)_{-1}$$

But it will be seen that in the years 1957 and 1958 a decrease in the lagged price ratio produced a decrease in the quantity of natural rubber consumed, a movement which was contrary to that experienced in the previous 9 years. This gives us room to suspect that there have been structural changes in the rubber market in the late fifties and that factors other than those specified in our model have arisen as important determinants of natural rubber consumption. Thus a use of the structural equation of 1948-57 to estimate consumption for 1958 yielded an estimate of 590,000 tons when the actual consumption was only 485,000 tons — an over estimation of natural rubber consumption by nearly 22%. Similarly the estimated figure of synthetic rubber consumption for 1958 of 766,000 tons deviated considerably from the figure of 880,000 tons actually consumed. Actual consumption was thus underestimated by nearly 13%. On the other hand, if we take the total of synthetic and natural rubber consumed the estimated value of 1,356,000 tons is very close to the actual value of synthetic and natural rubber consumption which was 1,365,000 tons, thus showing that the factors which determine the total demand for new rubber had remained unchanged while there had been a redistribution in the composition of this total, in the form of a shift away from natural and towards synthetic rubber. This may have been due to the growing research in synthetics which had led to the discovery of suitable substitutes for natural rubber for use in many of the markets hitherto monopolised by the natural rubber industry. This process has today culminated in the production of a synthetic rubber which it is claimed can be used for the manufacture of heavy duty tyres and, before long, with the successful marketing of this product the last great bastion of the natural rubber producing industry will have been invaded by the synthetic manufacturer.

Implications for producing countries

Thus natural rubber has today lost its last privileged hold on the rubber manufacturing market, and it is to be expected that, with the increasing substitutability between the synthetic and natural products, price would come to play an even more important role in the ensuing competition than it has ever done before.

The degree of price competition, in the long run, will necessarily be determined by the cost composition of the two commodities. Today the synthetic product selling at a lower price is in a much more advantageous position for an attack on the markets of the natural rubber industry than ever before. Hence, to achieve even the modest goal of even preserving the status quo in the division of the rubber market, the gap in prices between the synthetic and natural products will have to be considerably bridged. The lowering of natural rubber costs will depend on a number of factors. Firstly, costs of administration could be reduced if there is a proper reorganization of rubber estates on a regional basis in place of the presently prevalent system under which a single company's estates are distributed over a country in a haphazard and uneconomic manner due to circumstances which are mainly historical in character, such a reorganization by cutting down the number of companies operating in a given area could lead, not only to a lowering of overhead costs but also to an increase in the efficiency of production. Further, the adoption of new techniques of cultivation including the use of high yielding clones promises a substantial increase in yield per acre. This has acquired a new urgency and importance in view of the rising wage bill of the rubber estates consequent on the enforcement of higher wage rates by the newly independent governments, the rise in costs being significantly high due to the fact that a man-year of labour in the natural rubber industry produces between one to two tons of natural rubber while in the synthetic industry it produces between 500 and 1000 tons.[9] Thus, the question of increasing productivity has become extremely urgent in the natural rubber industry. In the synthetic industry labour costs are well under 10% of total production costs, the important items being the capital cost of constructing the synthetic rubber plants and the raw material cost of synthetic manufacture. Hitherto the interest cost of the capital outlay in the synthetic rubber industry has not been as heavy as it would have been if the government had not undertaken the preliminary cost of the setting up of the synthetic rubber plants. However, these items which account for nearly 50% of total cost today, will before long grow more burdensome as the need arises to finance replacement of depreciated equipment, to conduct research into the manufacture and use of synthetics and finally to construct new manufacturing plants as the existing plant wear out.

Furthermore, the price of the raw materials used in the manufacture of synthetic rubber, which are mainly obtained from the petroleum industry, have been substantially low owing to the monopoly control of the world mineral oil resources by Western Oil Companies. These agencies have made it a matter of policy to sell their products to the industries of their respective countries at prices which are relatively low. Such a policy is rendered easier

and more attractive by the fact that considerable holdings of shares in the synthetic industry are owned by these same oil interests. This fact has also made it both profitable and necessary for the oil companies in their own interests to help the synthetic industry in the battle against natural rubber by selling their products at low rates to the synthetic rubber producers. It is however, doubtful how long this trend will continue in the face of increasing control which is now coming to be exercised over the oil industry by those countries in which the oil is found, and their increasing clamour for a greater share of the profits being earned by the oil industry. Finally, it is felt in the natural rubber producing countries that the synthetic producer reaps his profits not primarily from the sale of the synthetic rubber itself, but from the sale of manufactured products made from synthetic rubber, thus enabling him to keep the price of synthetic at a level which can completely outprice natural rubber while at the same time making his margin of profit by the marking up of the price of the manufactured product. This becomes strictly evident from the fact that the price of synthetic rubber has remained stable over the period while tyre prices in the manufacturing countries have shown a noticeable rise.

Price Indices

Year	*Synthetic Rubber*	*Tyres and Tubes*
1947-49	100.0	100.0
1950	102.8	113.6
1951	135.3	133.9
1952	124.4	129.8
1953	124.4	127.2
1954	124.4	130.6
1955	124.4	144.9
1956	124·4	152.2
1957	124.4	150.9

Source: *Statistical Abstracts U.S.A.*

This has been made possible by the close link existing between the synthetic rubber producer and the tyre manufacturers who are the major consumers of synthetic rubber. The motor tyre industry has, accordingly, been closely associated with the development of the synthetic industry, and this connection has made it possible to control independent tyre producers who do not keep to line, by the threat of the denial to them of their raw material supply, by the highly organized synthetic rubber cum tyre manufacturers.

Commenting on the sale of government owned synthetic plants to private enterprise, a minority report of the Senate Committee on Banking and Currency pointed out that 88 per cent of the capacity for producing GR-S and butyl rubber (which together comprise the bulk of American synthetic rubber production) would be owned by four large rubber companies and three large oil companies.

"The remainder . . . . . is in the hands of other relatively large rubber fabricaters or users. It is from these source that small-businessmen must obtain their supply of synthetic rubber. The minority doubted whether guarantees provided in the sales contracts, that producers of GR-S should supply certain percentages of their output to small business enterprises, would be of much practical value".7

The report was equally sceptical regarding competition among the new owners.

These industries (rubber and oil)", it stated, "have been notorious in their disregard for antitrust laws, or Federal trade laws, or both. The hearings before committees of the Senate and the House are replete with documentation of court cases involving these industries with pleas of guilt or no contest to charges of price fixing, discounts, bonuses, classifications of customers, allocations of sales territories, etc. In short, the public record does not demonstrate a history of competitive actions but rather of concerted actions.[7]

Hence it is not surprising to find that the Chemical Good Year Division, a major producer of synthetic rubber, is an integral part of the Good Year Tyre and Rubber Company of Akron Ohio. Commenting on the remarkable stability of synthetic rubber prices Charles Meredith, writing in the *Tea and Rubber Mail*, says:

There is too much simple faith on the part of the advisers and critics of rubber growers in the alleged costs of rubber's synthetic competitors. It is an economic impossibility for the price of a material, composed of many kinds of other materials constantly fluctuating in value, to be maintained in the normal way at a fixed level. The large American manufacturers control sales of the artificial product and its price can be manipulated unnoticiably in that of what they term 'the end product' of which the rubber line material forms only a small percentage. In these circumstances there would be nothing to prevent them from fixing the price of synthetic below that of natural rubber. Broadly speaking the criticisms of the quality of natural rubber have emanated from the U.S.A. where it competes with their man made products. In this connection it is interesting to note that the Americans buy a large proportion of the so described inferior grades.[8]

Thus we can be fairly certain that the real profits of synthetic rubber manufacturers are not fully reflected in the price of synthetic rubber. The synthetic product is thus at an advantage in that profits are not such an important item in its market price as is the case with natural rubber where the profits of predominantly foreign owned companies are a significant item of cost.

Thus the price war between synthetic and natural rubber is entirely one sided in the sense that synthetic manufacturers have a control over the price of synthetic rubber, a connection which is absent in the case of natural rubber producers where price is mainly determined by factors which, as we have seen, are not within the control of the producer. In this context it is interesting to note the statement of Dr. J.D. Dianni, of the Good Year Tyre and Rubber Co., who in an address to the 5th annual meeting of the American Institute of Chemical Engineers in New York in 1961 has forecast that in five years from now the synthetic rubber component in the rubber consumed in the U.S. will rise to 80%. He stated:"The battle between natural and synthetic rubber will continue, but now purely on economic grounds".[2]

The main purpose of this article has been to fundamentally question this proposition. As we have seen the estimated structural equation denoting the demand for natural rubber

$$R^n = 784.02 - 143.53 \left(\frac{P_n}{P_s}\right)_{-1}$$

has changed in the years 1957 and 1958. The very considerable reduction in the price of natural rubber in relation to the price of synthetic rubber which took place during these years did not result in an increase even in the absolute quantity of natural rubber consumed (562,000 tons in 1956 as against 540,000

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tons in 1957), leave alone an increase in the percentage share of the total rubber consumed. In fact the contrary appeared to have taken place and the percentage of natural to total new rubber consumed actually decreased from 39.1% in 1956 to 36.8% in 1957. On the other hand, according to the structural relation, as estimated for the period 1947-57

$$\frac{R^n}{R^n + R^s} = 65.02 - 13.08 \left(\frac{P^n}{P^s}\right)_{-1} \qquad R = .71$$

a lowering of the price relative should have resulted in an increase in the percentage share of natural rubber consumed. Thus if we are to go on the facts of the actual quantities of the respective varieties of rubber consumed in the United States we are forced to conclude that price relatives are no longer an important determinant of the relative quantities of natural and synthetic rubber consumed.

Thus basing our conclusions on the data of prices, and consumption, of natural and synthetic rubber in the U.S., while we agree with Dr. Dianni of Good Year that the battle between synthetic and natural rubber will in the future continue on economic grounds, we are also left with the uncomfortable feeling that it might in the result be the economics of monopolistic trade practices which are characteristic of the American economy.

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APPENDIX

Year	National Income of U.S.A.	Profits before Taxes of American Corporations
	(Billions of dollars)	
1947	234·3	23.6
1948	259·4	30·8
1949	258·1	28·2
1950	284.6	35·7
1951	329·0	41·0
1952	347·0	37·7
1953	365·4	37·3
1954	363·1	33·7
1955	397·5	43·1
1956	419·2	42·9
1957	440·0	41·9

Source — *Statistical Abstracts, USA*, 1947 — 1958.