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ESTIMATION OF DEMAND AND SUPPLY FUNCTIONS FOR FRESH AND INDUSTRIAL MILK IN SOUTH AFRICA

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ABSTRACT

The average price elasticity of demand for fresh milk is estimated from time series data at -0,78 at retail level and -0,51 at farm level. Demand functions indicate that the elasticity of fresh milk demand increased over time to near unity at retail level, due to growing proportion of Black consumers and increasing prevalence of substitutes. Elasticity estimates of industrial milk varied from -0,47 at the farm level to -0,93 at retail level. Elasticities of industrial milk was also found to increase over time. Income elasticities for fresh and industrial milk using cross sectional data were +0,44 for fresh milk and +0,40 for industrial milk. Estimates agree with the Slutsky-Schultz and Hicks Allen relation (Wold and Juréen) stating that as a rule income elasticities of necessity are smaller than price elasticities. The increase in the price elasticity of milk implies that consumption has become slightly more price responsive and that price may become a more important feature in the selling of milk. The supply elasticity of industrial milk was estimated at +0,55 at farming level.

INTRODUCTION

Fresh milk consumption in South Africa has fallen from 64,0 kg per capita in 1955/56 to 34,7 kg per capita in 1981/82 (Abstract of Agricultural Statistics, 1984, p. 79). Information on the demand function is important as it casts light on important policy issues, i.e., how does the two-price system for fresh milk affect consumption and producer income? Could present pricing policies be encouraging consumption of substitutes? This was evident in the USA, where quotas for cotton stimulated the production of artificial fibres (Paarlberg). Also important is how the proposed quota for industrial milk will affect the wellbeing of producers and consumers.

There have been numerous studies estimating demand and supply functions in overseas countries. In the only previous study for South Africa, as far as the writers are aware Marais estimated a positive sloping demand function for fresh milk which is inconsistent with economic theory.

This paper deals with the estimation of demand and supply functions for fresh and industrial milk. As milk prices have been fixed in the past, single equation Ordinary Least Squares has been used throughout this study.

THE DEMAND FOR MILK IN SOUTH AFRICA

Traditionally fresh milk has been considered a basic necessity, implying an inelastic demand. Today fresh milk has many substitutes in the form of powdered milk, condensed milk, sterilised milk, blends and coffee creamers. Also fresh milk is an expensive item to the growing population of lower income consumers although not expensive in relation to soft drinks. Per capita consumption is low in relation to other countries. This must be partly attributed to lower consumer income in South Africa. This suggests that the consumption point may be established towards the upper and more elastic part of the demand curve. These points suggest that demand for fresh milk may not be completely inelastic and that the elasticity may increase with time.

Industrial milk in this study means Gouda and Cheddar cheese, milk powder and condensed milk. Intuitively one would expect cheese to be more price elastic than powdered and condensed milk. The latter products form a fairly important part of the lower-income population's food budget while cheese seems less of a necessity. The elasticity of demand for industrial milk is determined by relative elasticities and weights of the above products. Substitutes for powdered and condensed milk in the form of blends and sterilised milk have become increasingly prevalent. This and the growing ratio of low income consumers is expected to increase the price elasticity of industrial milk over time.

INCOME ELASTICITIES OF DEMAND

Income elasticities for fresh and industrial milk were estimated using cross-sectional data compiled by the Bureau of Market Research. Other data sources consulted included Loubser and E. Nel

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(1980, p. 59), Loubser (1980, p. 51, p. 53, p. 55), Martins (1980, p. 55), Van Wyk (1980, p. 55) and P. Nel (1975, p. 26). Data on household expenditure and incomes for urban Blacks in Pretoria, on the East and West Rand and in the Vaal Triangle and Durban, for Coloureds in the Cape Peninsula and for Indians in Durban were used.

In estimating the income elasticity, consumption expenditure (C_t) in rand was used as a proxy for consumption and taken as a function of income (Y_t). Consumption by Black population groups was weighted by their relative consumption expenditures. The consumption function for Blacks is as follows: (T statistic is presented in brackets).

$$C_t = 515{,}39 + \underset{(8{,}414)}{0{,}172}\ Y_t \quad \ldots\ldots\ldots\ldots \quad (1)$$

$R^2 = 0{,}887$
$d = 2{,}01$
$Ey = 0{,}574$

The income elasticity (Ey) of fresh milk for Black households is estimated at 0,574[1]. Similar information on White households was not available. Nel, 1975, estimated the White household income elasticity for milk products and eggs as 0,36. Using this as a proxy for fresh milk and weighting by their relative market shares,the income elasticity of fresh milk for all consumers (White and Black) is estimated as:

$$Ey = 61{,}8\,(0{,}36) + 38{,}2\,(0{,}574) \quad \ldots\ldots\ldots\ldots \quad (2)$$
$$= 0{,}438$$

The consumption functions for cheese, powdered milk and condensed milk for Black households are presented in Table 1.

The R^2 figures presented are fairly low because of the cross-sectional nature of the data. There is evidence of negative serial correlation in equations 1 and 3, possibly because of the discrete nature of the income variable.

TABLE 1 - Black household consumption functions - industrial milk products

Product	Constant	Income	R^2	d	Ey
1. Cheese	93,91	0,0402 t = (4,038)	0,644	3,34	0,62
2. Powdered milk	0,961	0,492 t = (3,279)	0,544	2,92	0,67
3. Condensed milk	725,855	0,1162 t = (4,065)	0,647	3,33	0,39

In estimating an industrial milk income elasticity for Black households, income elasticities (Ey) for each product were weighted by their relative consumption expenditures. The industrial milk income elasticity for Blacks is estimated as 0,487. The White household income elasticity is taken as 0,36 (Nel, 1975, p. 29). Weighting these two estimates by relative consumption expenditures, the industrial milk income elasticity for all consumers is estimated as 0,403.

DEMAND FUNCTIONS FOR FRESH MILK AT THE RETAIL LEVEL

National data for the years 1950/51 to 1980/81 were used. The estimated demand functions for fresh milk in South Africa are presented in Table 2.

During the period under investigation the annual per capita consumption of fresh milk declined from 58,8 litres to 37,4 litres, i.e. by 36,4 % (Abstract of Agricultural Statistics 1978, 1983). This study found that the increased consumption of substitutes proved a most significant factor contributing to this

TABLE 2 - Estimated demand functions for fresh milk in South Africa

Model	Dependent	Constant	Price	CPCM	D1	D2	INT	R^2	d	Ed
1	CFM	132,927	-178,587 (3,282)	-12,756 (9,649)	-16,834 (10,366)			0,899	1,585	- 0,717
2	CFM	121,321	-175,668 (3,164)	-11,702 (9,471)		- 70,285 (10,128)		0,894	1,606	- 0,705 (-0,987)+
3	CFM-0,046Y	126,697	-205,975 (3,697)	-23,827 (10,341)				0,905	1,554	- 0,823
4	CFM	101,04	-659,431 (8,932)		- 9,703 (5,875)		2480,50 (9,763)	0,902	1,213*	- 0,880
								average	elasticity	- 0,78

CFM = per capita consumption of fresh milk
Price = retail price of fresh milk deflated by the consumer price index
CPCM = per capita consumption of condensed and powdered milk
D1 = intercept dummy (1977/78 to 1980/81, D1 = 1)
D2 = slope dummy (specified as D1 x Price)
Y = real per capita disposable income
INT = interaction variable
Ed = price elasticity of demand at the retail level

The figures presented in brackets are the T values. All are significant at the 1 % level
* Non-significant at the 1 % level. Otherwise no indication of first order serial correlation
+ = Not included in the calculation of average elasticity

decline, since the CPCM variable (per capita consumption of condensed and powdered milk) is negative and highly significant. Per capita consumption of condensed and powdered milk increased from 1,9 kg to 2,4 kg (or by 26,3 %) during the relevant period (Abstract of Agricultural Statistics 1978, 1983). Sufficient observations on the retail price of powdered milk were unobtainable. The retail price of condensed milk proved non-significant and was dropped from the analysis. Between 1976/77 and 1980/81 annual consumption of powdered and condensed milk fell by 0,6 kg per capita and annual fresh milk consumption fell by 5 litres per capita. As real per capita disposable income increased during this period, the backward shift in demand was deemed to be due to the increasing prevalence of ulterior fresh milk substitutes. A dummy variable (D1) used in Models 1 and 4 to account for this shift proved significant. (Data on other substitutes were unobtainable). A slope dummy (D2) was fitted in Model 2 (Table 2), to test whether the price elasticity had changed because of the increasing availability of substitutes. The dummy proved significant and the effect was to increase the price elasticity of demand. The price elasticity was measured at -0,705 for the period 1950/51 to 1976/77 and -0,984 for the period 1977/78 to 1980/81.

Model 3 (Table 2) uses the fresh milk income elasticity of 0,438 (calculated from cross-sectional data) in a restricted regression because of multicollinearity between income and the consumption of powdered and condensed milk (Gujarati, 1978, p. 184). The effect is to increase the elasticity estimate (Ed) compared with Models 1 and 2.

Model 4 takes into account the changing population structure over time. In 1975 Blacks comprised 83,4 per cent of the population yet they held only 38,2 per cent of the fresh milk market (Nel, 1975, p. 29). Reasons may be that many Blacks lack refrigeration, prefer unpasturised milk for making maas and have much lower incomes than Whites. Model 4 shows that the increasing population of low income consumers reflects in a lower overall per capita consumption over time. This tends to alter the price elasticity over time.

The interaction term (INT) in Model 4 is specified as the percentage of Whites in the population multiplied by the price of fresh milk. Consumption of powdered and condensed milk was negatively colinear with the interaction term and was dropped from the model. This will tend to give the interaction term a downward bias. By holding other variables constant and inserting the population ratio for various years into the interaction term, the effect of changing population structure on the price elasticity of fresh milk can be measured (Table 3).

As expected, the increasing number of Blacks in South Africa tends to increase the elasticity of demand for fresh milk. The elasticities presented for latter years are very close to unity. This agrees with Model 2, which predicts an elasticity of -0,987 over the years 1976/77 to 1980/81. The elasticity of demand at the retail level may be close to unity at present.

TABLE 3 - Change in the price elasticity of demand for fresh milk (Ed) in response to the changing population structure

Year	Percentage Whites	Ed
1951	19,4	- 0,71
1955	19,0	- 0,75
1960	18,2	- 0,83
1965	17,7	- 0,88
1970	17,0	- 0,95
1975	16,6	- 0,99
1981	16,3	- 1,02

THE PRICE ELASTICITY OF DEMAND FOR FRESH MILK AT FARM LEVEL

It is possible to estimate the elasticity of demand of fresh milk at the farm level if one knows the elasticity at retail level and the marketing margin. Margins (M) are often a combination of a constant absolute amount (C) and a constant percentage of retail price (a). Studies show that margins generally behave consistently with this hypothesis (Tomek and Robinson 1981, p. 61).

$$M = C + a\,Pr \qquad \text{.....} \qquad (3)$$

Using this assumption Tomek and Robinson , 1981, show the farm elasticity to be:

$$Ef = Er \left\{ 1 - \frac{C}{(1-a)\ Pr} \right\} \qquad \text{.....} \qquad (4)$$

Where Ef = Elasticity at farm level
Er = Elasticity at retail level
Pr = Price at retail level

The average price received by farmers in controlled areas for fresh milk (Pf) was regressed on the retail price of fresh milk (Pr), yielding:

$$Pr = 6{,}67 + \underset{(10{,}900)}{1{,}110}\,Pf \qquad \text{.....} \qquad (5)$$

$(\bar{R}^2 = 0{,}797)$
$(d = 1{,}979)$

Substituting equation (5) in equation (4) and retail elasticities of -0,78 and -0,88, as calculated in Table 2, corresponding elasticities for fresh milk at farm level are -0,51, and -0,65.

COMPARISON OF FRESH MILK ELASTICITY ESTIMATES WITH INTERNATIONAL STUDIES

Elasticity estimates from international studies on fresh milk are presented in Table 4. Elasticity estimates presented in this study for South Africa are higher than those shown for the USA and Canada. This is to be expected in the light of the large population of low income consumers in South Africa. It is, however, noteworthy that estimates are similar to those shown for Venezuela.

TABLE 4 - Elasticity estimates of fresh milk demand

Country	Source	Demand elasticity - retail level	Demand elasticity - farm level	Income elasticity
USA	Ippolito and Masson	- 0,30 to - 0,83	- 0,12 to - 0,34	
	Dahlgran		- 0,01 to - 0,50	
	Buxton and Hammond		- 0,35	
Canada	Zuhair and Sahi	- 0,32 to - 0,44		0,48 to 0,83
Europe and N. America	Street			-0,30 to 0,30
EEC	Buckwel, Harvey, Thompson and Patton	- 5,0		
Australia	Street			0,35
Venezuela	Street	- 0,59 to - 1,02		0,48 to 0,55
U K	Street			0,24 to 0,55
S. Africa	This study	- 0,78 (-0,98)*	- 0,51 (-0,65)*	0,438

Note: The elasticities presented are often the range of estimates from numerous studies
* There is evidence that elasticities have increased to these levels over the latter part of the period under study

According to the homogeneity condition or Slutsky-Schultz relation the sum of the commodities own price elasticity, its cross-price elasticities and its income elasticity is zero. This implies that the price elasticity of a commodity with many substitutes and few complements should be greater than its income elasticity. This relation holds for elasticities estimated in this study (Table 4). Using the Slutsky-Schultz and the Hicks Allen relations, Wold and Juréen (1962, p. 115) state that "as a rule, income elasticities of necessities are smaller than their price elasticities, whereas income elasticities of luxuries are greater than their price elasticities".

DEMAND FUNCTIONS FOR INDUSTRIAL MILK AT FARM LEVEL

Data for the years 1963/64 to 1980/81 were used. The milk equivalent consumption of Gouda and Cheddar cheese, skimmed and whole milk powder and condensed milk is termed industrial milk consumption. The price of industrial milk was taken as a weighted average of the producer price of cheese and condensing milk (condensing milk is milk used for the production of milk powder and condensed milk). Estimated demand functions for industrial milk in South Africa are presented in Table 5.

During the period under review annual per capita consumption of industrial milk increased from 17,29 to 27,44 kg. A significant factor was the increase in real disposable income during this period. Scattergram analysis indicated a shift in the demand function between 1971/72 and 1972/73. The dummy variable used to account for this shift was highly significant in Model 2. However, it was only significant at the 8 per cent level in Model 1. The price of fresh milk was included as a substitute for powdered and condensed milk and the meat price index was included as a substitute for cheese. Both variables proved not significant on all accounts.

Model 2 includes an interaction term, calculated as the percentage of Whites in the population, multiplied by the price of industrial milk. The income variable was dropped from the model as it was negatively correlated with the interaction term, leading to collinearity. This will tend to give the interaction term a downward bias. By holding other variables constant and inserting the percentage of Whites in the population for various years, the effect of increasingly more Blacks in the population on the demand elasticity of industrial milk can be calculated.

TABLE 6 - The effect of the changing population structure on the price elasticity of demand for industrial milk

Year	Percentage of Whites	Ed
1965	17,7	- 0,34
1970	17,0	- 0,35
1975	16,6	- 0,35
1981	16,3	- 0,36

TABLE 5 - Estimated demand functions for industrial milk in South Africa

Model	Const.	Price	Income	D1	INT	$\bar{R}^2$	d	Ed	Ey
1	12,523	- 155,088	0,0432	2,330		0,884	1,720	-0,47	0,92
		(4,598)	(4,417)	(1,917)*					
2	35,527	- 173,839		6,467	347,82	0,848	1,61	-0,35	
		(4,542)		(8,543)	(3,340)				

Price = real disposable income per capita
D1 = intercept dummy
Ed = price elasticity of demand
Ey = income elasticity of demand

The T values are given in brackets
* Significant at the 8 per cent level, otherwise all variables are significant at the 1 per cent level. There is no evidence of first order serial correlation

The increasing number of Blacks relative to Whites in South Africa has tended to increase the elasticity of industrial milk over time. The effect on elasticity is not as marked as in the case of fresh milk. This could be due to the fact that the consumption of powder milk has become increasingly popular amongst Blacks (South African Dairy Foundation, 1980, p.iv).

THE PRICE ELASTICITY OF DEMAND FOR INDUSTRIAL MILK AT RETAIL LEVEL

The retail price of industrial milk posed a problem in that a price series for Gouda cheese and full cream milk powder was unobtainable. The longest series of skim milk powder prices ran from 1972 to 1981. The retail price of Cheddar cheese was used as a proxy for that of Gouda. The retail price of full cream milk powder was taken as 25 per cent higher than that of skim milk powder. (This figure is based on data received from NCD on wholesale prices of skim and full milk powder for the last eight years.) These prices were weighted by their relative consumption (Dairy Board Annual Reports, various years) to give the industrial milk price at retail level. The producer price (Pf) of industrial milk was then regressed on the retail price (Pr).

$$Pr = 6{,}8 + \underset{(7{,}378)}{1{,}048}\ Pf \qquad \ldots\ldots\ldots\ldots \qquad (6)$$

$$(R^2 = 0{,}858)$$
$$(d = 2{,}08)$$

Using equation (6) and farm level elasticities of -0,35 and -0,47 in equation 4 corresponding retail elasticities of -0,70 and -0,93 were derived.

COMPARISON OF ELASTICITY ESTIMATES FOR INDUSTRIAL MILK

Demand elasticity estimates for industrial milk are compared in Table 7. The elasticity estimates obtained by this study are slightly higher than those obtained in the USA. This is to be expected because of the larger proportion of low income consumers in South Africa. An income elasticity of demand for industrial milk in South Africa of 0,4 was calculated using cross-sectional data. Regressions used in its calculation showed a low R^2, so the estimation may be weak. An income elasticity of 0,92 was calculated using time series data. This figure when considered in the light of the homogeneity condition (discussed previously), lends support to the higher retail elasticity of 0,93 presented in Table 7. This elasticity estimate stems from Model 1 (Table 5), which is felt to be the superior model.

SUPPLY FUNCTION FOR FRESH MILK

A stock adjustment model for fresh milk supply using the years 1963/64 to 1980/81 was attempted. Supply was calculated as total consumption plus surplus fresh milk received by industrial milk factories in South Africa. No significant price elasticity was obtained. This could be a consequence of present stabilisation measures penalising supply variation.

SUPPLY FUNCTION OF INDUSTRIAL MILK

The supply of industrial milk is taken as the amount of cheese and condensing milk supplied to industrial milk factories. The amount received by factories is assumed to be unrestricted for the following reasons. First, there has been a local shortage for most of the years under review (South African Dairy Foundation, 1980, p. 6). Secondly, the Dairy Board contracts to buy up surplus cheese and powdered milk (National Marketing Council, p. 7). Thirdly, it is assumed that industrial milk factories prefer to work at full capacity. The weighted producer price for cheese and condensing milk, deflated by the consumer price index, is used as the price variable.

The following model presents the supply of industrial milk (SIM_T) as a function of the deflated price of industrial milk (PIM_T) and the number of cows over two years old in South Africa (C_t).

$$SIM_T = -1014{,}05 + \underset{(9{,}413)}{0{,}360}\ C_t + \underset{(1{,}861)}{28{,}447}\ PIM_T$$
$$\bar{R}^2 = 0{,}877$$
$$d = 1{,}688$$

The elasticity of supply for industrial milk is calculated as 0,55. The adjusted R^2 is high and there is no indication of serial correlation. The price coefficient, however, is only significant at the 8 per cent level of significance.

TABLE 7 - Elasticity estimates of industrial milk demand

Country	Source	Price elasticity - retail level	Price elasticity - farm level	Income elasticity
USA	Ippolito and Masson*	- 0,54 to - 0,66	- 0,20 to - 0,26	
	Dahlgran*		- 0,12 to - 0,68	
	Buxton and Hammond		- 0,50	
South Africa	This study	- 0,70 to - 0,93	- 0,35 to - 0,47	0,40 to 0,92

* These estimates are the range taken from numerous studies cited by the author of the source document

TABLE 8 - Elasticity estimates of milk supply

Country	Source	Fresh milk	Industrial milk
USA	Ippolito and Masson	0,4 to 0,9	
	Dahlgran	1,74 +	0,85 +
S. Africa	This study	-	0,55
		Aggregate milk supply	
USA	Halvorson*	0,15 to 0,89	
Australia	Powel and Gruen*	0,42	
UK	Gardner and Walker*	0,66	

+ the average elasticity taken from studies in 16 different American States
* Cited by Askari and Cummings 1976, p. 406

INTERNATIONAL ESTIMATES OF MILK SUPPLY ELASTICITIES

Table 8 presents elasticity estimates of milk supply for various countries. The estimation in this study is slightly lower than that of the USA. Aggregate milk supply seems to be generally inelastic. Dahlgran (1980) presents an average fresh milk elasticity (taken from several studies in the USA) of 1,74. This seems to be high and out of line with the other estimates.

THE SUPPLY OF MILK IN SOUTH AFRICA

Halvorson (1955, p. 1197) discussed a number of reasons inherent in milk production that would lead one to expect a low elasticity of milk supply in general. There are also a number of reasons to believe that industrial milk supply would be more elastic than fresh milk supply.

In the long run heavy fixed investments reduce the speed of adjusting supply. Fresh milk health regulations require specialised milking sheds, representing further capital outlay. Increasing the size of the national dairy herd also takes time owing to the length of the production cycle. The present Dairy Control Scheme places a premium on stability of milk production, especially in the case of fresh milk. The present summer quota system for fresh milk penalises variable production.

In the short run one could alter supply by changing feeding and culling patterns, or the amount of milk marketed (or kept on the farm). Altering feeding patterns is not easy. If the price of milk falls, a reduction in feeding would cause incomes to decline further. As far as a price increase is concerned, many fresh milk farmers are feeding to the biological optimum already. Fresh milk farmers are unlikely to undertake a large amount of culling because of the time rebuilding a specialised dairy herd takes. The less specialised industrial milk producer might be more willing to undertake culling on a larger scale. Fresh milk farmers generally sell most of their milk production. Many industrial milk producers (who often sell industrial milk as a secondary enterprise to beef production) might be in a position to alter the amount of milk marketed or kept on the farm.

These points suggest that milk supply would be inelastic in general. Industrial milk supply may, however, be more elastic than fresh milk supply. "From the available statistics it is clear that there is a considerable time lapse between an increase in prices and expansion in production" (National Marketing Council, 1983, p. 22).

CONCLUSION

Although the real price of fresh milk has shown no definite trend, the per capita consumption of fresh milk has declined steadily since 1955/56. Models indicate that the increasing proportion of Blacks in the population and the increasing consumption of substitutes have been significant factors accounting for this trend. Concern has been expressed about Blacks consuming substitutes with relatively little nutritional value.

The average price elasticity of demand for fresh milk is calculated at -0,78 at retail level and -0,51 at farm level. Owing to the increasing prevalence of fresh milk substitutes and growing proportion of low income Black consumers in the population, the elasticity of fresh milk demand is shown to have increased over time. Estimates show that demand elasticities may have increased to close on unity at retail level and -0,65 at farm level during the latter part of the study.

The elasticity of demand for industrial milk was also shown to have increased over time, although not as markedly as that for fresh milk. Best elasticity estimates for industrial milk are -0,93 at retail level and -0,47 at the farm level.

The increase in demand elasticity for milk shows that consumption has become more sensitive over time to price increases (or decreases). This implies that price will become a more important feature in the selling of milk.

Demand elasticity estimates for both fresh and industrial milk were slightly higher in comparison with those estimated in the USA. This is to be expected because of the relatively large population of low income consumers in South Africa.

The supply elasticity for industrial milk was estimated at 0,55 at the farm level. This is slightly lower than that reported for the USA by Dahlgran, 1980. Although no supply elasticity was calculated for fresh milk it is felt that the supply elasticity of fresh milk should be lower than that of industrial milk.

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1. Income elasticities calculated using expenditure as the dependent variable are usually larger than those calculated using quantity (Tomek and Robinson, 1981, p. 49).

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