The Structure of Food Demand in Tunisia : a Differential System Approach

Abderraouf LAAJIMI
Boubaker DHEHIBI
José Maria GIL

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Abderraouf LAAJIMI*, Boubaker DHEHIBI**, José Maria GIL**

La structure de la demande alimentaire en Tunisie : une approche par systèmes différentiels

Résumé – Dans ce travail, on décrit en premier lieu l'évolution de la consommation des produits alimentaires en Tunisie. Plusieurs changements, dus à un ensemble de facteurs d'ordre économique et sociodémographique, ont affecté la structure de la demande alimentaire en Tunisie. Deux aspects principaux témoignent de ces changements : i) la diminution relative des dépenses alimentaires lorsque le revenu augmente, et ii) l'augmentation relative des produits d'origine agro-industrielle face aux produits non transformés. Pour analyser la structure de la demande, un système de demande différentiel avec des effets prix fixes (modèle CBS) a été retenu car il permet, comparé à d'autres modèles (Rotterdam, AIDS et NBR), de mieux expliquer la structure de la demande alimentaire sur la base de données de séries chronologiques pour les principaux groupes de produits alimentaires. Les résultats de l'estimation du modèle, en imposant les conditions d'homogénéité et de symétrie, indiquent plus de sensibilité face à des variations dans la dépense totale ou les prix propres que dans les prix croisés. En conclusion, certaines recommandations de stratégies et de politiques en matière d'alimentation sont proposées sur la base des résultats empiriques.

Mots-clés :
consommation alimentaire, système de demande, approche différentielle, changement structurel, élasticités, Tunisie

The structure of food demand in Tunisia : a differential system approach

Summary *– In this paper the evolution of food consumption in Tunisia is first described. In recent years, the pattern of food consumption in Tunisia has been changing. The factors behind these changes are both economic and socio-demographic. Two important aspects of these changes are : i) the reduction in relative terms of expenditure on food as real income increases (Engel's law) and ii) the relative increase of manufactured products from agro-food industries in comparison to non processed products. In order to study the response of demand for food to prices and total expenditure, a differential demand system with fixed prices effects (CBS model), has been estimated, which better explains consumer's food structure in Tunisia based on a time series of food data calculated from food balances compared with other models (Rotterdam, AIDS and NBR). Structural change is also considered. Calculated elasticities from the CBS model with both homogeneity and symmetry imposed are more sensitive to variations in total expenditure or in prices than in cross prices, even some relations of complementarity and substitution possibilities emerge. The demand is inelastic for all food groups. Finally, some policy and marketing considerations are provided on the basis of the empirical results.*

Key-words:
food consumption, demand system, differential approach, structural change, elasticities, Tunisia

* *Département d'économie et de développement rural, Institut National Agronomique de Tunisie (INAT), 43 avenue Charles Nicolle, 1002, Tunis Belvédère, Tunisie*
e-mail : l_raouf@webmails.com

** *Unidad de Economia Agraria, Servicio de Investigación Agroalimentaria (DGA), P.O. Box 727, 50080 Zaragoza, Spain*
e-mail : bdhehibi@aragob.es
chema.gil@upc.es

THE estimation of food demand elasticities has been the principal subject of many studies because food expenditure is still important for the household budget in the developing countries. In fact, in many developing countries, food expenditure accounts for more than half of the household budget. Decision makers concerned by food and nutrition are interested in studying the dynamics of food consumption and the means to predict and adjust its future evolution.

In Tunisia, the government developed an action policy in the price formation mechanisms through retail prices. Such policy has led to many important consequences in income distribution. Taking into account the changes occurred in the food demand evolution in Tunisia and the necessity to evaluate the food policies established, the analysis of food demand structure will gain great importance. This topic is not new ; nevertheless, the literature shows a lack of studies on studying food demand on the basis of a micro econometric analysis.

Most of the studies carried out in Tunisia aimed to find future projections for demand, for planning objectives, considering only two variables: population and income. However, prices play a determinant role, and some food products are still subsidised.

This paper has several objectives:

i) to analyse the structure of total food demand and to identify the principal characteristics of Tunisian food consumption trends,

ii) to estimate the demand parameters using a complete demand system,

iii) to test for structural change,

iv) to compare and choose among different functional forms.

From a methodological point of view and considering that this study investigates the empirical performance of four different functional forms for food consumer models, we assess which of the four functional forms provides the best fit of the data. Then, the basic model is completed by considering a possible structural change due to the price policy liberalisation in 1986.

In Tunisia, works conducted by authors like Fuglie (1994) and Lahiani (1996) aimed to give information on Tunisian consumers behaviour, regarding changes in relative prices, and some common information related to income effects, including some demographic variables, even for the food products, whose prices have been subject to direct intervention from government. The first study used cross section data from the National Budget Survey without including prices in the estimated models. It analysed the demand for selected products in Tunisia in order to identify the degree of substitution between cereals and potatoes. Elasticities were calculated based on simple regression equations between food quantities and food expenditure. Cross-section and time series data were combined and Stone's approach was used. The second study carried by Lahiani used the same methodology, combining also cross-section and time series data, but focused on the demand for oils in the capital city of Tunisia.

This study is different from the papers mentioned above. The analysis is undertaken at a national level. The methodology followed uses different functional forms for food consumer models with structural change. The introduction of dynamics (differential approach) and structural change in the estimation of a demand system contributes to generate better results that can be used to estimate food demand projections in Tunisia.

The paper is structured as follows. After introducing the subject and establishing the objectives, a descriptive analysis for the structure and evolution of food consumption in Tunisia is presented. The following section describes the econometric modelling of food demand. First, we discuss the main features of model specification for the four systems. The basic model is completed by considering a possible structural change due to the reduction of price subsidies in some products in 1986. Second, we describe data sources and the estimation procedure. We then present the empirical results and discussions. The final section summarises major findings and conclusions.

EVOLUTION OF FOOD CONSUMPTION IN TUNISIA: CHANGES AND NEW TRENDS

In general, food consumption depends on the economic, industrial and social structure of the country. Food is also related to population composition, life style and the potentials and characteristics of each region. Geographic environment, climatology, productive resources, predominant activity, principal agricultural activity are conditioning the nature of the food products consumed.

As in most developing countries, food expenditure represents a high percentage of total expenditure. A simple diagnosis of food expenditure evolution in Tunisia shows that as the standard of living improves, households increase their food expenditure but less than the expenditure allocated to other budget heading like health, housing, transportation, communication and leisure. This trend is particularly for the 1975-1995 period, as the food budget share went from 41 % in 1975 to 38 % in 1995 (INS, 1998).

However, the evolution of the food consumption structure in recent years shows that the pattern of food consumption has been constantly changing. There have been two major trends in food consumption:

i) The reduction in relative terms of expenditure on food as real income increases (Engel's law), as a response to the increase in the available income and improvement in the standard of living.

ii) The origin of food is modified, there is a higher incidence of manufactured products from the agro-food industries and a lower incidence of non-manufactured products. Food expenditure shares have been modified because of changes in relative prices, income, and variations in tastes and preferences. Therefore, food demand seems to be well diversified, particularly at the quality level.

In order to highlight the changes as well as the new trends characterising food demand in Tunisia, the analysis will be conducted in terms of expenditure structure. Thus, the descriptive analysis is conditioned by the available information. The analysis covers the period from 1975 to 1995, since the last National Budget Survey, whose results are published by INS was carried out in 1995. This evolution can be examined in table 1.

Table 1. **Evolution of the food expenditures structure in Tunisia (%)**

Food Groups	Budget Share (%)				
	1975	1980	1985	1990	1995
Cereals	8.9	8.2	6.1	6.2	5.7
Legumes and condiments	1.5	1.4	1.3	1.5	1.4
Vegetables	6.7	6.6	6.8	6.9	6.0
Fruits and nuts	2.3	2.6	2.2	2.7	2.4
Meat	7.6	8.6	8.6	9.0	8.3
Fish	1.1	1.1	1.2	1.3	1.3
Milk, dairy products and eggs	2.8	3.8	3.9	4.2	4.3
Sugar and pastry	2.1	1.8	1.1	1.2	1.2
Oils and fats	4.7	3.0	2.3	2.5	1.8
Beverages	4.0	4.6	5.5	4.5	5.0
Food/Total expenditure	41.7	41.7	39.0	40.0	37.7

Source: INS. *Enquête nationale sur le budget et la consommation des ménages* (various years)

i) The budget shares of dry legumes, vegetables, fruits and nuts have not shown a substantial variation.

ii) The consumption of animal products (meat, fish, milk, dairy products and eggs) has substantially increased over the period 1975-1995. The proportion of meat and fish expenditure has shown a small increase to stay around 8.3 % and 1.3 %, respectively. On the other hand, the share of milk, dairy products and eggs shows a substantial increase over the period of the study. The importance of animal products is higher when considering expenditure values than when using calorie intakes as prices of such products are also higher.

iii) The budget share for sugar and other products decreased from 2.1 % to 1.2 %.

iv) The relative importance of oils and fats has decreased from 4.7 % to 1.8 %. The consumption of these products is affected by lower relative prices and self-consumption of olive oil in this period. Moreover, a subsidy policy is still implemented to oils purchased in bulk.

Food consumption in Tunisia has experienced many changes, not only in terms of expenditures but also in terms of quantities (Table 2). The quantity of cereals increased by 3.1 %, despite the slow decreasing tendency since 1985. This aspect, together with a decrease in real expenditures, indicates a decrease in relative prices.

Eggs (78.2 %), dairy products (58.5 %), oil and fats (46.5 %), meat (40.9 %), fish (13.7 %), tea (20 %) and fresh and processed vegetables (12.3 %) and (26.7 %), respectively, are among the products that showed an increase in the quantity consumed. After a decrease in 1990, green legumes recovered an increasing trend (16.9 %). However, dry legumes showed a decrease after stagnation. The main products that experienced a decrease in quantities consumed are: fruits (-37.7 %) and fresh milk (-27.6 %), with a strong decrease between 1980 and 1990.

Table 2. **Evolution of quantities consumed (kg/capita/year)**

Food groups	1975	1980	1985	1990	1995	95/75 (%)
Cereals (1)	181.3	210.2	204.4	196.4	187.0	3.1
Dry legumes	3.2	3.2	3.2	3.2	2.6	-18.7
Green legumes	5.9	7.2	8.7	5.8	6.9	16.9
Fresh vegetables	64.7	66.2	77.6	81.5	72.7	12.3
Processed vegetables (2)	41.5	42.5	46.8	52.2	52.6	26.7
Fruits	66.0	37.6	38.9	53.0	43.1	-37.7
Meat and poultry	14.9	16.9	17.8	19.9	21.0	40.9
Fish	5.1	5.5	6.1	7.1	5.8	13.7
Fresh milk	55.3	40.6	37.5	38.8	40.0	-27.6
Dairy products (3)	15.9	20.4	14.1	19.6	25.2	58.5
Eggs (4)	55.0	71.0	77.0	97.0	98.0	78.2
Oils and fats	15.7	15.8	20.8	25.1	23.0	46.5
Sugar and sweets	14.5	14.5	16.5	17.4	16.1	11.0
Tea	1.2	1.3	1.6	1.7	1.5	20.0
Coffee	0.7	0.7	0.8	0.7	0.7	0.0

Source: INS. *Enquête nationale sur le budget et la consommation des ménages* (various years)
(1) Bean equivalents; (2) Fresh vegetable equivalents; (3) Fresh milk equivalent and (4) Pieces

The global evolution observed in food consumption is irregular and non-uniform. Some fluctuations are still linked to the agricultural production levels, particularly during the survey period (1995), after two difficult harvests, which strongly affected some agricultural products like vegetables and fruits (INS, 1998). Therefore, food consumption in Tunisia is still characterised by an important consumption level of cereals, although the average quantity has decreased over the last years, a moderate consumption of meat and fish, and increasing diversification in fruits and vegetables. Moreover, we can notice in general, that the consumption of high-value products (processed vegetables, fresh fish, meat, poultry and dairy products) has increased, while the consumption of traditional or domestically produced products (fresh vegetables, fruits) has decreased, as a consequence of the improved standard of living, as well as of the subsidies which permitted the imports of some products during the last years.

Since 1982, the Tunisian economy fell into recession. As a response, the government designed (1983-1985) and implemented (1986) a structural adjustment program which affected the price subsidies system. Some policy makers started questioning the effectiveness of this system because it became costly and inefficient, since subsidies turned into an increasing share of the public budget.

The main food policy instruments adopted affected many food products. Meat subsidies were eliminated, while those for sugar, cereals for animal consumption and feed were gradually reduced. Cereals for human consumption, vegetable oils (excluding olive oil), and milk maintained their level of subsidization. In the case of cereals, subsidies accounted for almost 40 % of the final consumer price, while for vegetable oils and milk, subsidies reached up to 60 % and 67 %, respectively.

A DIFFERENTIAL SYSTEM APPROACH OF FOOD DEMAND IN TUNISIA

Empirical Model

The specification used implies that the various food items are separable from the other non-food items in the consumer budget. Therefore, weak separability [1] of preferences has been assumed and the multibudge-

[1] In demand analysis, researchers often are interested in consumer demand for one commodity or a commodity subgroup. In a two-stage (conditional) demand analysis, weak separability frequently is assumed as a maintained hypothesis. However, a test may be performed when modelling conditional demand to determine if weak separability holds. Pudney (1981) presents alternative forms of separability when analysing the structure of consumer preferences. The restrictions that can be used for testing weak separability are provided in Moschini *et al.* (1994) and in Sellen and Goddard (1996). In this study weak separability has been assumed and not tested because information of non-food group is not actually available.

ting process is then justified (Deaton and Muellbauer, 1980a ; Theil *et al.*, 1989). First consumers allocate their budget to broad consumption groups. Given the budget for the broad groups, consumers then make budget decisions for items within each group. By weak separability, we focused on a food-demand structure by allocating food expenditures to various food categories.

In empirical work, the ideal specification should be consistent with theory, easy to estimate and fit the data, which includes good predictive performance. To estimate price and income elasticities of consumer demand, many demand systems have been developed in the past. There are now numerous specifications of demand systems, including among others, the linear and quadratic expenditure systems, the Rotterdam model, the CBS[2] model, the NBR[3] model, translog model, the Almost Ideal Demand System (AIDS).

Most of these demand systems have become popular to analyse the demand for food products (Lee *et al.*, 1994; Alston and Chalfant, 1993). However, the assumptions used to parameterise these models have different implications. For example, the marginal expenditure share and the Slutsky terms are assumed constants in the Rotterdam model, while they are assumed functions of budget shares in the AIDS (Brown *et al.*, 1994). However, economic theory does not provide criteria to choose *ex ante* among these models. Therefore, the decision must be taken once the demand model has been estimated. Then, the theoretical consistency and the statistical inference give the appropriateness of the model.

The Rotterdam Model

On the basis of previous literature, the absolute-price version of the Rotterdam model, developed by Theil (1965), is expressed as:

$$w_i \, d\ln q_i = \gamma_i \, b_i \, d\ln Q + \sum_{j=1}^{k} s_{ij} \, d\ln p_j \qquad (1)$$

where w_i represents the average budget share of commodity i; q_i and p_j, are quantity and price of food i, respectively; γ_i is treated as change in consumer's behaviour in food i; $b_i = w_i \dfrac{\partial \ln q_i}{\partial \ln m}$ is the marginal propensity to consume; m is total expenditure; and

[2] CBS: Central Bureau Voor de Statistiek, the Dutch name of Statistics Netherlands.

[3] The model is named after the Netherlands Central Bureau of Statistics and the National Bureau of Research, where Neves worked when the model was developed.

$d\ln Q = d\ln m - \sum_{j=1}^{n} w_j d\ln p_j = \sum_{j=1}^{n} w_j d\ln q_j$ is the Divisia volume index. The marginal shares b_i and the Slutsky coefficients s_{ij} were treated as constants.

These equations (1) satisfy adding-up condition if $\sum_{i=1}^{n} \gamma_i = 0$; and Engel and Slutsky aggregation if $\sum_{i=1}^{n} b_i = 1$ and $\sum_{i=1}^{n} s_{ij} = 0$. The homogeneity condition in the Rotterdam system requires $\sum_{j=1}^{n} s_{ij} = 0$, while the Slutsky symmetry condition implies $s_{ij} = s_{ji}$. Finally, the negativity condition needs $\sum_{i=1}^{n} \sum_{j=1}^{n} x_i s_{ij} x_j \leq 0 \ \forall \ x_i, x_j \neq$ constant and $s_{ij} \leq 0$ (Deaton and Muellbauer, 1980b, p. 44).

An attractive feature of the Rotterdam system is that all of the restrictions are expressed in terms of the parameters of the system, so that they are easily incorporated into the estimation and testing procedures.

The CBS Model

The system defined in (1) has an important limitation. It assumes that marginal budget shares are constant. However, there is no strong *a priori* basis for this conclusion. Various authors conclude that this assumption is a severe handicap that may limit the validity of the model (Gao and Spreen, 1994 ; Lee *et al.*, 1994 ; Gao *et al.*, 1995). To escape this dilemma, an alternative parameterisation is based on the Working model (Working, 1943):

$$w_i = \alpha_i + \beta_i \ln m \qquad (2)$$

As the sum of budget shares is unity, it follows from (2) that $\sum_{i=1}^{n} \alpha_i = 1$ and $\sum_{i=1}^{n} \beta_i = 0$.

To derive the marginal shares implied by Working's model, we multiply (2) by m and then differentiate with respect to m, which results in

$$\frac{\partial (p_i q_i)}{\partial m} = \alpha_i + \beta_i (1 + \ln m)$$

or,

$$b_i = w_i + \beta_i \qquad (3)$$

Hence, under Working's model the *ith* marginal share differs from the corresponding budget share by β_i as the budget share is not constant with respect to income, neither is the associate budget share.

By replacing b_i in (1) with (3) and rearranging terms, we obtain the CBS model (Keller and van Driel, 1985 ; Theil and Clements, 1987):

$$w_i\,(d\ln q_i - d\ln Q) = \gamma_i\,\beta_i\,d\ln Q + \sum_{j=1}^{n} s_{ij}\,d\ln p_j \tag{4}$$

In this case, the dependent variable is the (w_i-weighted) deviation of the log change in q_i from the (w_i-weighted) average log change in the quantities of all n goods. That is, the left-hand side is the weighted change in the volume share, q_i/Q, of the *ith* product.

The AIDS System

The next model to consider is the Almost Ideal Demand System (AIDS) of Deaton and Muellbauer (1980a) which can be written in terms of levels of variables as follows:

$$w_i = d_i + c_i(\ln m - \ln P^*) + \sum_{j=1}^{n} r_{ij}\ln p_j \tag{5}$$

where

$$\ln P^* = \alpha_0 + \sum_{k=1}^{n} d_k \ln p_k + \tfrac{1}{2}\sum_{k=1}^{n}\ \sum_{j=1}^{n} r_{kj}\ln p_k \ln p_j \tag{6}$$

An approximation to (6) is provided by Stone's index:

$$\ln P^* = \sum_{j=1}^{n} w_j \ln p_k \tag{7}$$

Then substituting (7) into (5), we obtain the Linear Approximated AIDS system (LA/AIDS) in levels:

$$w_i = d_i + c_i(\ln m - \sum_{j=1}^{n} w_j \ln p_j) + \sum_{j=1}^{n} r_{ij}\ln p_j \tag{8}$$

By adding a constant ξ_i to each equation to represent autonomous trends in demand, the differential version of (8) can be written as follows:

$$dw_i = \xi_i + c_i\,d\ln Q + \sum_{j=1}^{n} r_{ij}\,d\ln p_j \tag{9}$$

This model is very similar on the right-hand side to the Rotterdam model equation (1), although the dependent variables are different. The AIDS model explains the change in the budget share of each good, whilst the Rotterdam model only deals with the quantity component,

$w_i d\ln q_i$, of the budget share change (the price and total expenditure components are treated as exogenous[4]).

The similarity of the AIDS model (9) and the Rotterdam model (1) allows the coefficients of the two models to be linked in the following way.

Consider the logarithmic differential of the *ith* budget share $\left(w_i = \dfrac{p_i q_i}{m}\right)$:

$$d\ln w_i = d\ln p_i + d\ln q_i - w_i \ln m \tag{10}$$

Multiply both sides through by w_i:

$$w_i\, d\ln w_i = dw_i = w_i\, d\ln p_i + w_i\, d\ln q_i - d\ln m \tag{11}$$

Sum (11) over all i:

$$\sum_{i=1}^{n} dw_i = 0 = \sum_{i=1}^{n} w_i\, d\ln p_i + \sum_{i=1}^{n} w_i\, d\ln q_i - d\ln m \tag{12}$$

Therefore,

$$d\ln m - \sum_{i=1}^{n} w_i\, d\ln p_i = \sum_{i=1}^{n} w_i\, d\ln q_i = d\ln Q \tag{13}$$

where the real income term $d\ln Q = \sum_{i=1}^{n} w_i\, d\ln q_i$ is recognised as the Divisia quantity index for the change in real income.

If we replace $w_i d\ln q_i$ in (11) by the right-hand side of the Rotterdam model (1), and replace $d\ln m$ by $d\ln Q + \sum_{j=1}^{n} w_j\, d\ln p_j$, we obtain:

$$dw_i = \xi_i + (b_i - w_i)\, d\ln Q + \sum_{j=1}^{n} (s_{ij} + w_i \delta_{ij} - w_i w_j)\, d\ln p_j \tag{14}$$

i.e.,

$$w_i\, d\ln q_i = \xi_i + (c_i + w_i)\, d\ln Q + \sum_{j=1}^{n} (r_{ij} - w_i \delta_{ij} + w_i w_j)\, d\ln p_j \tag{14a}$$

where $\delta_{ij} = 1$ if $i = j$, 0 otherwise.

Equation (14) is identical in form to the AIDS model (9), and this comparison reveals, therefore, that the AIDS and Rotterdam coefficients are linked through the following relationships:

$$c_i = b_i - w_i$$

$$r_{ij} = s_{ij} + w_i \delta_{ij} - w_i w_j$$

[4] For estimation purposes, the conditional demand equations have been treated as a system of seemingly unrelated regressions. This requires that, in turn, all of the right hand side variables be exogenous.

The NBR System

Neves (1994) developed the fourth system, the NBR model, that was considered in this study. This is another hybrid system because it has the Rotterdam income coefficients and the AIDS price coefficients. If we replace c_i in the AIDS system (14) by $b_i - w_i$ and move $w_i d\ln Q$ over to the left-hand side, we obtain the NBR system:

$$dw_i + w_i\, d\ln Q = \gamma_i + b_i\, d\ln Q + \sum_{j=1}^{k} r_{ij}\, d\ln p_j \qquad (15)$$

These four models (1,4,14a,15) are not nested but, following Barten (1993), a general demand system can be developed which nests all four. The general system is:

$$w_i\, d\ln q_i = (\delta_1 w_i + d_i)\, d\ln Q + \sum_{j=1}^{n} (e_{ij} - \delta_2\, w_i\, (\delta_{ij} - w_j))\, d\ln p_j \qquad (16)$$

where $d_i = \delta_1 b_i + (1 - \delta_1)$; $e_{ij} - \delta_2\, \delta_{ij} + (1 - \delta_2) s_{ij}$; and δ_1 and δ_2 are additional parameters: when $\delta_1 = \delta_2 = 0$, system (16) reduces to the Rotterdam specification. When $\delta_1 = 1$ and $\delta_2 = 0$, system (16) reduces to the CBS one. When $\delta_1 = \delta_2 = 1$, system (16) reduces to the AIDS and when $\delta_1 = 0$ and $\delta_2 = 1$, system (16) reduces to the NBR one.

The demand restrictions on (16) are:

Adding-up: $$\sum_{i=1}^{k} d_i = 0,\ \sum_{i=1}^{k} e_{ij} = 0 \qquad (17)$$

Homogeneity: $$\sum_{j=1}^{k} e_{ij} = 0 \qquad (18)$$

Symmetry: $$e_{ij} = e_{ji} \qquad (19)$$

According to Deaton and Muellbauer (1980b, p. 44), the negativity condition will hold if matrix E with elements e_{ij}:

$$\sum_{i=1}^{k} \sum_{j=1}^{k} \tau_i\, e_{ij}\, \tau_j \leq 0 \quad \forall\ \tau_i,\ \tau_j \neq \text{constant and } e_{ij} \leq 0 \qquad (20)$$

must be negative semi-definite of rank (N-1), where N is the number of equations in the system. The negativity condition implies that the eigenvalues of E matrix must all be no positive. Since the rank of E is (N-1) therefore, the negative semi-definite condition requires that the eigenvalues be one, zero and the remaining (N-1) negative.

The demand system specified above can be extended to account for potential structural breaks as a consequence of the price policy liberalisation of some food products in 1986. Thus, a new variable h_t has been introduced in (16) in the following way:

$$w_{it}\, d\ln q_{it} = \theta_i h_t + (\delta_1 w_i + d_i + \zeta_i h_t)\, d\ln Q$$
$$+ \sum_{j=1}^{n} (e_{ij} - \delta_2\, w_i\, (\delta_{ij} - w_j) + \zeta_{ij}\, h_t)\, d\ln p_{jt} + u_{it} \tag{21}$$

where θ_i, ζ_{ij}, ζ_i are parameters to measure the potential impact of the structural change on different variables of the system and u_{it} is the error term. In (21), theoretical restrictions hold if the new parameters satisfy:

$$\sum_{i=1}^{n} \theta_i = 0\ ;\ \sum_{i=1}^{n} \zeta_{ji} = 0\ ;\sum_{j=1}^{n} \zeta_{ij} = 0\ ;\ \text{and}\ \zeta_{ij} = \zeta_{ji} \tag{22}$$

The selection of the functional form of h_t is important for a correct specification of system (21) (Moschini and Moro, 1996). Among the different alternatives, the approach proposed by Ohtani and Katayama (1986) and applied by Moschini and Meilke (1989) has been considered. It is assumed that h_t adopts the following expression:

$$h_t = \begin{cases} 0 & \text{for } t = 1,\ldots, \Gamma_1; \\ (t - \Gamma_1)/(\Gamma_2 - \Gamma_1) & \text{for } t = \Gamma_1 + 1,\ldots, \Gamma_2 - 1; \\ 1 & \text{for } t = \Gamma_2,\ldots, T; \end{cases}$$

where Γ_1 and Γ_2 represent the ending point of the first period and the starting point of the second period, respectively. Note that the traditional dichotomous dummy variable is a particular case in this formulation when $\Gamma_2 = \Gamma_1 + 1$.

Data and Estimation Procedure

Data

The data come from a number of sources. Annual consumption data for each commodity group are from the Food Balance Sheet elaborated by the Food and Agricultural Organisation (FAO) and represent national consumption. In order to get per capita data, population figures were collected from the International Monetary Fund (IMF). Annual consumer price series for each commodity are found in the *Bulletin Mensuel de Statistique* (*Monthly Statistical Bulletin*) published by the Institut National de la Statistique (National Statistics Institute, INS). Food products have been aggregated into six broad categories: 1) bread and cereals; 2) meat and fish; 3) milk and dairy products; 4) fruits, vegetables and potatoes; 5) oils and fats; and 6) other food. The sample period covers yearly data from 1973 to 1996.

Estimation Procedure

The Rotterdam, CBS, AIDS, and NBR models are read in differentials. In order to arrive at estimable equations, the models equations had to be converted to finite changes. We followed the usual practice of approximating w_{it}, $d\ln p_{it}$ and $d\ln q_{it}$ for $\frac{(w_{it} + w_{it-1})}{2}$, $\ln \frac{p_{it}}{p_{i,t-1}}$ and $\ln \frac{q_{it}}{q_{i,t-1}}$, respectively, where subscript t indicates time.

The four empirical models and the synthetic model have been estimated using the Full Information Maximum Likelihood (FIML) procedure in the TSP4.4 program. The "other food" equation was deleted to avoid singularity of the variance and covariance matrix of residuals due to the adding-up restriction. Economic theory restrictions (homogeneity and symmetry) were imposed in order to obtain parameters consistent with demand theory.

Values Γ_1 and Γ_2 in (21) have been determined using the method proposed by Quandt (1960) and applied by Moschini and Meilke (1989), Xu and Veeman (1996) and Rickertsen (1996), among others. In our case, results indicate that structural change has taken place between 1984 and 1987[5] which are the chosen values for the two parameters mentioned above.

The second step consist on check which parameters in demand for food products system were affected by the structural change. The null hypothesis of no structural change affecting prices and Divisia price index ($d\ln Q$) could not be rejected, at the 5 % level of significance (in this case the LR statistic was 33.18, which under the critical value $\chi^2_{25} = 37.7$). Therefore, the structural change has only affected intercepts. In others words, these results indicate that, after the reduction in price subsidies of some products, only average budget shares have changed. On the other hand, effects of changes in prices or in the Divisia price index ($d\ln Q$) have remained more or less stable over time.

Therefore, the final estimated model was:

$$w_{it} d\ln q_{it} = \theta_i h_t + (\delta_1 w_i + d_i)\, d\ln Q + \sum_{j=1}^{n} (e_{ij} - \delta_2\, w_i\, (\delta_{ij} - w_j))\, d\ln p_{jt} + u_{it} \qquad (23)$$

Because (23) with its two additional parameters nests all four, it can be used as a model selection tool. The final step in the estimation process consists in comparing between the four competing systems. For comparison, a likelihood ratio test has been used. The Likelihood Ratio Test (LRT) for model selection is:

$$\text{LRT} = -2\, [\ln L(\theta^*) - \ln L(\theta)] \qquad (24)$$

[5] Note that synthetic and the four conditional demand systems (AIDS, Rotterdam, CBS and NBR) pick the same years.

where θ is the vector of parameter estimates of a restricted model (Rotterdam, CBS, AIDS, and NBR); θ^* is the vector of parameter estimates of the synthetic model; and L (.) is the value of the likelihood function (Amemiya, 1985). For example, under the null hypothesis that the differential AIDS best describes the data, test statistic LRT has an asymptotic χ^2 (r) distribution, where r is the number of restrictions imposed with $r = 2$, number of degrees of freedom equal to the difference between the number of parameters in the general model and in the Rotterdam, CBS, AIDS, and NBR, respectively.

Table 3 presents the log values of the likelihood function and the corresponding statistics for model selection. In pairwise likelihood ratio tests between the synthetic model and the four individual systems, the Rotterdam, differential AIDS, and NBR were firmly rejected by the hybrid model. However, the tests leave little doubt at either level of significance that CBS is not rejected by the synthetic system.

Table 3.
Tests results for the competing demand models and the synthetic system: Likelihood Ratio Test statistics

Demand Systems	Maximised Log Likelihood	Likelihood Ratio Test: Named Demand System *vs* the Synthetic System[a]
Synthetic System[b]	408.940	–
ROT	405.327	7.226
CBS	407.972	1.936
AIDS	404.267	9.346
NBR	403.981	9.918

[a] With two degrees of freedom, the critical value at the 5 percent significance level is 5.99. The 1 percent critical value is 9.21.
[b] The estimates for δ_1 and δ_2 in (23) are 0.89 and 0.18 with standard errors of 2.64 and 109.12, respectively.

Elasticity Estimates from the CBS Model

In the estimated CBS system, the theoretical restriction of adding-up is satisfied, where homogeneity and symmetry are imposed. The negativity condition cannot be tested statistically. However, the eigenvalues of the matrix parameters can be used to indicate whether, on the average level, this condition holds. The five nonzero eigenvalues obtained from the Slutsky coefficients matrix for the CBS system are: -0.0786, -0.00592, -0.02311, -0.04254 and -0.07880, respectively. The sixth eigenvalue must be equal to zero. Indeed, the negativity condition is confirmed to be satisfied in the CBS model.

The expenditure elasticity of each commodity group (η_i), the uncompensated price elasticities (E_{ij}) and the compensated price elasticities (ε_{ij}) for the CBS model are:

– Total expenditure: $$\eta_i = \frac{\beta_i}{\overline{w_i^b}} + 1 \tag{25}$$

– Uncompensated price elasticities: $$E_{ij} = \frac{\pi_{ij}}{\overline{w_i^b}} - \eta_i \overline{w_j^b} \tag{26}$$

– Compensated price elasticities: $$\varepsilon_{ij} = \frac{\pi_{ij}}{\overline{w_i^b}} \tag{27}$$

These elasticities correspond to the period after the structural break. To calculate elasticities for the first period, we substitute $\overline{w_i^b}$ by $\overline{w_i^a}$ where $\overline{w_i^a}$ is the average budget share of *i-th* product before the structural change (Moschini and Meilke, 1989).

Endogeneity, Homotheticity and Goodness of Fit Tests for the CBS

The $d\ln Q$ term of CBS model may be correlated with the error terms. To examine the potential endogeneity problem, we invoke the theory of rational random behaviour (Theil, 1980; Duffy, 1987; Lee *et al.*, 1994; Fousekis and Pantzios, 2000). In this context, Theil (1980) shows that if $d \ln Q$ is exogenous, the disturbance covariance terms are proportional to the Slutsky terms and satisfy $cov\ (\varepsilon_i\ \varepsilon_j) = \alpha s_{ij}$. Using the CBS disturbance covariance terms, the regression of the covariance terms shows that: $cov\ (\varepsilon_i\ \varepsilon_j) = 0.411\ (10^{-5})\ (5.83\ (10^5))\ -0.195(10^{-3})\ (0.128(10^{-3}))$, with $R^2 = 0.14$, where standard errors of estimates are in parentheses. The regression results show that $cov\ (\varepsilon_i\ \varepsilon_j)$ is proportional to the Slutsky terms, so the $d\ln Q$ is considered as exogenous for the data set.

For testing homotheticity of preferences, a Wald test has been used. The empirical value is 0.3944 while the critical value (χ^2_5 with five degrees of freedom at 5 % level) is 11.1. Thus, the assumption of homothetic preference for food products is not rejected.

In order to assess the overall goodness of fit of the system, a system-wide measure has been used which has a similar interpretation to the single-equation measure. The system R^2 compares the current model with a benchmark which in this case is a model with intercepts only (Bewley and Young, 1987). It has the following expression:

$$R^2 = 1 - \frac{1}{1 + 2*\ [LLu - LLb]*\frac{1}{T*(N-1)}} \tag{28}$$

Where LLu is the log likelihood of the unrestricted model, LLb is the log likelihood of the base model (only intercepts), T is the number of observations, and N is the number of equations in the system. The R^2

value for the CBS model was 0.487, indicating that the whole system explains 49 % of the variation in allocation.

Results and discussion

The estimated income and own-price coefficients of the CBS model before and after the structural change with homogeneity and symmetry are significant at the 5 percent significance level. Own-price coefficients exhibit a significant effect in three equations [6]. Finally, most of the cross-price parameters are significant.

The most interesting economic parameters for policy analysis are elasticities. Parameter estimates of the CBS model are used to calculate the price and expenditure elasticities. Price elasticity is calculated in two ways. The first is uncompensated elasticity that contains both price and income effects. The second is compensated elasticity, which includes only price effects. In examining the expenditure elasticities in table 4, it seems that this parameter is significant for four (meat and fish, fruits and vegetables, oils and fats and other food stuffs) of the six food groups.

Cross-price elasticities show substitution or complementary relations among products. Positive cross-price elasticity indicates substitute products while negative cross-price elasticity means that products are complement. Post structural Marshallian and Hicksian price and expenditure elasticities were calculated at mean, from the parameter estimates, using equation (25) to (27).

In general terms, meat and fish, fruits and vegetables can be considered as luxury goods from the food expenditure point of view. Expenditure on such products increases more than proportionally when total food expenditure increases. However, expenditure elasticities of milk and dairy products, oils and fats and other foodstuffs suggest that they are necessities in the Tunisian diet. So an increase in total food expenditure induces less than proportional increases for such products.

The total expenditure elasticity of cereals and bread is negative, suggesting that this group of products may be considered as an inferior good. Nevertheless, the obtained parameter is not significantly different from zero.

The expenditure elasticity obtained for meat and fish is plausible in magnitude, since an increase in total expenditure would induce more than proportional increase in the quantity demanded. Nevertheless, it is worth pointing out that if a separability hypothesis had been considered between the different products included in this group, calculated elasticities would have been higher, since lamb meat is considered a luxury

[6] Results from alternative models are available from authors upon request.

good, much more in rural areas than in urban areas, while beef and chicken are more appreciated in urban areas and near town cities.

Milk and dairy products are considered a necessity. This indicates the new trend and changes that occurred in the food structure, since expenditures on products from animal origin are increasing, particularly in urban areas, as a response to income increases. An income effect is created through milk subsidies and a change is observed towards the use of reconstituted milk packed in less convenient cartons, which are less appealing to the rich. On the other hand, the current tendency is towards purchasing local and fresh milk in carton packages with long storage life.

Fruits and vegetables exhibit a higher expenditure elasticity. Such result seems to be implausible, but not if it is borne in mind that this is a heterogeneous group, containing a large variety of products, particularly fruits, whose retail price is often higher.

Oils and fats are considered a necessary good, since the corresponding expenditure elasticity is less than one. It is important to notice the low responsiveness of these typical Mediterranean products to income changes. In fact this is due to the high price of olive oil and the low price of vegetable oil, and the habit of consuming typical products in the Mediterranean diet. Furthermore, self-consumption of olive oil is decreasing, and the consumed component purchased on the market tends to increase, although it is still small. On the other hand, cooking oil subsidies were applied to generic products purchased from bulk drums and consumption pattern is reflected by the magnitude of the elasticity obtained.

The group « other foodstuffs » includes a large variety of products (coffee, tea, sugar, spices, etc.) considered as necessities, given the obtained expenditure elasticity value. However, it is worth pointing out the heterogeneity of such a group that contains sugar, a subsidised product that is heavily consumed in Tunisia.

Marshallian and Hicksian own-price elasticities have the expected negative sign, that is, changes in own-prices have inverse impacts on quantities demanded. The resulting demand for all groups is inelastic. Among the six food groups, own price elasticity of meat and fish is the largest in absolute terms, followed by fruits and vegetables, milk and dairy products and bread and cereals.

The positive estimate of the compensated own-price elasticity for oils and fats (which contradicts theoretical restrictions on preferences) is unusual, but it may be due to quality changes in oil and fat consumption. Since the 1980s, Tunisian households have substituted olive oil (more expensive) for vegetable oil. When higher quality oil is substituted for lower quality (vegetable oil), the average price paid for a given quantity rises even if the prices of the oil products remain unchanged. The switch from vegetable oil to olive oil has also been accompanied by an increase in per capita oil and fat consumption.

Table 4. **Expenditure and price elasticities** [7]

	Cereals	Meat and fish	Milk and dairy products	Fruits and vegetables	Oils and fats	Other food stuffs
Expenditure (%)	0.2106 (0.220)	0.23 (0.223)	0.064 (0.059)	0.231 (0.220)	0.084 (0.091)	0.178 (0.185)
Expenditure elasticities	-0.019 (0.01)	1.07* (1.08*)	0.95 (1.09*)	1.90* (1.91*)	0.98* (0.93*)	0.95* (0.98*)
Marshallian elasticities						
Cereals	-0.11* (-0.12*)	0.047 (0.035)	0.066 (0.064)	0.028 (0.032)	0.036 (0.039) -	0.04 (-0.06)
Meat and fish	-0.18* (-0.20*)	-0.53* (-0.54*)	0.015 (0.02)	-0.24* (-0.25*)	-0.047 (-0.06)	-0.07 (-0.05)
Milk and dairy products	0.013 (0.004)	0.085 (0.077)	0.18 (-0.20)	-0.99* (-1.12*)	0.26 (0.28) -	-0.014 (-0.11)
Fruits and vegetables	-0.37* (-0.38*)	-0.43* (-0.44*)	-0.33* (-0.35*)	-0.26* (-0.25*)	-0.27* (-0.29*)	-0.20 (-0.18*)
Oils and fats	-0.12 (-0.10)	-0.10 (-0.11)	0.20 (0.19)	-0.54* (-0.49*)	0.055 (0.074)	-0.46* (-0.49*)
Other foodstuffs	-0.26* (-0.28*)	-0.06 (-0.035)	-0.049 (-0.029)	-0.046 (-0.017)	-0.21* (-0.24*)	-0.31 (-0.37*)
Hicksian elasticities						
Cereals	-0.16* (-0.12*)	0.042 (0.037)	0.065 (0.065)	0.024 (0.035)	0.035 (0.041)	-0.05 (-0.06)
Meat and fish	0.039 (0.036)	-0.28* (-0.29*)	0.084 (0.085)	-0.0002 (-0.016)	0.042 (0.039)	0.12 (0.15*)
Milk and dairy products	0.212 (0.24)	0.303 (0.32)	-0.12 (-0.14)	-0.77* (-0.88*)	0.34* (0.37*)	0.031 (0.089)
Fruits and vegetables	0.022 (0.035)	-0.0002 (-0.016)	-0.21* (-0.24*)	0.17 (0.16)	-0.11* (-0.11*)	0.13 (0.17)
Oils and fats	0.086 (0.099)	0.11 (0.098)	-0.59* (-0.58*)	-0.31* (-0.28*)	0.13 (0.16)	-0.28* (-0.31*)
Other foodstuffs	-0.58 (-0.07)	0.15 (0.18*)	0.011 (0.028)	0.173 (0.20)	-0.13* (-0.15*) -	0.14 (-0.19)

* denotes significance at 5 % level.
Values in parentheses correspond to the parameters in the period before the structural change.

[7] The values of *t*-ratio for each elasticity are obtained by dividing the correspondent value by the approximated standard deviation. The standard errors of the elasticities were calculated assuming mean budget shares to be fixed. The variance-covariance matrix of estimated elasticities (E), VAR (E) is: VAR (E) = A VAR(b) A', where A is a constant matrix, VAR (b) is the variance-covariance matrix of b (vector of estimated CBS model parameters). This procedure over-estimates the *t*-ratios of the corresponding elasticities for the suppressed equation.

From the compensated cross-price elasticities view point, some food groups are gross complements, although their elasticities are small. The level of aggregation does not show clear relations among food groups. Thus, we may conclude in general, that these kinds of food groups tend to be complementary and they may be purchased and consumed simultaneously.

CONCLUSIONS AND POLICY IMPLICATIONS

In this study, we estimated a complete demand system for Tunisia, with emphasis on food demand, using the differential demand systems specification. Statistical tests show that the CBS model fits the data better than the AIDS, the NBR, or the Rotterdam models.

The findings of the analysis previously presented can provide a useful basis that is quite relevant for policy-makers, planners, and traders, taking into account the efforts implemented by the Tunisian government in order to achieve the favourable conditions and means to consolidate food security and achieve self-sufficiency.

Hence, the results of the analysis indicate a clear move towards high value and superior foods as per capita income of Tunisians increases and the level of affluence of Tunisian society rises. Most evident is the calculated demand elasticities that indicate that meat and fish, fruits and vegetables and oil and fats have the highest income and own-price elasticities. These products are considered luxury goods, and in the foreseeable future the demand for these food items would most likely increase. Therefore, an increase in the consumption of such products, contributes to higher incomes for agricultural producers, that can generate growth, particularly in the livestock and fruit sectors with the spillover effects from increases in rural incomes and expenditure on processed and high value-added products, which could create additional employment and income in rural areas. However, an increase in expenditure induces less than proportional increases in oil and fats, dairy products and other food.

As regards price elasticities, for all food groups the demand is inelastic. Besides the complementarity and substitution relations, demand is revealed to be more sensitive to total expenditure than prices. Nevertheless, it is worth to mention the limitation due to the short sample used, that may result in some insignificant elasticities. More over, the interpretation of elasticities is to be considered within a conditional demand system, given the hypothesis of weak separability adopted. Therefore, the weak sensitivity behaviour of demand to price variations in some products must be considered to adjust production. So, it is recommended to be specialised on the basis of technological potential, to improve the supply position of some quality products with a better productive organisation and an adequate commercial system at the distribution level.

The general picture exhibited shows that the elasticities-based results are closely related to Tunisia's experience in self-targeted food subsidies. In general, income augmenting policies, particularly in the rural areas, may also be effective in influencing consumption patterns, together with a progressive reduction of food subsidies for low-income elasticity products, and a better practice of targeting.

From a marketing point of view, an extension of this model to a more disaggregated level and the specification of a segmentation among households may provide not only a complete panorama of food consumption in Tunisia but also useful information on price and non-price factors affecting demand for particular foods.

Finally, it would be more interesting from a policy-maker point of view to analyse the influence of socio-demographic characteristics of consumers. However, data needed to carry out such cross-section studies are not yet available. Future data availability could be important, especially if we segment households in terms of income classes, to carry out the study of food demand in Tunisia.

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