ELASTICITIES OF SUBSTITUTION BETWEEN CARBOHYDRATES IN SOUTH AFRICA

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Elasticities of substitution between carbohydrates in South Africa

Elasticities of substitution were estimated to determine how easily consumers switch from one carbohydrate product to another by using a translog function and the dual approach. Results indicate that carbohydrate pairs are substitutional in behaviour, which supports the observed interdependence between carbohydrates.

Elastisiteite van substitusie tussen koolhidrate in Suid-Afrika

Elastisiteite van substitusie is bereken ten einde te bepaal hoe maklik verbruikers van een stysel na 'n ander verander deur gebruikmaking van 'n getransformeerde logaritmiese funksie en die duale benadering. Resultate toon dat koolhidraatpare substitute is, wat die waargenome interafhanklikheid tussen koolhidrate bevestig.

1. Introduction

South Africa's carbohydrate industry consists mainly of the maize, wheat, potato and the rice industries. Maize, wheat and potato production take place on a wide array of farms of varying sizes with large farms producing most, and sometimes competing for the same land, especially in the Orange Free State. Pricing issues in the various segments of the carbohydrate industry in South African have been researched and reported on by a number of people, including Cadiz (1984), Cownie (1991), Elliott (1991), Elliott & Van Zyl (1991), Langley (1990), Niebuhr (1991), Nieuwoudt (1990), Sartorius von Bach *et al* (1992), Sartorius von Bach & Van Zyl (1993) and Van Zyl (1986a). Although some of this research, notably that of Sartorius von Bach *et al* (1992) and Sartorius von Bach & Van Zyl (1993), concentrated on aspects of the interrelatedness in the carbohydrate market, no attempt has been made to determine how easily consumers substitute one carbohydrate product for another.

In the above-mentioned research, primarily own price elasticities and cross price elasticities of demand for the major carbohydrates were determined. However, these cross effects should also be determined over time by making use of the theory of elasticity of substitution, which is an indication of how easily consumers switch from one product to another. These elasticities are necessary to provide further information on the carbohydrate market.

Elasticities of substitution in the South African carbohydrate market are empirically quantified in this article by using the duality between consumption and cost functions along the expansion path[1] to provide an indication of the shape of the isoquants. The elasticity of substitution indicates the degree of flexibility in dealing with price changes of the main carbohydrates consumed. A large elasticity indicates a quick adjustment of consumption when relative prices change.

To compare various carbohydrates, the percentage extraction rate (starch endosperm) of the raw carbohydrates was used as a proxy for utility derived from consuming South Africa's most important complex carbohydrates, namely maize meal, white bread, brown bread, potatoes and rice. The percentage of starch endosperm in effect indicates the importance of carbohydrates in the human diet.

2. Data and method used

To analyse the elasticity of substitution between pairs of carbohydrates, maize meal, white bread, brown bread, potatoes and rice were selected as South Africa's main carbohydrates. Time series consumption and price data for maize, wheat products, and potatoes were obtained (or constructed) from either the Maize Board (1991), Wheat Board (1991), Potato Board (1991) and Central Statistical Services (1991).

A translog cost function (Debertin & Pagoulatos, 1985) was derived by using factor shares from cost data. Following Van Zyl (1986b), the function was specified as follows:

$$\ln C = \alpha_0 + \alpha_y \ln Y + \Sigma_i \alpha_i \ln P_i + \tfrac{1}{2} \beta_{yy} (\ln Y)^2 + \tfrac{1}{2} \Sigma_i \Sigma_j \beta_{ij} \ln P_i \ln P_j + \Sigma \tau_{yi} \ln Y \ln p_i + \phi_t t + \tfrac{1}{2} \phi_{tt} t^2 + \phi_{ty} t \ln Y + \Sigma_i \phi_{ti} t \ln P_i \quad (1)$$

where:

C	=	minimum total cost;
i,j	=	MM, WB, BB, PO;
Y	=	output (starch endosperm);
MM	=	white maize meal;
WB	=	white bread;
BB	=	brown bread;
PO	=	potatoes ;
t	=	time; and
P_i, P_j	=	prices of MM, WB, BB and PO.

By assuming the translog function to be continuous, monotonically increasing, concave, homogeneous of degree one with respect to prices and representing constant returns to scale satisfaction (Brown & Christensen, 1981), the following restrictions are implied:

α_y $= 1$
$\Sigma\tau_{yi}$ $= 0$ (i = inputs: MM, WB, BB and PO)
β_{yy} $= 0$
ϕ_{ty} $= 0$

The cost share (S_i) for the i^{th} input (MM, WB, BB and PO) is determined by partially differentiating Equation (2) with respect to the i^{th} input price, assuming the above restrictions and invoking Shephard's lemma ($\delta \ln C/\delta \ln P_i = \delta C/\delta P_i * P_i/C = X_iP_i/C$):

$$S_i = \alpha_i + \Sigma\beta_{ij}\ln P_j + \tau_{yi}\ln Y + \phi_{ti}t \quad (2)$$

Shephard's lemma is a particular application of the envelope theorem to the cost function, representing the least cost of consuming a particular carbohydrate. It states that the change in cost for the cost function arising from the extention path conditions with respect to the change in the price of the i^{th} factor, evaluated at any particular point of output (starch endosperm) on the least cost total cost function is equal to the least cost quantity of the i^{th} factor that is used (Debertin & Pagoulatos, 1985). Using the cost share (S_i), the Allen elasticity of substitution (AES) (ϵ^A_{ij}) is derived as follows:

$$\epsilon^A_{ij} = (\beta_{ij} + S_iS_j)/S_iS_j \quad (3)$$

The Allen elasticity of substitution is the cross price demand elasticity. The usual approach is to insert the mean of the cost shares (S_i) for each input category in the data for the period under consideration in order to obtain the Allen estimate. From this estimate, the Morishima elasticity of substitution (MES) (ϵ^M_{ij}) and the Shadow elasticity of substitution (SES) (ϵ^S_{ij}) can be calculated as shown below. These were used in this study to determine the elasticity of substitution between South African carbohydrates:

$$\epsilon^M_{ij} = S_j(\epsilon^A_{ij} - \epsilon^A_{jj}) \quad (4)$$

$$\epsilon^S_{ij} = [(S_iS_j)/(S_i + S_j)][2\,\epsilon^A_{ij} - \epsilon^A_{ii} - \epsilon^A_{jj}] \quad (5)$$

The Morishima measure is the difference between the cross and the own price elasticity of demand evaluated at constant output, while the Shadow elasticity of substitution corresponds closest to the original definition of the elasticity of substitution $[(\delta \ln X_2 - \delta \ln X_1)/(\delta \ln P_1 - \delta \ln P_2)]$ of Hicks (1939). The MES is an example of the two output-one input and the SES an example of the two output-two input price elasticity of substitution (McFadden, 1963; Koizumi, 1976; Fuss *et al.*, 1978; Ball & Chambers, 1982). An analysis was made on aggregate data, both on a national and regional basis. The national results are subsequently discussed.

3. Empirical results and discussion

3.1 Introduction

Estimates of elasticities of substitution for the Morishima (MES) and Shadow (SES) measures were determined for pairs of South African carbohydrates for three periods, (1) the period 1984-1990, (2) before the structural adjustment in the Maize Board in May 1987 and (3) thereafter. Restricted three-stage least squares regression was used to simultaneously solve the system of equations. The estimates of MES and SES for national consumption are shown in Tables 1 and 2. Classifications shown in parenthesis ($\epsilon_{ij} < 0$) indicate that factors i and j are complements, while positive values ($\epsilon_{ij} > 0$) indicate that factors i and j are substitutes (Debertin & Pagoulatos, 1985). Values of greater than one, one, less than one and zero thus show classifications of elastic, unitary elastic, inelastic and totally inelastic elasticities, respectively.

3.2 National results

All carbohydrate estimates of MES and SES were positive for the period January 1984 to December 1990, indicating that pairs are substitutes. This substitutional effect between all carbohydrate pairs supports the observed interdependence between carbohydrates and makes the simultaneous equation approach a necessity. By evaluating the carbohydrate pairs over a shorter time period, the period before the structural change by the Maize Board, only two consistent pairs, namely the substitutes (1) maize meal and brown bread and (2) brown bread and potatoes, were found. After the change, three pairs were consistently substitutes, namely (1) maize meal and brown bread, (2) brown bread and potatoes and (3) maize meal and potatoes. The overall conclusion from an analysis of the MES and SES estimates is that the shift in the Maize Board's price policy changed carbohydrate pairs to become stronger substitutes than before. With respect to the elasticities, the most elastic pairs were white bread and brown bread, followed by maize meal and brown bread, while the lowest elasticities were obtained for pairs which include potatoes. In general, the effect of the pricing policy change by the Maize Board increased the elasticity of substitution between carbohydrate pairs.

3.3 Regional results

In order to model regional differences, the country was divided into several regions, namely the Pretoria, Witwatersrand and Vereeniging (PWV) area, Durban/-Pietermaritzburg, Port Elizabeth/Uitenhage, Cape Peninsula and the rural areas. The methodology described above was again used to determine substitutability between carbohydrate pairs. The regional results are subsequently discussed[2].

The rural areas have the most constant demand for carbohydrates given changing relative prices, while the Pretoria, Witwatersrand and Vereeniging consumers are the least consistent in carbohydrate consumption. The elasticities in the rural areas were the lowest of all regions. The only region where the general trend towards substitution between carbohydrate pairs was inconsistent was Port Elizabeth/Uitenhage. When specific pairs are considered, the regional analysis showed that in general, maize meal and potatoes are complementary.

However, despite these minor differences, the regional results in general correspond to a large extent with the results obtained on a national basis.

4. Conclusions

Findings using the elasticity of substitution approach, lead to the conclusion that carbohydrate pairs are substitutional in behaviour, which supports the observed interdependence between carbohydrates. Furthermore, the adjustment of the Maize Board's price policy in 1987 influenced substitution between carbohydrates, i.e. (1) that pairs become stronger substitutes than they were previously and (2) that the elasticities increased, indicating that consumers find it easier to react to relative price changes in the carbohydrate market. The most elastic pairs were white bread and brown bread, followed by maize meal and brown bread, while the lowest elasticity was calculated for carbohydrate pairs of which potatoes form a part. In general the regional results to a large extent correspond with the results obtained on a national basis.

Table 1: Morishima elasticities of substitution for national carbohydrate consumption

Period	Input	MM	WB	BB	PO
Total	MM	-	0.971	1.296	0.008
Before	MM	-	-0.400	0.594	0.109
After	MM	-	3.281	1.917	-0.056
Total	WB	0.509	-	1.706	0.060
Before	WB	0.412	-	-0.650	0.041
After	WB	0.880	-	4.151	0.111
Total	BB	0.771	1.253	-	0.050
Before	BB	1.053	-0.852	-	0.102
After	BB	0.319	4.786	-	0.037
Total	PO	0.268	0.917	1.090	-
Before	PO	0.452	-0.478	0.329	-
After	PO	0.191	3.082	1.868	-

Total = period 1984-1990, Before = before May 1987, After = after April 1987
MM=maize meal, WB=white bread, BB=brown bread, PO=potato.
$\epsilon_{ij} > 0$: factors i and j are substitutes; $\epsilon_{ij} < 0$: factors i and j are complements.

Table 2: Shadow elasticities of substitution for national carbohydrate consumption

Period	Input	WB	BB	PO
Total	MM	0.886	1.142	0.260
Before	MM	-0.210	0.734	0.441
After	MM	2.741	1.470	0.184
Total	WB	-	1.413	0.911
Before	WB	-	-0.796	-0.475
After	WB	-	4.514	3.059
Total	BB		-	1.080
Before	BB		-	0.326
After	BB		-	1.849

Total = period 1984-1990, Before = before May 1987, After = after April 1987
MM=maize meal, WB=white bread, BB=brown bread, PO=potato.
$\epsilon_{ij} > 0$: factors i and j are substitutes; $\epsilon_{ij} < 0$: factors i and j are complements.

Notes

1. A similar approach of using the duality between the production and cost functions along the expansion path was used by Aoun (1983), Debertin & Pagoulatos (1985) and Van Zyl (1986b).

2. Detailed results are provided in Sartorius von Bach (1992).

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