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TESTING FOR AND ESTIMATION OF MODELS SUBJECT TO MULTICOLLINEARITY

by

G.S. Gupta
Devi Singh

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TESTING FOR AND ESTIMATION OF MODELS SUBJECT TO MULTICOLLINEARITY

G.S. Gupta and Devi Singh*

The use of regression analysis in analysing changes in variables over the time has become very common in the present day world. Undoubtedly, the method is very powerful but it has to be used properly. Many of the empirical researchers using this technique are either totally unaware of the limitations (assumptions) of this method or are not familiar with the methods of testing and corrections when its assumptions do not hold good. This paper attempts to explain the testing procedures and the appropriate methods of estimation of models which are subject to multicollinearity, a serious problem of regression analysis. The demand for cotton textiles' function is estimated from the time series data of the Indian economy for illustration purposes.

The Model:

By the theory of consumer behaviour, the demand for cotton textiles may be hypothesized as:

$$D_c = f(y, P_c, P_f, P_s, \frac{UP}{TP})$$

$$f_1, f_4 > 0 > f_2, f_3, f_5 \ldots\ldots \quad (1)$$

The authors are Professor and Research Assistant, respectively, at the Indian Institute of Management, Ahmedabad.

where

D_c = demand for cotton textiles

y = private disposable real income

P_c = price of cotton textiles

P_f = price of food articles

P_s = price of synthetic fibres

UP/TP = ratio of urban population to total population

f_i = partial derivative of 'f' with respect to the i-th independent variable.

The demand for cotton textiles is hypothesized to be a positive function of (a) income, for it is a normal (superior) commodity, and (b) the price of synthetic fibres, for clothes made of synthetic fibres are a substitute to those made of cotton textiles. It is assumed to be a negative function of (c) the price of cotton textiles by the law of demand, of (d) the price of food, for food and clothes are complimentary goods because both are essentials of life and in a developing country like India, the more is spent on food, the less is left for clothing, and of (e) the ratio of urban population to total population, for cotton clothes in comparison to synthetic fibre clothes are used more, generally speaking, in rural areas than in urban areas.

The linear version of the model (equation) was estimated through the Ordinary Least Squares (OLS) method, using annual time series data for

1954-55 to 1972-73 (Table 1). The results obtained are

$$D_c = -421.81 + 0.008\,y - 0.853\,P_c - 0.217\,P_f + 1.356\,P_s$$
$$\quad (0.84) \qquad (0.62) \qquad (1.15) \qquad (0.41) \qquad (1.20)$$

$$+ 5126.75\,\frac{UP}{TP} \quad \ldots\ldots \quad (2)$$
$$(1.55)$$

$$\bar{R}^2 = 0.836, \quad R^2 = 0.887, \quad DW = 2.10, \quad F = 20.51$$

Numbers in parentheses are corresponding t-values, $\bar{R}^2$ is coefficient of determination (R^2) adjusted for degrees of freedom, DW stands for the Durbin-Watson statistic, and F for the value of F-statistic. D_c is measured in crores of metres, y in crores of rupees at 1960-61 prices, prices are in index numbers, P_c and P_f with base 1961-62 = 100 and P_s with base 1960-61 = 100, and $\frac{UP}{TP}$ is measured in fraction.

Multicollinearity Problem:

It will be seen by a comparison of equation (1) and equation (2) that one of the estimated coefficients do not conform to its theoretical sign. The reason for this could be that the straight application of the OLS method is inappropriate. It is known that the OLS method yields good (best linear unbiased) estimates of such single equation models under certain assumptions. One of these assumptions, which is often violated in a time series study of this kind, is that no two independent variables should be highly correlated.

Table 1 : Time Series Data on Variables in Cotton Textiles' Demand Function

Year	Consumption demand for Textiles	Private disposable income at 1960-61 prices	Price of cotton textiles	Price of food articles	Price of synthetic fibres	Urban to total population
	(in crores of metres)	(in crores of rupees)	(1961-62 = 100)		(1960-61 = 100)	Ratio
	(1)	(2)	(3)	(4)	(5)	(6)
1954-55	531.90	10561.00	83.8	87.3	65.86	0.174
1955-56	561.80	10727.10	64.4	79.5	65.14	0.176
1956-57	586.63	11022.83	90.8	83.3	62.99	0.178
1957-58	589.14	10986.35	90.8	88.9	61.56	0.180
1958-59	591.33	11702.47	87.7	93.6	66.57	0.182
1959-60	579.26	11876.49	91.6	99.2	68.72	0.183
1960-61	594.09	12613.65	100.2	100.0	74.45	0.185
1961-62	647.38	12978.36	100.3	100.0	85.90	0.186
1962-63	645.55	13144.16	102.6	112.0	94.49	0.188
1963-64	672.67	13737.15	106.5	117.1	100.21	0.189
1964-65	710.45	14924.08	108.3	134.0	99.50	0.191
1965-66	701.93	14234.28	109.9	149.0	102.36	0.192
1966-67	683.06	14539.42	113.9	164.0	113.10	0.193
1967-68	677.28	15731.82	121.2	192.0	114.00	0.194
1968-69	734.54	16430.32	124.8	196.0	113.60	0.194
1969-70	709.65	17302.89	129.4	190.0	114.40	0.195
1970-71	726.24	18107.94	125.0	200.0	116.70	0.196
1971-72	679.52	18374.44	153.9	203.0	124.40	0.199
1972-73	738.91	18377.58	161.3	216.0	129.50	0.197

Sources : Cols.1 to 5 : Mote, Paul & Gupta : Managerial Economics : Concepts and Cases; Tata McGraw Hill, 1977.

Col. 6 : Gupta, G.S. and Deepak Chawla, Demand for Tea in India, Dynamic Management, Vol. 2, Sept. 1977.

The estimation problem which is associated with such a violation was called as multicollinearity problem by R. Friseh as early as in 1930's. If the two explanatory variables are perfectly correlated, that is, the simple correlation coefficient between the two is (plus or minus) unity, there is perfect multicollinearity. If the correlation coefficient is close to one, there is a high degree of multicollinearity. The multicollinearity is low if the correlation coefficient is low in relation to unity.

If the multicollinearity is perfect, the OLS estimates cannot be obtained, for the determinant $|X'X|$ vanishes.[1] If the multicollinearity is high, the estimates are, of course, unbiased, but the ones which are obtained from any particular sample can show large errors; if the multicollinearity is low, there is no problem.[2] In actual practice, researchers generally work with one sample only and therefore the OLS estimates in the presence of high multicollinearity are not good estimates of the population parameters and hence the policy conclusions based on them are untenable. To avoid such problems, one needs to test whether multicollinearity is perfect or high and if so use alternative estimation procedures. Through an illustration

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[1] See Johnston, J (1963) : Econometric Methods, McGraw Hill, New York, Chapter 8, p.204.

[2] Koutsoyiannis, A (1973) : Theory of Econometrics, Macmillan, London, Chapter 11, pp.226-30.

of the cotton demand function, the testing for and the methods of correcting for high multicollinearity are discussed. On a priori ground, multicollinearity seems to be high if the model (equation 1) is to be estimated from time series data, for there is a common trend factor in income, price variables and urbanisation. Even if cross-section data are used, say, from different regions of a country or from different countries of the world, multi-collinearity could be high because, generally, prices are high where income is high and vice versa.

Testing For Multicollinearity

The existence or otherwise of perfect multicollinearity can easily be tested by computing the matrix of simple correlation coefficients between all the explanatory variables of the model. The correlation matrix for the model for the time series data (Table 1) is given in Table 2.

Table 2 : Correlation Matrix for Explanatory Variables

	y	P_c	P_f	P_s	UP/TP
y	1				
P_c	0.938	1			
P_f	0.967	0.916	1		
P_s	0.954	0.907	0.948	1	
UP/TP	0.953	0.906	0.924	0.961	1

It will be seen that none of these coefficients is unity and hence there is no perfect multicollinearity.

The extent of multicollinearity could be tested by the value of the determinant $|X'X|$ where X is the n x k determinant, and X' is the transpose of X (n = number of observations, k = number of parameters). A zero value of this determinant implies perfect multicollinearity and the closer its value is to zero, the higher the degree of multicollinearity. However, what value of this determinant means high degree and what value means low degree of multicollinearity is not known and hence this test is inadequate to test for the existence or otherwise of the degree of multicollinearity. The value of the determinant for the sample data is approximately zero.

Another measure of multicollinearity is defined in terms of "R^2 deletes".[3] Under this procedure, R^2 of one regression is obtained which includes all the explanatory variables and R^2's of all the other possible regressions are obtained which includes all but one explanatory variables. The results of such an exercise for the model are provided in Table 3.

It is clear that the multicollinearity is high, for the difference between R^2 (0.887) and the highest of the "R^2-deletes" (0.886) is very small. However, this method is also subject to the limitation of the previous method, for how small it should be for ascertaining the high degree is not known.

Yet, an another method of measuring the degree of multicollinearity

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3 Kmenta, Jan (1971) : Elements of Econometrics, Macmillan, New York Ch. 10, pp.389-90.

Table 3 : R^2 and "R^2-Deletes"

Dependent Variable	Explanatory Variables	R^2
D_c	y, P_c, P_f, P_s, UP/TP	0.887
D_c	y, P_c, P_f, P_s	0.866
D_c	y, P_c, P_f, UP/TP	0.875
D_c	y, P_c, P_s, UP/TP	0.886
D_c	y, P_f, P_s, UP/TP	0.883
D_c	P_c, P_f, P_s, UP/TP	0.884

is through computing R^2's of regressions of each explanatory variable on all the other explanatory variables. Such results for the model are presented in Table 4.

Table 4 : R^2's and F-values for Regressions of Explanatory Variables.

Regressand	Regressors	R^2	F-value
y	P_c, P_f, P_s, UP/TP	0.97	95.9
P_c	y, P_f, P_s, UP/TP	0.88	26.5
P_f	y, P_c, P_s, UP/TP	0.95	60.1
P_s	y, P_c, P_f, UP/TP	0.95	64.5
UP/TP	y, P_c, P_s, P_f	0.94	56.0

The degree of multicollinearity is high if the highest of these R^2's is close to unity. For the model, the highest R^2 is 0.97, indicating high multicollinearity. Again, like the earlier methods, no cut-off value for R^2 is known precisely to conclude the degree of multicollinearity through this test.

None of the above methods is conclusive about the presence or otherwise of high degree of multicollinearity. This is more so because some multicollinearity almost always exists, the question is, at what point does the degree of multicollinearity cease to be normal and become harmful. This question has not yet been answered satisfactorily. However, according to one criterion, "multicollinearity is regarded as harmful if at, say, the 5% level of significance, the value of the F statistics is significantly different from zero but none of the t-statistics for the regression coefficients (other than the regression constant) is".[4] Applying this criterion to equation (2), it can be concluded that the model suffers from serious multicollinearity.[5] Klein has also suggested a criterion for this purpose.[6] According to him, multicollinearity is tolerable if

$$\left| r_{ij} \right| < R$$

where r_{ij} is the simple correlation coefficient between any two (i and j)

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4 Kmenta, J. (1971) : Ibid, p.390.

5 This conclusion follows even on Gujarati's criterion, where he suggests that if the t-values of regression coefficients are significant, one need not worry too much about the problem of multicollinearity.

See Gujarati, D. (1967) : A comment on Measurement of Productivity and Production Function in Sugar Industry in India, 1951-61, Indian Journal of Industrial Relations, p.401.

6 Klein, L R (1973) : Introduction to Econometrics, Prentice-Hall, New Delhi, pp. 64 and 101.

explanatory variables and R is the square root of the coefficient of determination. For the model, $R = \sqrt{0.887} = 0.942$, which is less than many of the simple correlation coefficients (Table 2). Thus, on this criterion also, the model represented by equation (1) and annual time series data of Table 1 is subject to high degree of multicollinearity.

Farrar and Glauber have also developed a test for multicollinearity.[7] Their procedure is in three steps. In the first step, the severity of multicollinearity is tested by a Chi-square (χ^2) test. In the second step, location of collinear variables is found through an F-test. In the final step, t-test is used to find out the pattern of multicollinearity.

The value of the Chi-Square is given by

$$\chi^2 = - \left[n-1- \frac{1}{6}(2k + 5)\right] \left[\text{Log}_e \text{ (value of standard determinant)}\right]$$

where

n = number of observations

k = number of explanatory variables other than constant term

Degrees of freedom = $\frac{1}{2}k\,(k-1)$

Standard determinant = k x k determinant of the simple correlation coefficients of the explanatory variables.

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7 Farrar, DE and RR Glauber (1967) : Multicollinearity in Regression Analysis, Review of Economics and Statistics, Vol. 49, pp.92-107.

The standard determinant of the model (Table 2) is

1	0.938	0.967	0.954	0.953
0.938	1	0.916	0.907	0.906
0.967	0.916	1	0.948	0.924
0.954	0.907	0.948	1	0.961
0.953	0.906	0.924	0.961	1

and its value comes to 0.000062. It should be noted that the value of this determinant will be equal to zero if the multicollinearity is perfect (i.e., $r_{ij} = 1$, for all $i \neq j$) and it will be equal to unity, if multicollinearity is zero (i.e. $r_{ij} = 0$, for all $i \neq j$).

The value of χ^2 for the model is given by

$$\chi^2 = - \left[19 - 1 - \frac{1}{6}(2 \times 5 + 5)\right] \left[\log_e (0.000062)\right]$$

$$= - [15.5] \; [-9.69]$$

$$= 150.2$$

The theoretical Chi Square at the 5% significance level with $\left[10 \frac{1}{2} k (k-1), k=5\right]$ degrees of freedom equals 3.94. Since the computed χ^2 is higher than its corresponding theoretical value, it can be concluded that there exists a substantial degree of multicollinearity in the model.

To find out the multicollinear variables, the coefficients of determination and their associated F-statistics within the set of explanatory variables are needed which are given above in Table 4. The theoretical F at the 5% significance level with 4 and 14 degrees of freedom has a value of 3.11. Since all the F-values in the table exceed this value, all R^2 in the table are significantly different from zero. Since the F-value is the highest for y, y is the most affected variable by multicollinearity. P_s and P_f, are the other affected variables, in that order.

Finally, to find out the factors which are responsible for the multicollinearity in the variables y, P_s and P_f, the partial correlation coefficients were computed and the same are reported in Table 5.

Table 5 : Matrix of Partial Correlation Coefficients

	y (1)	P_c (2)	P_f (3)	P_s (4)	UP/TP (5)
y	-				
P_c	$r_{12.345}$ = 0.353 (1.41)	-			
P_f	$r_{13.245}$ = 0.599 (2.80)	$r_{23.145}$ =0.085 (0.32)	-		
P_s	$r_{14.235}$ = -0.036 (0.13)	$r_{24.135}$ =0.015 (0.06)	$r_{34.125}$ =0.444 (1.85)	-	
$\frac{UP}{TP}$	$r_{15.234}$ = 0.400 (1.63)	$r_{25.134}$ =0.067 (0.25)	$r_{35.124}$ =-0.248 (1.17)	$r_{45.123}$ = 0.705 (3.72)	-

Note : The numbers in parentheses are the corresponding t-values.

The t-test is used to test whether a particular partial correlation coefficient is significantly different from zero or not. The value of t, for example, for $r_{12.345}$ is computed as

$$t_{(n-k)} = \frac{r_{12.345}}{\sqrt{(1-r^2_{12.345})/n-k}} = \frac{0.353}{\sqrt{(1-.125)/19-5}} = 1.41$$

The theoretical value of t at the 5% significance level with 14 degrees of freedom (two tail) is 2.145. All the partial correlation coefficients having a t-value greater than 2.145 are thus significant.

The results of Table 5 reveal that the cause of multicollinearity lies mainly in inter-correlation between y and P_f, and UP/TP and P_s. Thus, we conclude that the multicollinearity problem in equation 2 is serious and hence its parameter estimates are unreliable. Further, the problem is located mainly in y, and then in P_s and P_f and that it is due to a high intercorrelation between y and P_f, UP/TP and P_s.

Correction for Multicollinearity

If the multicollinearity is perfect, the only method to correct it is to drop one of the two perfectly correlated variables from the regression equation. Which one is to be dropped is immaterial from the statistical point of view and hence it could be decided on the theoretical ground. This is so simple. However, cases of perfect multicollinearity are very rare, the common problem is of dealing with a high degree of it, like in the model of this paper. The two methods of dealing with high degree of multicollinearity are illustrated in what follows. Under the first method, the problem is avoided through using time series data alone and in the second through pooling of time series and cross-section data.

To avoid multicollinearity problem using time series data alone, the first step would be to obtain simple regression results. The same for the cotton textiles' demand function are reported in Table 6.

Table 6 : Simple Regression Results

I $$D_c = \underset{(9.36)}{348.206} + \underset{(8.27)}{0.021}\, y$$
$$R^2 = 0.801; \quad D.W. = 1.04$$

II $$D_c = \underset{(9.57)}{409.273} + \underset{(5.77)}{2.219}\, P_c$$
$$R^2 = 0.662; \quad D.W. = 1.123$$

III $$D_c = \underset{(21.17)}{493.425} + \underset{(7.14)}{1.146}\, P_f$$
$$R^2 = 0.750; \quad D.W. = 0.93$$

IV $$D_c = \underset{(16.53)}{413.616} + \underset{(9.75)}{2.539}\, P_s$$
$$R^2 = 0.848; \quad D.W. = 1.62$$

V $$D_c = \underset{(5.86)}{-850.55} + \underset{(10.35)}{7984.82}\, UP/TP$$
$$R^2 = 0.863; \quad D.W. = 2.00$$

All the explanatory variables are significant individually. However, all have positive signs, some of which are in conflict with the theory and the conflict could be because the corresponding simple models are wrong. On the basis of both theory (signs of the coefficients) and statistical inference (R^2 and t-value), y and P_s turns out to be the important explanatory variables. Theoretically, P_c is very much a relevant variable.

The step-wise regressions were then estimated, starting with the most important explanatory variable first and then in that order and the results are reported in Table 7.

In the last equation, the coefficient of UP/TP has wrong sign. Besides, we have seen above that there is a high correlation between y and P_f and UP/TP and P_s. Further, the coefficient of both P_f and UP/TP are insignificant. Thus, the middle equation, which is reproduced below for convenience, seems to be the best:

$$D_c = \underset{(10.04)}{393.03} + \underset{(1.08)}{0.010}\, y - \underset{(1.05)}{0.805}\, P_c + \underset{(2.44)}{2.16}\, P_s$$

$$R^2 = 0.862; \quad D.W. = 1.52$$

This provides good estimates of equation (1) from time series data alone.

An another method of correcting for multicollinearity is through using some a priori information on the coefficients, if available. If the coefficients of one or more of the explanatory variables are known, those

Table 7 Step-wise Regression Results

Dependent Variable	Constant	Coefficients (and t-ratios) of					$\bar{R}^2$	R^2	DW
		y	P_c	P_s	P_f	UP/TP			
D_c	348.21 (9.36)	0.021 (8.27)					.777	.801	1.04
D_c	343.71 (8.96)	0.026 (3.46)	-0.597 (0.69)				.770	.806	1.03
D_c	393.03 (10.04)	0.010 (1.08)	-0.805 (1.05)	2.16 (2.44)			.825	.862	1.52
D_c	363.74 (5.55)	0.015 (1.32)	-0.760 (0.97)	1.954 (2.41)	-0.210 (0.47)		.819	.866	1.62
D_c	-421.81 (0.84)	0.008 (0.62)	-0.853 (1.15)	1.356 (1.20)	-0.217 (0.41)	5126.75 (1.55)	.836	.887	2.10

could be assumed for the model and then the remaining coefficients could be estimated. This, in other words, is the restricted least squares method. This method would avoid the problem, if the coefficient of one of the two highly correlated variables is known from somewhere outside the sample. One way of knowing this for the model is through cross-section data. Since prices and the ratio of urban population to total population are given at a point of time, they do not change over the cross section (regions, groups of people, etc.). In contrast, income change over cross-section. Thus, the cross-section version of the model represented by equation (1) is:

$$D_c = f(y) \qquad \ldots\ldots\ldots\ldots \qquad (4)$$

Region-wise data on cotton textiles demand and private disposable income are not available. However, National Sample Survey data are available on per capita total expenditure and consumption expenditure on cotton textiles over groups of people based on per capita expenditure class. These data are presented in Table 8. If the total consumer expenditure could be used as the proxy for income and consumption expenditure on cotton textiles as the proxy for cotton textiles demand, equation 4 could be estimated. The OLS estimates of equation 4 using these data are as follows:

$$D_c = \underset{(5.87)}{-3.227} + \underset{(24.15)}{0.1338\, y} \qquad \ldots\ldots\ldots \qquad (5)$$

$$R^2 = 0.976; \quad D.W. = 8.9$$

Table 8 : Cross-section Data on Expenditures

(in Rs.)

Monthly per capita expenditure class	Monthly average total consumer expenditure (all areas)	Monthly average consumption expenditure on cotton textiles (all areas)
0-13	9.52	0.02
Above 13-15	13.86	0.07
Above 15-18	16.91	0.33
Above 18-21	19.62	0.13
Above 21-24	22.61	0.28
Above 24-28	26.11	0.45
Above 28-34	31.08	0.53
Above 34-43	38.45	0.84
Above 43-55	48.73	1.57
Above 55-75	63.80	3.23
Above 75-100	85.63	5.85
Above 100-150	113.51	12.41
Above 150-200	170.34	18.04
200 and above	286.26	36.96

Source : Sarvakshena (Journal of the National Sample Survey Organization), Vol. 1, No. 1, July 1977.

Thus, from cross section data, the coefficient of y is estimated to be 0.1338. If we assume this to be the value of the said parameter, the linear version of equation (1) becomes

$$D_c - 0.1338 = a + b\,P_c + c\,P_f + d\,P_s + e\,UP/TP$$

or $$D_c^* = a + b\,P_c + c\,P_f + e\,UP/TP \qquad \ldots\ldots\ldots \qquad (6)$$

where,

$$D_c^* = D_c - 0.1338\,y \qquad \ldots\ldots\ldots \qquad (7)$$

The annual time series on D_c^* can be obtained from its definition (equation 7), and the time series data on D_c and y. The so derived data are given in Table 9.

The OLS estimates of equation (6) from annual time series data for 1954-55 through 1972-73 (Tables 1 and 9) are as follows:

$$\underset{}{D_c^*} = \underset{(0.86)}{1231.91} - \underset{(1.86)}{3.832}\,P_c - \underset{(2.68)}{3.440}\,P_f + \underset{(0.27)}{0.923}\,P_s - \underset{(0.97)}{8838.34}\,UP/TP \quad \ldots\ldots(8)$$

$$\bar{R}^2 = 0.933; \; R^2 = 0.951; \; D.W. = 1.15$$

Substituting for D_c^* from equation (7) in equation (8), the restricted least-squares estimates of equation (1) are obtained as follows:

$$D_c = 1231.91 + 0.1338\,y - 3.832\,P_c - 3.440\,P_f + 0.923\,P_s - 8838.34\,UP/TP \qquad \ldots\ldots\ldots\ldots \qquad (9)$$

Equation (9) provides estimates of equation (1) through pooling of cross-section and time series data. All the coefficients have ***a priori***

Table 9 : Time Series Data on D_c^* (= D_c - 0.1338 y)

Year	D_c^*	Year	D_c^*	Year	D_c^*
1954-55	-880.74	1960-61	-1009.34	1966-67	-1261.73
1955-56	-873.06	1961-62	-1088.61	1967-68	-1427.01
1956-57	-887.78	1962-63	-1112.61	1968-69	-1463.18
1957-58	-880.39	1963-64	-1164.81	1969-70	-1604.78
1958-59	-973.99	1964-65	-1285.80	1970-71	-1695.88
1959-60	-1009.34	1965-66	-1202.05	1971-72	-1778.25
				1972-73	-1719.28

signs and the coefficients of y, P_c, and P_f are significant at 5% level, as will be verified from their t-values in equations 5 and 8.[8] R^2 has improved and the DW value does not indicate autocorrelation. Through pooling of data, multicollinearity due to intercorrelations between y and prices and y and UP/TP is removed.

Before concluding the paper, it will be pertinent to interpret the coefficients of the estimated model. Equation 9 indicates that, other things remaining the same,

(a) an increase in private disposable income by rupees one crore results into an increase in cotton textiles demand by 13,38,000 metres,

(b) an increase in the price index of cotton textile by one unit tends to decrease cotton textiles demand by 3,83,20,000 metres,

(c) an increase in price index of food articles by one number causes a decrease in cotton textiles demand by 3,44,00,000 metres,

(d) an increase in price index of synthetic fibres by one results into an increase in cotton textiles demand by 92,30,000 metres, and

(e) an increase in the ratio of urban population to total population by 0.01 causes a decrease in cotton textiles demand by 88.38 crore metres.

An inference from these is that if all the three price indices increase by one, the demand for cotton textiles will decline by 6.349 crore metres. These results could be used to manage the said demand through an appropriate price-income-urbanisation policy.

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[8] Although these t-values may not be quite relevant for this purpose, in the absence of any alternative test, these are taken as suggestive.