SYNTHETIC FIBRES IN THE WOOL TEXTILE INDUSTRY

A STUDY OF THE ROLE OF PRICE IN TECHNOLOGICAL ADJUSTMENT*

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1. *Introduction*

Conventional growth curves, such as the logistic and Gompertz, though both useful and successful as descriptive measures, lack economic substance.[1] Where a new product is developed expressly to compete with an existing close substitute, any economist might reasonably expect the relative prices of the two goods to be relevant to the rate at which the innovation is adopted. Yet growth curves of the class mentioned above are functions of time only.[2]

In this paper we attempt to allow for the influence of price. The logistic law of growth remains basic to the pattern of adoption in our model. However, it is assumed that relative prices can both *accelerate* the rate of adoption, and affect the *long-run share* of the market enjoyed by the new product. (We shall use the term *price-accelerated trend* to designate this type of model.) Such a model is fitted to U.S. quarterly mill consumption of synthetic staples and virgin raw wool for the period 1954-1962, with some surprising results.

2. *Pure Trend Fitted*

Since the advent of rayon between the two world wars, no new man-made substitutes for wool became commercially important until the late 1940's. Since that time there has been a steady growth in the consumption of synthetic staples;[3] so that, by June, 1962, as much

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[1] A highly successful example of the use of the logistic in describing the process of market saturation is afforded by Zvi Griliches, "Hybrid Corn: An Exploration in the Economics of Technological Change", *Econometrica,* 25 (4), 1957, 501-522. Griliches, however, goes on to give economic substance to his study by explaining cross-sectional differences in fitted logistics by factors of supply and demand.

[2] For a mathematical description of these (and other) growth curves, see, e.g., A. Hald, *Statistical Theory with Engineering Applications,* Wiley, New York, 1952, pp. 658-662.

[3] Our attention in this paper is confined to synthetic materials in staple form since these tend to be more directly competitive with wool than filament yarn which is known to have displaced substantial quantities of cotton, silk, and rayon. For our present purpose this seems a legitimate restriction for we do not claim to investigate the entire pattern of inter-fibre competition, but merely attempt to assess the impact of new textile technology and of changing wool-synthetic prices in an area where wool has suffered the most serious set-backs in recent years. The results which we obtain should evidently be interpreted in that light.

non-cellulosic man-made fibre was consumed in the U.S. textile industry as virgin apparel wool.[4]

If a variable y_t is defined as the ratio (consumption of synthetic staples) / (consumption of raw virgin wool + synthetic staples) in the t^{th} quarter, for textile mills in the U.S., we obtain the series reproduced

TABLE 1

Quarterly Price and Consumption Data for Synthetic Staples and Virgin Raw Wool: United States, 1954-1962

1 Year and Quarter	2 Consumption of Virgin Raw Wool million lb.	3 Estimated Consumption of Non-Cellulosic Synthetic Staples million lb.	4 Price of Non-Cellulosic Synthetic Staples cents per lb.
1954 M	62.91	9.13	157.2
J	72.86	14.80	150.8
S	69.87	17.25	150.8
D	62.19	20.77	150.8
1955 M	70.75	20.31	150.8
J	71.76	21.77	150.8
S	68.39	27.41	150.8
D	70.25	24.16	139.8
1956 M	79.63	26.21	124.8
J	77.44	30.15	124.8
S	70.27	31.00	124.8
D	69.36	31.02	125.7
1957 M	70.35	38.85	127.7
J	67.94	41.25	127.7
S	58.51	40.81	127.7
D	44.61	33.86	128.8
1958 M	48.34	34.16	128.8
J	54.29	34.50	128.8
S	57.22	45.89	128.8
D	58.37	46.12	128.8
1959 M	64.13	49.41	128.0
J	71.17	52.33	128.0
S	66.90	54.07	128.0
D	59.05	51.81	128.0
1960 M	64.11	56.01	128.0
J	67.43	57.59	128.0
S	61.63	49.83	128.0
D	50.90	48.71	128.2
1961 M	57.37	52.67	129.5
J	70.15	64.40	125.5
S	68.25	57.37	124.5
D	68.10	58.58	122.5
1962 M	71.87	65.30	
J	74.32	72.84	

Sources: Column 2. U.S. Department of Commerce, *Survey of Current Business*, 1954-1962.
Column 3, derived from *Textile Organon*, 1954-1962.
Column 4, derived from U.S. Department of Agriculture, *Wool Statistics and Related Data, Supplements*, for 1957, 1959 and 1961; and U.S. Department of Commerce, *Survey of Current Business*, 1954-1962.

[4] See Table 1.

TABLE 1 (continued)

Quarterly Price and Consumption Data for Synthetic Staples and Virgin Raw Wool: United States, 1954-1962

5 Year and Quarter	6 Wool Price Boston Market cents per lb.	7 Synthetics' Share of the Market 3/(2 + 3)	8 Relative Price of Wool 6/4
1954 M	147.8	12.7	0.940
J	152.3	16.9	1.010
S	154.4	19.8	1.024
D	145.8	25.0	0.967
1955 M	141.5	22.3	0.938
J	134.9	23.3	0.895
S	129.1	28.6	0.856
D	120.9	25.6	0.865
1956 M	124.6	24.8	0.998
J	122.5	28.0	0.982
S	127.3	30.6	1.020
D	140.5	30.9	1.118
1957 M	144.0	35.6	1.128
J	148.8	37.8	1.165
S	150.1	41.1	1.175
D	137.7	43.3	1.069
1958 M	120.9	41.4	0.939
J	106.8	38.9	0.829
S	106.5	44.5	0.827
D	103.5	44.1	0.804
1959 M	102.8	43.5	0.803
J	113.1	42.4	0.884
S	122.8	44.7	0.959
D	122.5	46.7	0.957
1960 M	120.8	46.7	0.944
J	119.4	46.1	0.933
S	116.1	44.7	0.907
D	112.2	48.9	0.875
1961 M	110.3	47.9	0.852
J	113.7	47.9	0.906
S	116.9	45.7	0.939
D	117.6	46.2	0.960
1962 M		47.6	
J		49.5	

Column 6, derived from U.S. Department of Agriculture: *Wool Statistics and Related Data, Supplements* for 1957, 1959 and 1961.

(See Appendix for details of the derivation of the data appearing in this table.)

in column 7 of Table 1.[5] This series is consistent with a sigmoid growth pattern, as may be seen from Figure 1. Figure 2 shows the same data plotted on a semi-logarithmic chart, together with a fitted logistic trend function.[6] The fitted curve explains 96 per cent of the variance of the

[5] For a discussion of the sources and method of compilation of the data, see the Appendix.

[6] The method of fitting follows Griliches (*op. cit.*). However, the limiting share of the market was varied and the (conditional) least-squares estimates of the logistic transform iterated until the minimum residual sum of squares was obtained. This estimating procedure did not result in a large departure from orthogonality in the analysis of variance, the term due to the cross product being — 3 per cent of the total sum of squares.

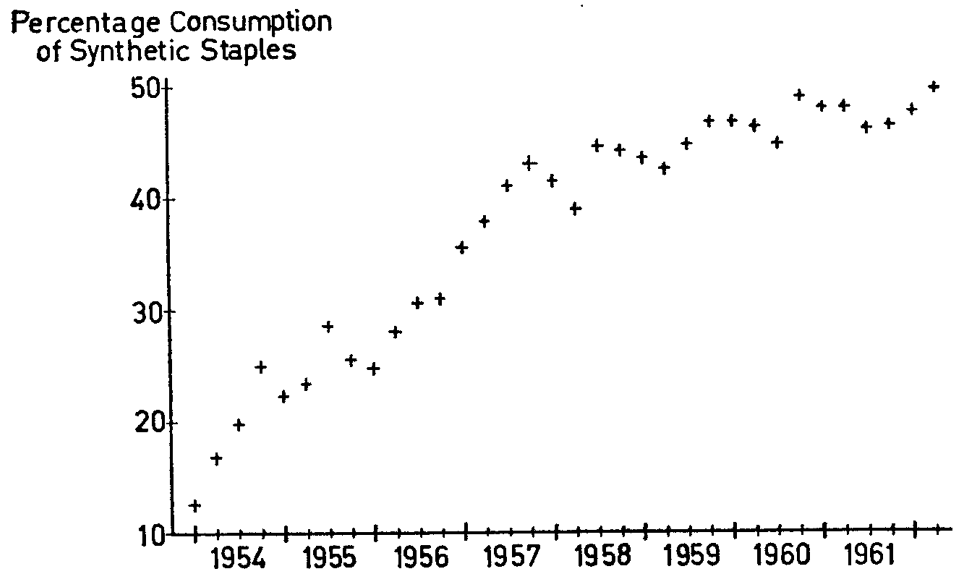
Percentage Consumption
of Synthetic Staples
50
40
30
20
10
1954
1955
1956
1957
1958
1959
1960
1961

FIG. 1

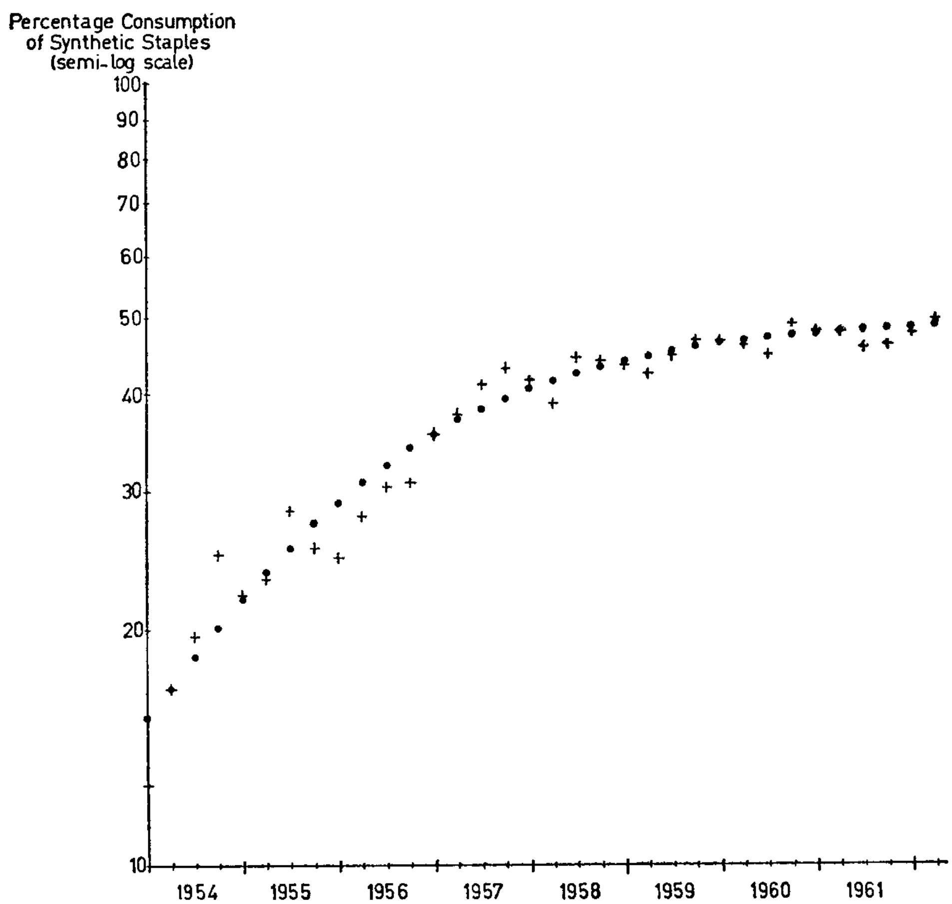
Percentage Consumption
of Synthetic Staples
(semi-log scale)
100
90
80
70
60
50
40
30
20
10
1954
1955
1956
1957
1958
1959
1960
1961

FIG. 2

+ Observations
● Trend values

series $\{y_t\}$, and has a ceiling of 50 per cent. Clearly, there is little scope for improving the fit by introducing price considerations. Moreover, the lack of a significant correlation ($\hat{r}^2 = .02$, $N = 34$) between the deviations from fitted trend and the relative price variable, did not augur well. But unless an attempt is made to allow for the effect of price, we can say nothing—not even a negative something—about its role in the technological adjustment of the market. The existence of a trend in relative prices would, of course, make inference difficult; whilst its absence would make a good fit unlikely. In fact the latter eventuates, as will be seen.

3. *Price Accelerated Trends—Theory*

Each y_t is assumed to lie (apart from a random error) on a logistic function L_t. The logistic trend function has three parameters, which have been termed (in loose parlance) the *origin,* the *rate of adoption,* and the *ceiling.*[7] All three of these terms are retained, although the concept of the *long run share of the market*[8] will be used interchangeably with the last. The following postulates are adopted:

1. The rate of adoption β_t specific to any L_t is a monotonic increasing function of the relative wool price p_t = (price of wool in t) / (price of synthetics in t). This function is assumed to be of the shape shown in Figure 3, so that there exists some finite wool

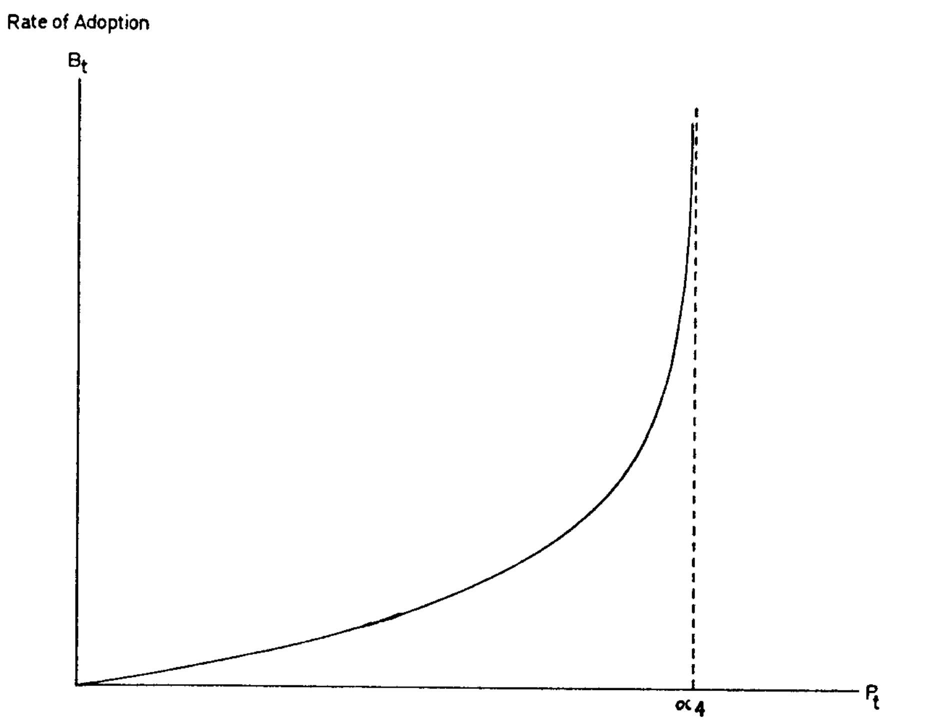

FIG. 3

[7] Griliches, *op. cit.*

[8] It will be appreciated that "share of the market" takes a restricted meaning within the present context, since the fibre market is more broadly based than is indicated by considering two fibres alone.

price level a_4 which would theoretically result in an instantaneous switch into synthetics.

2. The long run share of the market K_t associated with any L_t is also assumed to be monotonic increasing in the relative wool price and of sigmoid shape.

The predicting equation of the resulting model of price-accelerated trends is

$$(1) \qquad \hat{y}_t = K_t \,/\, \{1 + \exp\,(-\,a_1 - \beta_t t)\}$$

K_t is interpreted as the long run share of the market since it represents the limiting market share to which the use of synthetics would tend at a rate β_t if the price ratio p_t persisted indefinitely. a_1 is an origin-fixing parameter which is assumed to be common to all L_t. [9]

The logical constraints on the ceiling K_t are [0, 1]. It seems reasonable that the long run market share enjoyed by synthetics should approach unity as the price ratio p_t approaches infinity. Likewise, one would expect this share to approach zero as the price of wool approaches zero. Thus a sigmoid shape for the response of K_t to p_t seems indicated, and once more we adopt the logistic form as a convenient approximation:

$$(2) \qquad K_t = 1 \,/\, \{1 + a_2 \exp\,(-\,a_3\, p_t)\}.$$

Under the assumptions made, the only structural inconsistency in this formulation of K_t is that this function does not approach zero as p_t approaches zero, the limit being $1/(1 + a_2)$ instead. However, the approximation should prove adequate in the neighbourhood relevant to the empirical data. In fact, this formulation possibly is superior in that new uses for synthetics may be found in the long run for which wool fibre would never be substituted, irrespective of price.[10]

The rate of adoption is less easily formulated as a function of price. It has logical limits [0, + ∞]. The lower bound implies that the percentage use of synthetics would remain invariant over time at some fraction of the hypothetical ceiling value. The upper bound implies an instantaneous adoption of the full ceiling content of synthetics. Since one can conceive of a (finite) wool price a_4 so high that virtually instantaneous adoption of synthetics would take place, it would seem that we need a function β_t with the following properties:

$$\beta_t\,(0) = 0$$

and

$$\lim_{p_t \to a_4 +} \beta_t\,(p_t) = \infty \quad .$$

Consider the functional form:

$$(3) \qquad \beta_t = \ln a_4 - \ln\,(a_4 - p_t).$$

[9] Strictly speaking, this parameter determines (for a given β_t) the date at which any arbitrary percentage adoption will have taken place. The logistic has no proper origin, being asymptotic to zero as time approaches minus infinity.

The above formulation implies that, had price conditions in the past remained stable at p_t, the date at which (say) 10 per cent of K_t would have been realised, is inversely proportional to β_t. The constant of proportionality in this relation is hence assumed constant for all L_t.

[10] The specific functional form chosen is not critical, since none of the observed data lie in the neighbourhood of the lower bound; and since, at all events, we do not intend to make predictions in this neighbourhood.

It is clear that (3) satisfies these requirements. Moreover, this function has derivative $1 / (\alpha_4 - p_t)$, and hence is approximately linear over lower values of p_t, but rapidly approaches infinity when p_t is large. The fact that only a single parameter is involved adds to the suitability of (3) for empirical work.

Long-Run Elasticity of Demand

Implicit in our formulation so far has been the assumption that the *total* demand for fibre by wool textile manufacturers will vary in response to changes in per-capita real income, population, and perhaps other macro-variables. Moreover, we explicitly assume that the effects of fluctuations in total demand do not discriminate between the competing fibres, except in so far as any such differential impact is reflected in relative prices. Under these conditions it is possible to define a long-run demand elasticity concept with a precise operational significance; i.e.:

$$(4) \qquad \eta = \frac{\partial\,(1 - K_t)}{\partial\, p_t} \frac{p_t}{(1 - K_t)} = - \alpha_3\, p_t\, K_t$$

$$= - \alpha_3\, p_t \,/\, \{1 + \alpha_2 \exp\,(- \alpha_3\, p_t)\}\ .$$

This measure indicates the percentage change in the long run share of the market enjoyed by apparel wool per one per cent change in the relative price regime. That is to say, if one imagines two regimes of stable relative prices, in the second of which the price persisting indefinitely is 1 per cent above that of the first regime, the measure η will determine the percentage difference between the long run market shares which (eventually) would attain in each case. This elasticity, as expected, is an increasing function of price and is independent of the date of measurement.

4. *Estimates of Price-Accelerated Trends*

The critical consideration affecting the suitability of any particular method of fitting the model is, of course, the distribution of the error term implicit in (1). One of two assumptions is typically made by empirical workers in situations of this sort. The first is to assume an additive error $u_t = (\hat{y}_t - y_t)$ which has zero expectation, is not autocorrelated, and follows the normal distribution. The alternative is to assume a multiplicative error with unit geometric mean and which, when transformed into the logarithms, has the same properties as u_t.

Either of these assumptions will enable the computation of (quasi) maximum-likelihood estimates of the parameters, and asymptotic standard errors of the estimates. Alternatively, least-squares estimates may be computed. The assumption of normally distributed errors may be used in order to compute approximate confidence regions for the parameters from small-sample theory.[11] In this paper, the least-squares approach is employed, although—as will be seen—not altogether successfully.

[11] A highly elaborate theory of such confidence regions has been developed by E. M. L. Beale. See his "Confidence Regions in Non-Linear Estimation", *Journal of the Royal Statistical Society* (Series B), 22 (1), 1960, 41-88. Empirical applications to date have been few, even in the analysis of controlled experiments.

Computational Procedure

Even though the model of price-accelerated trends involves but a single equation, its extreme non-linearities result in computational problems no less formidable than those met in fitting a simultaneous linear system by maximum likelihood. Explicit solutions are not available, and it becomes necessary to use a gradient method of minimisation. We have employed an algorithm, using the Newton metric in computing the estimates presented here.[12] Although using this technique we were able to locate the approximate neighbourhood of the minimum of the sum-of-squares function, the precise minimising values of the parameters escaped detection. This was very probably due to attenuated ridges of the surface in parameter space. However, our most important conclusions can be inferred from the results so far obtained. Since a very heavy further investment in research effort would be required to obtain results of little marginal value, we have deferred the problem of obtaining an optimal fit for the time-being.[13] Instead, we present here two sets of results which are in the neighbourhood of the minimum, and which almost certainly straddle the least-squares estimates. Comparison of the two sets can be interpreted as a somewhat stringent sensitivity analysis. From our researches to date, it seems highly unlikely that the model of price-accelerated trends can be made to fit the time-series throughout its entirety with anything like the precision afforded by a simple logistic trend.

Estimated Parameters

Table 2 gives details of the estimates. These were computed on the assumption that the response in consumption lags one quarter behind price changes. The results would almost certainly be insensitive to changes in the length of lag, since the price series is highly autocorrelated.

In Figure 4.1 are plotted the original market share data, together with *ex post* "predictions" made using the model of price-accelerated trends (Set I estimates). The most remarkable feature of this chart is that the predictions become very badly biased downwards beginning at or about the June quarter, 1958. This was an invariant feature of the results obtained: any set of estimates which predicted reasonably well over the first half of the series, badly understated the rate of growth in synthetics' consumption from about 1958 on. In this connexion we note that evidence of a "structural break" in the wool market at the same date was also uncovered (but not explained) in a recent analysis of the demand for wool in the United States.[14] This sudden and dramatic shift in the conditions of demand for wool is, perhaps, the most puzzling feature of the post-war market for raw wool.

In figure 4.2, predictions are made from the second set of estimates

[12] See H. Chernoff and N. Divinsky, "The Computation of Maximum Likelihood Estimates of Linear Structural Equations", Ch. 10 in W. C. Hood and T. C. Koopmans (eds.), *Studies in Econometric Method,* Wiley, New York, 1953, pp. 246-249.

[13] For details of a method of circumventing the difficulties posed by attenuated ridges, see G. P. Box, "Fitting Empirical Data", *Annals of the New York Academy of Sciences,* 86 (3), 1960, 792-816.

[14] C. E. Ferguson and Metodey Polasek, "The Elasticity of Import Demand for Raw Apparel Wool in the United States", *Econometrica,* 30 (4), 1962, 670-699.

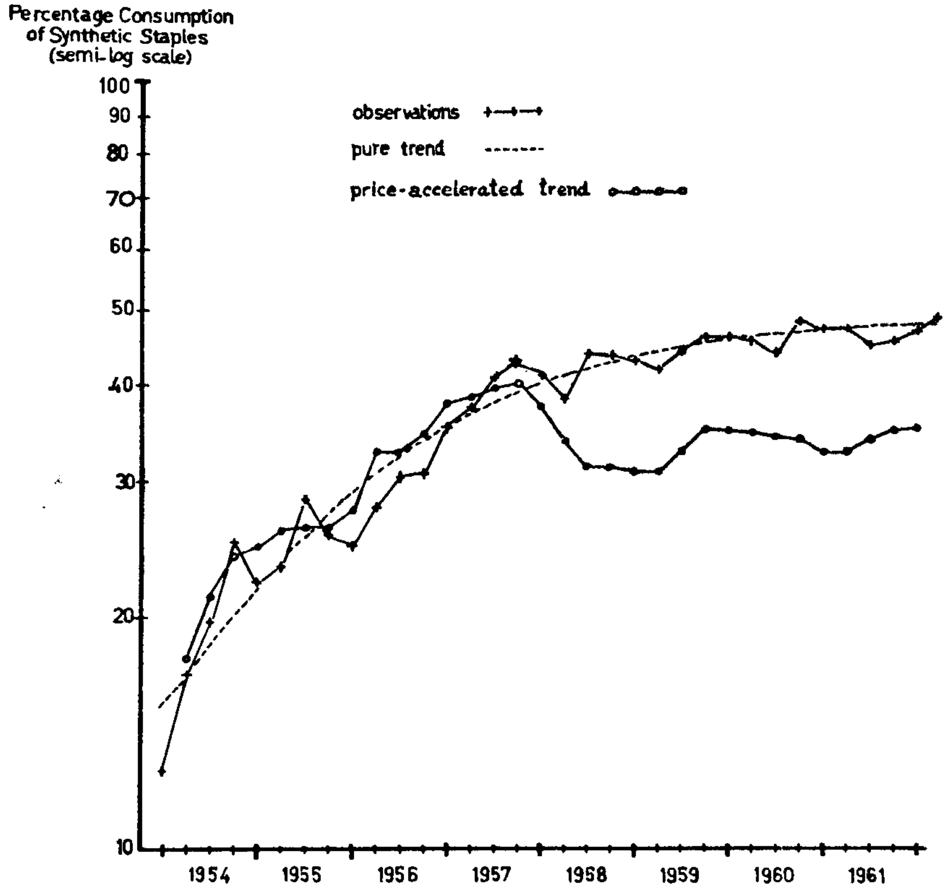

FIG. 4·1

(Set II), which overestimated synthetics' share of the market in the early period, but underestimated this share during the latter half of the series. This set gave a somewhat better fit in terms of the residual sum of squares, but this was due to a reduction in the extent of the underestimation of the market share in the latter half of the series: the early part of the series was rather badly overstated. Sets of estimates fitting the observed series well in the early period, invariably gave poor fits for the latter period, and *vice-versa.* It seems that no single structure of price-accelerated trends would fit the series well throughout its entirety. Ideally, we would have fitted separate curves to each sub-period of the series, but this has been deferred until we have a reliable computer programme for fitting this model. If indeed our conjecture about a change in the structure of demand is correct, then an explanation is called for.

Failure of the Model to Predict, June, 1958 to March, 1962

We confine our attention to Set I, since this set obviously is *very* close to the exact minimising solution for the first half of the series. Accordingly, we may have reasonable confidence that the parameters of the model are correctly estimated for the early period. At the time

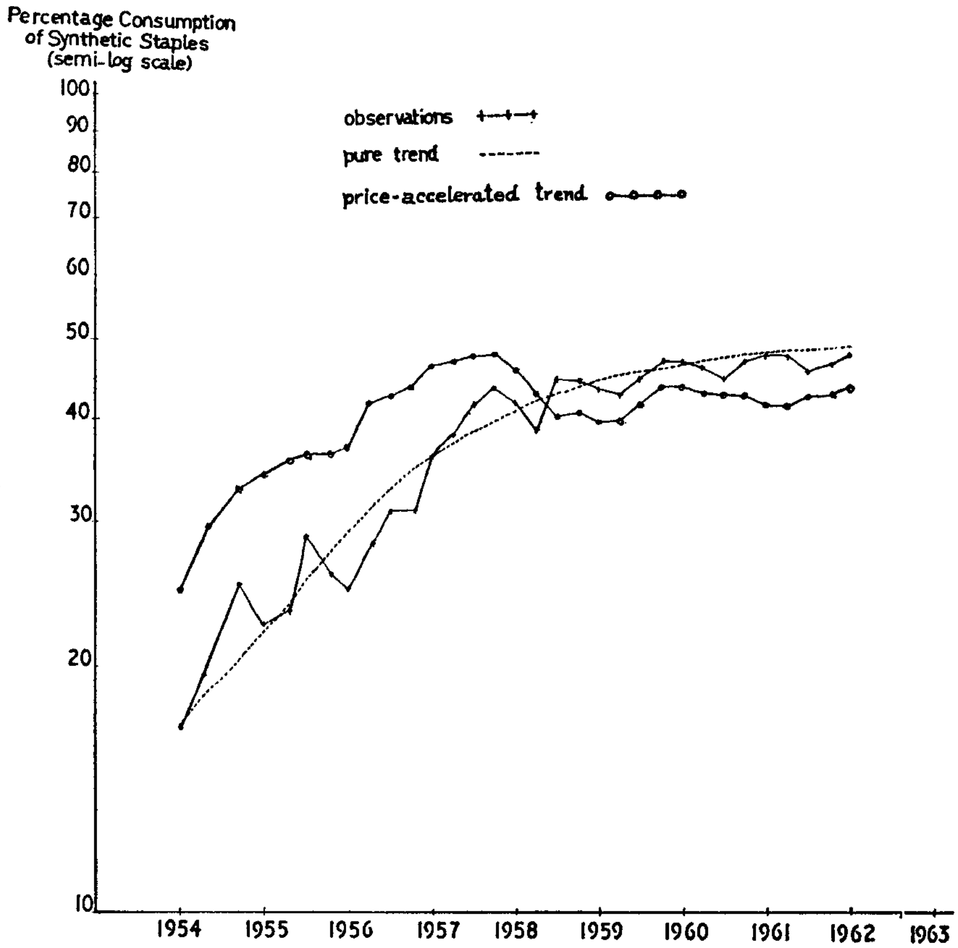

FIG. 4·2

at which the model begins to predict very badly, there occurred a fairly sudden, and sustained reversal in the terms of trade for wool, as may be seen from perusal of Table 1. This coincided with what has been termed the "Textile Recession" of 1958-59. However, in spite of the drop in the relative price of wool (which caused our model to predict a slowing-down in the adoption of synthetics), the process of innovation in the market continued almost unabated. It seems that the textile recession discriminated against wool both in terms of consumption rates *and* prices. We do not claim to be able to explain this phenomenon satisfactorily; however the factors listed below may be relevant:

1. The process of market-saturation may be irreversible. Once lost, wool's share of the market may not be regainable by moderate falls in the price of wool.
2. Textile manufacturers may use a period of slack demand in the trade to "re-tool" (or at all events, re-organize) their plants to accommodate the new fibre.
3. The most important variable omitted from our analysis—relative promotion expenditures—may account for the discrepancy. If so, the promotional effort of the big chemical firms must have

TABLE 2

*Estimates of Price-Accelerated Trends: U.S. Quarterly Data, 1954-1962**

1. Estimates of Parameters

	a_1	a_2	a_3	a_4
Set I	−0.2061	5.030	1.060	4.185
Set II	0.0164	2.906	0.829	3.546

2. Observations, Predictions and Errors

Year and Quarter	Observed Value Synthetics' Share of the Market y_t	Set I Predicted Value $\hat{y}_t$	Set I Predicting Error $\hat{u}_t$	Set II Predicted Value $\hat{y}_t$	Set II Predicting Error $\hat{u}_t$
1954 J	16.9	17.9	1.0	24.9	8.0
S	19.8	21.5	1.7	29.5	9.7
D	25.0	24.2	−0.8	32.9	7.9
1955 M	22.3	24.9	2.6	34.0	11.7
J	23.3	26.0	2.7	35.3	12.0
S	28.6	26.3	−2.3	35.8	7.2
D	25.6	26.4	0.8	36.0	10.4
1956 M	24.8	27.8	3.0	37.4	12.6
J	28.0	32.9	4.9	41.9	13.9
S	30.6	33.2	2.6	42.1	11.5
D	30.9	35.0	4.1	43.5	12.6
1957 M	35.6	38.3	2.7	46.0	10.4
J	37.8	38.8	1.0	46.4	8.6
S	41.1	40.0	−1.1	47.3	6.2
D	43.3	40.5	−2.8	47.6	4.3
1958 M	41.4	37.7	−3.7	45.3	3.7
J	38.9	34.4	−4.5	42.6	3.9
S	44.5	31.6	−12.9	40.2	−4.3
D	44.1	31.7	−12.4	40.3	−3.8
1959 M	43.5	31.3	−12.2	39.9	−3.6
J	42.4	31.3	−11.1	39.9	−2.5
S	44.7	33.4	−11.3	41.6	−3.1
D	46.7	35.3	−11.4	43.2	−3.5
1960 M	46.7	35.3	−11.4	43.2	−3.5
J	46.1	35.0	−11.1	42.9	−3.2
S	44.7	34.8	−9.9	42.7	−2.0
D	48.9	34.1	−14.8	42.2	−6.7
1961 M	47.9	33.4	−14.5	41.5	−6.4
J	47.9	32.8	−15.1	41.2	−6.7
S	45.7	34.2	−11.5	42.2	−3.5
D	46.2	35.0	−11.2	42.8	−3.4
1962 M	47.6	35.5	−12.1	43.3	−4.3

* Two sets of estimates, from the neighbourhood of the least-squares solutions, are shown. Set I shows a negative predicting bias; Set II a positive bias. The residual sums of squares are respectively 2308 and 1836.

increased dramatically (either in amount or efficacy) in the latter half of 1958.[15]

4. During a recession in the textile trade, the prices at which sales of synthetic fibres to mills are closed may be at a considerable discount below quotations. Here we have used quoted prices for synthetic staples; so that the effective wool/synthetic price ratio may not have fallen as drastically as the series we have used indicate. This would explain (in part) the apparent unresponsiveness to price of the trend in consumption.
5. Finally, it has been noted that during periods of recession, the relative consumption of non-virgin wool increases.[16] Whereas we have plotted a variable y_t defined by the ratio (consumption of synthetic staples)/(consumption of virgin wool + synthetic staples), ideally the consumption of shoddy (and perhaps other substitutes) would be added to the denominator of this ratio. No similar adjustment seems warranted in the numerator, however, since (as far as we can ascertain) the trade in reprocessed and waste synthetic fibres is unimportant. If in fact the consumption of non-virgin wool increased during the textile recession of 1958-59, then the values of y_t as computed for the later period show a *relative* bias upwards as compared with the earlier years.[17] Allowance for such a differential bias would reduce the gap between the observed and the predicted series.

5. *Elasticity Estimates*

Notwithstanding the difficulties encountered, it is of some interest to record the estimates obtained for the long-run elasticity of the market share with respect to relative price. Values for the elasticity η of equation (4) are set out in Table 3 for price-ratios of 0·8, 1·0 and 1·2. (Linear interpolation between these values will give fairly accurate results.)

The estimated elasticities are seen to be quite insensitive to differences in the estimates, Set I and Set II, of the parameters. In fact, it is

TABLE 3

*Estimates of the long-run elasticity of the market share of raw apparel wool with respect to the wool/synthetics price ratio**

Price Ratio p_t	Elasticity $\eta = [\partial(1-K_t)/\partial p_t]\,[p_t/(1-K_t)]$	
	Set I	Set II
0.8	− 0.269	− 0.266
1.0	− 0.386	− 0.365
1.2	− 0.528	− 0.480

* The elasticities shown represent the long term percentage changes in wool's share of the market which would occur as the result of an (indefinitely persisting) 1 per cent rise in the wool/synthetics price ratio.

[15] The authors are making attempts to obtain a series on promotion. Such data is very elusive and only supplied on an understanding of strictest confidence.

[16] See F. B. Horner, "The Pre-War Demand for Raw Wool", *Economic Record*, 28 (54), 1952, 14-17.

[17] Such statistics as are available lend some support to this hypothesis. See U.S. Department of Agriculture, *Wool Situation*, October 1960, pp. 28, 29.

a simple computational exercise to demonstrate that any estimates of the parameters which are "reasonable" in the sense of fitting the data at all well, will yield elasticity estimates closely bunched in the range indicated in Table 3. This conclusion depends upon the validity of the way in which the ceiling content, K_t, of synthetics has been formulated as a function of price, and on the surmise gleaned from Figure 2 (and the associated pure trend estimates) that the long run market share for synthetics is approximately 50 per cent when the price ratio is in the neighbourhood of unity. The validity of these elasticity estimates also hinges upon our estimates of the parameter α_3 not being too far wide of the mark.

6. *Conclusion*

On the basis of the foregoing analysis we are forced to conclude that the role of price in the adjustment of the U.S. textile market to synthetic substitutes for wool has been of minor importance. The dominant characteristic of the market has been the adherence of the market share enjoyed by synthetic staples to a steady logistic trend. Even in the face of a considerable price-reversal in the late 1950's there is no evidence of this trend having been arrested. Of course, the true role of price during this period may have been masked by the promotional activity of producers of synthetic fibres. Further analysis will become possible when data on this variable is available.

Figure 4·1 suggests that a structural change in our model may have occurred at some time in 1958. This aspect is currently under investigation. However, the available statistical tests for a change in structure refer only to linear models.[18] Further theoretical development would be needed before such a test could be applied to the model of price-accelerated trends.

If any practical conclusion be warranted from this analysis, it is that the long run prospects for the Australian wool industry are largely independent of moderate movements in the price of wool. It may be a source of some comfort to woolgrowers that in the U.S., at least, the worst *seems* to be over. The market share captured by synthetics stands at about 50 per cent, at which level it *seems* to have stabilized.[19] *Prima facie* it seems unlikely that the wool industry would lose further ground to synthetics should the chemical fibre industry reduce the price of staples marginally. On the other hand it would be equally futile for the wool industry to attempt to regain its former market share by cutting price.

[18] C. Radhakrishna Rao, *Advanced Statistical Methods in Biometric Research,* Wiley, New York, 1952, pp. 112-114; Gregory C. Chow, "Tests of Equality Between Sets of Coefficients in Two Linear Regressions", *Econometrica,* 28 (3), 1960, 591-605; and Richard E. Quandt, "The Estimation of the Parameters of a Linear Regression System Obeying Two Separate Regimes", *Journal of the American Statistical Association,* 53 (283), 1958, 873-880.

[19] We have twice italicized the verb "seems" to emphasize the considerable degree of uncertainty which must accompany the extrapolation of all trends. Any structural change in the market conditions underlying the observed pattern of growth could invalidate our inference.

APPENDIX

Wool and Synthetic Data

The purpose of this appendix is to comment on the method of compilation of the data appearing in Table 1.

The wool consumption data shown in column 2 relate to virgin apparel wool actually used up in the process of wool textile manufacture. They were computed from the *Survey of Current Business* by adding monthly data over each quarter. Estimates of consumption of non-cellulosic synthetic staples were obtained by adjusting quarterly staple and tow shipments by U.S. manufacturers for net exports (i.e., exports minus imports) and stock changes from the preceding quarter. The reasons for focusing the statistical analysis only on non-cellulosic staple fibres were two-fold; non-cellulosics, which are produced by polymerization of chemical substances, have become in recent years a powerful rival to wool in nearly all end-uses which have been traditionally wool's domain. Secondly, in the wool textile industry these new non-cellulosic fibres find use mainly in the form of staple fibre. The process of making staple fibre entails the cutting of continuous filament yarn into lengths corresponding to those found in wool. However, some types of filament yarn also find use in wool textile manufacture, and to that extent the competitive pressure of synthetics measured by the ratio y_t is somewhat understated.

In constructing the wool price series appearing in Table 1, it was necessary to design a price index in which the three quality categories, fine, cross-bred and low grade wools, were represented in accordance with their importance as components of total wool consumption in any given year. First, the following quarterly price series were obtained:

Territory wool, raw, graded, 64's, 70's, 80's, fine, good French combing and staple, clean basis.

Australian wool, raw 64-70's, good top making, clean basis, in bond, Boston market, duty paid.

Raw wool, bright, graded fleece, 56-58's, (3/8 blood), good French combing and staple, clean basis.

Graded fleece shorn wool, 1/4 blood, good French combing and staple, clean basis.

These prices were then weighted by the ratio of consumption within each of the four categories to total apparel wool consumption. The results of these calculations appear in column 6 of Table 1.

The non-cellulosic prices are simple quarterly averages of the following:

Nylon, staple and tow, 3 denier, semi-dull, normal tenacity, crimpset.

Orlon acrylic staple fibre, 3 denier.

Acrilan staple fibre, 3 and 5 denier, bright and semi-dull.

Dacron polyester, staple and tow, 3, 4, 5, and 6 denier.