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

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

Mots-clés: consommation alimentaire, système de demande, approche différentielle, changement structural, équilibre, Tunisie

Résumé – Dans ce travail, on décrit en premier lieu l'évolution de la consommation des produits alimentaires en Tunisie. Par la suite, on évalue, à l'aide de méthodes quantitatives, le comportement de la demande alimentaire en Tunisie. Les deux aspects principaux traités sont (1) l'analyse de la structure de la demande en alimentation en Tunisie et (2) la détermination de la structure de la demande alimentaire. La méthode utilisée consiste à évaluer la structure de la demande alimentaire en utilisant des modèles CB et NBR, de même que les coefficients d'élasticité de la demande alimentaire. Les résultats de cette étude sont présentés en détail dans le texte principal. Les résultats montrent que la demande alimentaire en Tunisie a connu une évolution importante ces dernières années.

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. Two factors behind these changes are: (a) the decrease in relative terms of expenditure on food at a mean income increase (Engel's Law) and (b) the relative increase of manufactures products. Two important aspects of these changes are: (a) the reduction in relative terms of expenditure on food at a mean income increase (Engel's Law) and (b) the relative increase of manufactures products. In order to study the change in the pattern of food consumption in Tunisia, a differential approach is used. The model estimated suggests that the structural change in food consumption in Tunisia is based on a price change of food due to a decrease in the relative price of manufactured products. Structural change is also considered. Calculated elasticities from the CB model with both homogeneity and symmetry imposed are more sensitive to variations in total expenditure or in price than in own price, with some relations of complementarity and substitutability possibilities shown. The demand is inelastic for all food groups. Finally, some policy and marketing considerations are provided on the basis of the empirical results.

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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-economic 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 (1995) aim 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 governments. 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 Lakjani 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 summa-
rizes 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, pre-
dominant 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, house-
holds 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

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 suggests 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 were published by INS was carried out in 1999. This evolution can be examined in Table 1.

<table>
<thead>
<tr>
<th>Food Groups</th>
<th>Budget Share (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grains</td>
<td>8.9</td>
</tr>
<tr>
<td>Legumes and condiments</td>
<td>1.5</td>
</tr>
<tr>
<td>Vegetables</td>
<td>6.7</td>
</tr>
<tr>
<td>Fruits and nuts</td>
<td>2.3</td>
</tr>
<tr>
<td>Meat</td>
<td>7.6</td>
</tr>
<tr>
<td>Fish</td>
<td>1.1</td>
</tr>
<tr>
<td>Milk, dairy products and eggs</td>
<td>3.8</td>
</tr>
<tr>
<td>Sugar and pastry</td>
<td>2.1</td>
</tr>
<tr>
<td>Oils and fats</td>
<td>4.7</td>
</tr>
<tr>
<td>Beverages</td>
<td>4.0</td>
</tr>
</tbody>
</table>

| Food/Total expenditure        | 41.7 | 41.7 | 39.0 | 40.0 | 37.7 |

Source: INS, Enquêtes nationales 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 8.5% and 1.5%, 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.

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

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, notably 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)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereals</td>
<td>181.3</td>
<td>210.2</td>
<td>204.4</td>
<td>194.4</td>
<td>187.0</td>
</tr>
<tr>
<td>Dry legumes</td>
<td>3.2</td>
<td>3.2</td>
<td>3.2</td>
<td>3.2</td>
<td>2.6</td>
</tr>
<tr>
<td>Green legumes</td>
<td>5.9</td>
<td>7.2</td>
<td>8.7</td>
<td>7.8</td>
<td>6.9</td>
</tr>
<tr>
<td>Fresh vegetables</td>
<td>64.7</td>
<td>66.2</td>
<td>77.6</td>
<td>81.5</td>
<td>72.7</td>
</tr>
<tr>
<td>Processed vegetables</td>
<td>41.5</td>
<td>42.5</td>
<td>46.8</td>
<td>52.2</td>
<td>52.6</td>
</tr>
<tr>
<td>Poultry</td>
<td>66.0</td>
<td>37.6</td>
<td>38.9</td>
<td>53.0</td>
<td>43.1</td>
</tr>
<tr>
<td>Meat and poultry</td>
<td>14.9</td>
<td>16.9</td>
<td>17.8</td>
<td>19.9</td>
<td>21.0</td>
</tr>
<tr>
<td>Fish</td>
<td>3.1</td>
<td>3.5</td>
<td>6.1</td>
<td>7.1</td>
<td>5.8</td>
</tr>
<tr>
<td>Fresh milk</td>
<td>55.5</td>
<td>40.6</td>
<td>37.3</td>
<td>38.8</td>
<td>40.0</td>
</tr>
<tr>
<td>Dairy products</td>
<td>15.9</td>
<td>20.4</td>
<td>14.1</td>
<td>19.6</td>
<td>22.0</td>
</tr>
<tr>
<td>Eggs</td>
<td>55.0</td>
<td>71.0</td>
<td>72.0</td>
<td>97.0</td>
<td>98.0</td>
</tr>
<tr>
<td>Oils and fats</td>
<td>15.7</td>
<td>15.8</td>
<td>23.8</td>
<td>25.1</td>
<td>25.0</td>
</tr>
<tr>
<td>Sugar and sweets</td>
<td>14.5</td>
<td>14.5</td>
<td>16.5</td>
<td>17.4</td>
<td>16.4</td>
</tr>
<tr>
<td>Tea</td>
<td>1.2</td>
<td>1.3</td>
<td>1.6</td>
<td>1.7</td>
<td>1.6</td>
</tr>
<tr>
<td>Coffee</td>
<td>0.7</td>
<td>0.7</td>
<td>0.8</td>
<td>0.7</td>
<td>0.7</td>
</tr>
</tbody>
</table>

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

(1) Fresh 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 (IFS, 1998). Therefore, food consumption in Tunisia is still characterized 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 separability¹ 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 (traditional) 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. Pederson (1983) 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 Machini et al. (1994) and in Sellen and Goddard (1996). In this study weak separability has been assumed and not tested because information on non-food group is not actually available.
ring process is then justified (Deutsch and Mundlauer, 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 cottofnum demand, many demand systems have been developed in the past. These are now numerous specifications of demand systems, including among others, the linear and quadratic expenditure systems, the Rotterdam model, the CBS \(^2\) model, the NBE \(^3\) 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; Alicea and Chalfant, 1995). However, the assumptions used to parameterise these models have different implications. For example, the marginal expenditure share and the Mundry terms are assumed constants in the Rotterdam model, while they are assumed functions of budget shares in the AIDS (Brown et al., 1994). However, economics theory does not provide criteria to choose between 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 (1960), is expressed as:

\[
\begin{align*}
\eta_i - p_i & = \gamma_i p_i \Delta \ln Q_i + \sum_{j=1}^{n} \gamma_j p_j \Delta \ln p_j
\end{align*}
\]  

where \(\eta_i\) represents the average budget share of commodity \(i\); \(q_i\) and \(p_i\) are quantity and price of food \(i\), respectively; \(\gamma_i\) is treated as change in consumer's behaviour in food \(i\); \(\gamma_i = \mu_i \frac{\Delta \ln Q_i}{\Delta \ln m}\) 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 Neter worked when the model was developed.
\[ d \ln Q = d \ln \rho = \sum_{j} \rho_j \ln \rho_j = \sum_{j} \rho_j \ln \rho_j \] is the Divisia volume index.

The marginal shares \( \delta \) and the Slutsky coefficients \( \epsilon \) were treated as constants.

These equations (1) satisfy adding-up condition if \( \sum \delta_j = 0 \); and Engel and Slutsky aggregation if \( \sum \delta_j = 1 \) and \( \sum \epsilon_j = 0 \). The homogeneity condition in the Rotterdam system requires \( \sum \delta_j = 0 \), while the Slutsky symmetry condition implies \( \delta_j = \delta_j \). Finally, the negativity condition needs \( \sum \epsilon_j \leq 0 \) \( \forall x_j, y \) constant and \( \epsilon_j \geq 0 \)
(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 (Gan and Spreeu, 1994; Lee et al., 1994; Gao et al., 1995). To escape this dilemma, a dynamic parameterisation is based on the Working model (Working, 1943):

\[ \omega_j = \alpha_j \cdot \beta_j \cdot \ln m \] (2)

As the sum of budget shares is unity, it follows from (2) that \( \sum \alpha_j = 1 \) and \( \sum \beta_j = 0 \).

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

\[ \frac{d\omega_j}{dm} = \alpha_j \cdot \beta_j \cdot \ln m \]

or

\[ \delta_j = \omega_j \cdot \beta_j \] (3)

Hence, under Working's model the \( \delta \) marginal share differs from the corresponding budget share by \( \beta \), as the budget share is not constant with respect to income, neither is the associate budget share.

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By replacing $b_t$ in (1) with (3) and rearranging terms, we obtain the CBS model (Selker and van Driel, 1985; Theil and Clemeres, 1987):

$$\eta_t; a \ln q_t' - b \ln r_t' = \gamma_t \beta_t a \ln q_t + \sum_{j=1}^{n} c_t \ln p_{t,j}$$  \hspace{1cm} (4)

In this case, the dependent variable is the ($\omega_t$-weighted) deviation of the log change in $q$ from the ($\omega_t$-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, $q_t/q_0$, of the $t$th 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:

$$\eta = \eta_t + \gamma_t (\ln \eta - \ln \eta') + \sum_{j=1}^{n} c_t \ln p_{t,j}$$  \hspace{1cm} (5)

where

$$\ln \eta' = \alpha_t + \sum_{j=1}^{n} d_t \ln p_{t,j} + \sum_{j=1}^{n} e_t \ln p_{t,j}$$  \hspace{1cm} (6)

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

$$\ln \eta' = \sum_{j=1}^{n} \eta_j \ln p_{t,j}$$  \hspace{1cm} (7)

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

$$\eta = \eta_t + \gamma_t (\ln \eta - \sum_{j=1}^{n} \eta_j \ln p_{t,j}) + \sum_{j=1}^{n} c_t \ln p_{t,j}$$  \hspace{1cm} (8)

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

$$d\eta_t = \xi_t + c_t a \ln Q + \sum_{j=1}^{n} e_t d \ln p_{t,j}$$  \hspace{1cm} (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, dln q, of the budget share change (the price and total expenditure components are treated as exogenous).\(^3\)

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 i-th budget share

\[
\left( w_i - \frac{p_i}{w} \right) d\ln w_i = d\ln p_i + d\ln q_i - w_i d\ln w
\]

Multiply both sides through by \(w_i\):

\[
w_i d\ln w_i = dw_i = w_i d\ln p_i + w_i d\ln q_i - d\ln w
\]

Sum (11) over all i:

\[
\sum_{i=1}^{n} w_i d\ln w_i = 0 = \sum_{i=1}^{n} w_i d\ln p_i + \sum_{i=1}^{n} w_i d\ln q_i - d\ln w
\]

Therefore,

\[
d\ln w = \sum_{i=1}^{n} w_i d\ln p_i + \sum_{i=1}^{n} w_i d\ln q_i = d\ln Q
\]

where the real income term \(d\ln Q = \sum_{i=1}^{n} w_i d\ln q_i\) is recognized 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 \(d\ln w\) by \(d\ln Q + \sum_{i=1}^{n} w_j d\ln p_j\), we obtain:

\[
dw_i = \xi_i + (\xi_i - \omega) d\ln Q + \sum_{j=1}^{n} \omega_j \xi_j - \omega w_j \omega d\ln p_j
\]

where \(\omega_j = 1\) 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:

\[
\xi_i = \delta_i - w_i
\]

\[
p_i = \xi_i + \omega_i \delta_i - w_i w_i
\]

\(^3\) 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 in the AIDS system (14) by \( \hat{h} - w \) and move \( w d\ln q \) over to the left-hand side, we obtain the NBR system:

\[
dw_i + w_i d\ln Q = \gamma_i + \hat{h} d\ln Q + \sum_{j=1}^{k} e_{ij} d\ln \hat{p}_j
\]

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

\[
w_i d\ln q = (\delta_i w_i + \lambda_i d\ln Q) + \sum_{j=1}^{k} e_{ij} w_i (\delta_j - \lambda_j) d\ln \hat{p}_j
\]

where \( \delta_i = \bar{\delta}_i + (1 - \bar{\delta}_i) \); \( \lambda_i = \bar{\lambda}_i + (1 - \bar{\lambda}_i) \); and \( \delta_j \) and \( \lambda_j \) are additional parameters. When \( \delta_i = \delta_j = 0 \), system (16) reduces to the Rotterdam specification. When \( \lambda_i = 1 \) and \( \lambda_j = 0 \), system (16) reduces to the CBS one. When \( \delta_i = \delta_j = 1 \) and \( \lambda_i = 0 \), system (16) reduces to the AIDS and when \( \delta_i = 0 \) and \( \lambda_j = 1 \), system (16) reduces to the NBR one.

The demand restrictions on (16) are:

- Adding-up:
  \[
  \sum_{i=1}^{n} d_{i} = 0, \sum_{i=1}^{n} e_{ij} = 0
  \]

- Homogeneity:
  \[
  \sum_{i=1}^{n} e_{ij} = 0
  \]

- Symmetry:
  \[
  e_{ij} = e_{ji}
  \]

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

\[
\sum_{i=1}^{n} \sum_{j=1}^{k} \sigma_i e_{ij} \tau_j < 0 \quad \forall \tau_j, \tau_j \text{ constant and } e_{ij} < 0
\]

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 non-positive. Since the rank of \( E \) is \((N-1)\) therefore, the negative semi-definite condition requires 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 \( \hat{h} \) has been introduced in (16) in the following way:
\[ w_s \ln q_{st} = \theta_s b_s + (\delta_s w_{st} + d_s + \xi_{st}) \ln Q_s + \sum_{j=1}^{n_s} (w_j - \delta_s w_j (\delta_j - w_j) + \xi_{st} b_j) \ln q_{jt} + u_s \]  

(21)

where \( \theta_s, \xi_s \) are parameters to measure the potential impact of the structural change on different variables of the system and \( u_s \) is the error term. In (21), theoretical restrictions hold if the new parameters satisfy:

\[ \sum_{s=1}^{n} \theta_s = 0; \sum_{s=1}^{n} \xi_s = 0; \sum_{s=1}^{n} \zeta_{st} = 0 \text{ and } \xi_s = \xi_s \]  

(22)

The selection of the functional form of \( b_s \) is important for a correct specification of system (21) (Mochini and Moro, 1990). Among the different alternatives, the approach proposed by Ohtani and Katayama (1986) and applied by Mochini and Meekle (1989) has been considered.

It is assumed that \( b_s \) adopts the following expression:

\[ b_s = \begin{cases} 
0 & \text{for } t = 1, \ldots, F_i \\
(T_s - F_i) & \text{for } t = F_i + 1, \ldots, F_s - 1 \\
1 & \text{for } t = F_s, \ldots, T_s 
\end{cases} \]

where \( F_i \) and \( T_s \) 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 \( F_i + 1 \).

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 Organization (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 Mensual de Estadística (Monthly Statistical Bulletin) published by the Instituto Nacional de la Estadística (National Statistics Institute, INE). Food products have been aggregated into six bread 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, CDS, 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 \( w_{ij} \), \( d\ln p_i \), and \( d\ln q_i \) for \( \Delta w_{ij} = \frac{w_{ij}}{2} \), \( \Delta \ln p_i = \ln p_{i+1} - \ln p_i \), and \( \Delta \ln q_i = \ln q_{i+1} - \ln q_i \), 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 TSPA-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 \( F_1 \) and \( F_2 \) in (21) have been determined using the method proposed by Quandt (1960) and applied by Mosteller and Meulke (1980), Xu and Verman (1990) and Hackett et al. (1990), among others. In our case, results indicate that structural change has taken place between 1984 and 19873 which are the chosen values for the two parameters mentioned above.

The second step consists of checking which parameters in demand for food products system were affected by the structural change. The null hypothesis of no structural change affecting prices and Divisa price index \( d\ln Q \) could not be rejected, at the 5% level of significance (in this case the LR statistic was 34.18, which under the critical value \( \chi^2_{9} = 37.7 \), therefore, the structural change has only affected intercepts. In other 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 Divisa price index \( d\ln Q \) have remained more or less stable over time.

Therefore, the final estimated model was:

\[
\Delta w_{ij} = 6 \beta_i\left(\frac{\Delta w_{ij}}{2}\right) + \sum_{j=1}^{k} \delta_{ij} \Delta (\Delta w_{ij}) d\ln p_i + x_y
\]

Because (23) with its two additional parameters are estimated 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:

\[
\text{LRT} = -2 \left[ \ln L(\hat{\theta}) - \ln L(\theta) \right]
\]

3 Note that synthetic and the four conditional demand systems (AID, Rotterdam, CBS and NBR) pick the same years.

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where $\theta$ is the vector of parameter estimates of a restricted model (Rotterdam, CBS, AIDS, and NBR); $\hat{\theta}$ is the vector of parameter estimates of the synthetic model; and $L(c)$ is the value of the likelihood function (Ameniya, 1985). For example, under the null hypothesis that the differential AIDS best describes the data, test statistic $LRT$ has an asymptotic $\chi^2$ distribution with $r$ 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>
<thead>
<tr>
<th>Demand Systems</th>
<th>Maximized Log Likelihood</th>
<th>Likelihood Ratio Test: Named Demand System to the Synthetic System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Synthetic System</td>
<td>408.940</td>
<td>-</td>
</tr>
<tr>
<td>ROT</td>
<td>405.327</td>
<td>7.226</td>
</tr>
<tr>
<td>CBS</td>
<td>407.972</td>
<td>1.959</td>
</tr>
<tr>
<td>AIDS</td>
<td>404.267</td>
<td>9.546</td>
</tr>
<tr>
<td>NBR</td>
<td>403.981</td>
<td>9.918</td>
</tr>
</tbody>
</table>

* 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.

* The estimates for $\delta_1$ and $\delta_2$ in (23) are 0.89 and 0.18 with standard errors of 2.64 and 1.05, respectively.

**Elasticity Estimates from the CBS Model**

In the estimated CBS system, the theoretical restriction of adding $-\mu_p$ 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: -0.07886, -0.0003792, -0.02411, -0.041274 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 ($e_j$), the uncompensated price elasticities ($e'_p$), and the compensated price elasticities ($e'_r$) for the CBS model are:

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- Total expenditure: \[ \eta = \frac{P_i}{w_i} + I \]  (25)

- Uncompensated price elasticities: \[ E_{x_j} = \eta - \eta \frac{w_j}{w_i} \]  (26)

- Compensated price elasticities: \[ e_{x_j} = \eta - \frac{w_j}{w_i} \]  (27)

These elasticities correspond to the period after the structural break. To calculate elasticities for the first period, we substitute \( w_i \) by \( \bar{w}_i \) where \( \bar{w}_i \) 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 \( \Delta lnQ \) 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 (Thiel, 1980; Dufuji, 1987; Lee et al., 1994; Fouskas and Partizian, 2000). In this context, Thiru (1980) shows that if \( \Delta \) is exogenous, the disturbance covariance terms are proportional to the Slutsky terms and satisfy \( e_n(e_t) = \alpha_n \). Using the CBS disturbance covariance terms, the regression of the covariance terms show that: \( cov (e_t, e_r) = 0.411 (10^{-3}) (5.83 (10^{-3}) -0.19(10^{-2}) (0.128(10^{-3})), with \( R^2 = 0.44 \), where standard errors of estimates are in parentheses. The regression results show that \( cov (e_t, e_r) \) is proportional to the Slutsky terms, so the \( \Delta lnQ \) 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 \( \chi^2 \) with five degrees of freedom at 5 % level is 11.1. Thus, the assumption of homogeneous 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 (Blewett and Young, 1987). It has the following expression:

\[ R^2 = 1 - \frac{1}{1 + 2\sqrt{LL_n - LL_0}^p} \frac{1}{T^*(N - 1)} \]  (20)

Where \( LL_n \) is the log likelihood of the unrestricted model, \( LL_0 \) 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. 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 3, it seems that this parameter is significant for four (meat and fish, fruits and vegetables, oils and fats and other foodstuffs) 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 complements. Post structural Marshallian and Houthiyan price and expenditure elasticities were calculated as 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 standpoint. Expenditure on such products increases more than proportionately 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 pliable 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 substitutability hypothesis had been considered, because 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 containers, 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 results seem to be plausible, 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 patterns are reflected by the magnitude of the elasticity obtained.

The group of 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 subsidized 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.

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<table>
<thead>
<tr>
<th></th>
<th>Grouds</th>
<th>Meat and fish</th>
<th>Milk and dairy products</th>
<th>Fruits and vegetables</th>
<th>Oils and fats</th>
<th>Other food stuffs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expenditure (90)</td>
<td>0.216</td>
<td>0.23</td>
<td>0.056</td>
<td>0.231</td>
<td>0.084</td>
<td>0.178</td>
</tr>
<tr>
<td></td>
<td>(0.0220)</td>
<td>(0.225)</td>
<td>(0.059)</td>
<td>(0.220)</td>
<td>(0.089)</td>
<td>(0.185)</td>
</tr>
<tr>
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<td>-0.019</td>
<td>1.07*</td>
<td>0.95</td>
<td>1.90*</td>
<td>0.98*</td>
<td>1.95*</td>
</tr>
<tr>
<td>ties (90)</td>
<td>(0.01)</td>
<td>(1.08*)</td>
<td>(1.09*)</td>
<td>(1.91*)</td>
<td>(0.95*)</td>
<td>(0.98*)</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Grouds</td>
<td>-0.11*</td>
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<td>0.66</td>
<td>0.028</td>
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<td></td>
<td>(-0.12*)</td>
<td>(0.053)</td>
<td>(0.64)</td>
<td>(0.052)</td>
<td>(-0.053)</td>
<td>(-0.01)</td>
</tr>
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<td>Meat and fish</td>
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<td>-0.53*</td>
<td>0.015</td>
<td>-0.24*</td>
<td>-0.047</td>
<td>-0.07</td>
</tr>
<tr>
<td></td>
<td>(-0.20*)</td>
<td>(-0.54*)</td>
<td>(0.05)</td>
<td>(-0.25*)</td>
<td>(-0.06)</td>
<td>(-0.05)</td>
</tr>
<tr>
<td>Milk and dairy pro</td>
<td>0.03*</td>
<td>0.085</td>
<td>0.18</td>
<td>-0.99*</td>
<td>0.26</td>
<td>-0.01*</td>
</tr>
<tr>
<td>ducts</td>
<td>(0.004)</td>
<td>(0.077)</td>
<td>(0.07)</td>
<td>(-1.12*)</td>
<td>(0.08)</td>
<td>(-0.11)</td>
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<tr>
<td>Fruits and vegetab</td>
<td>0.37*</td>
<td>-0.43*</td>
<td>-0.35*</td>
<td>-0.26*</td>
<td>-0.27*</td>
<td>-0.20</td>
</tr>
<tr>
<td>les</td>
<td>(0.58*)</td>
<td>(-0.44*)</td>
<td>(0.35*)</td>
<td>(-0.25*)</td>
<td>(-0.29*)</td>
<td>(-0.18)</td>
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<tr>
<td>Oils and fats</td>
<td>-0.12</td>
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<td>0.30</td>
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<td>0.055</td>
<td>-0.46*</td>
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<td></td>
<td>(-0.10)</td>
<td>(-0.11)</td>
<td>(0.10)</td>
<td>(-0.69*)</td>
<td>(0.03)</td>
<td>(-0.49)</td>
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<tr>
<td>Other foodstuffes</td>
<td>-0.26*</td>
<td>0.06</td>
<td>-0.04</td>
<td>-0.06</td>
<td>-0.21*</td>
<td>-0.31</td>
</tr>
<tr>
<td></td>
<td>(-0.28*)</td>
<td>(-0.105)</td>
<td>(0.029)</td>
<td>(-0.017)</td>
<td>(-0.24*)</td>
<td>(-0.57)</td>
</tr>
</tbody>
</table>

| Hickman elasticities|        |               |                         |                      |              |                  |
| Grouds              | -0.16* | 0.042         | 0.065                   | 0.024                | 0.015        | -0.05            |
|                     | (-0.12*)| (0.037)       | (0.06)                  | (0.055)              | (0.06)       | (-0.06)          |
| Meat and fish       | 0.039  | -0.28*        | 0.084                   | -0.002               | 0.012        | 0.12             |
|                     | (0.060) | (-0.29*)      | (0.089)                 | (-0.016)             | (0.069)      | (0.15)           |
| Milk and dairy pro| 0.212  | 0.361         | -0.12                   | -0.71*               | 0.54*        | 0.031            |
| ducts               | (0.24) | (0.32)        | (-0.14)                 | (-0.88*)             | (0.37*)      | (0.089)          |
| Fruits and vegetab| 0.022  | -0.0002       | -0.21*                  | 0.17                 | -0.11*       | 0.13             |
| les                  | (0.033) | (-0.016)      | (-0.24*)                | (0.16)               | (-0.24)      | (0.17)           |
| Oils and fats        | 0.096  | 0.11          | -0.59*                  | -0.31*               | 0.11         | -0.28*           |
|                     | (0.099) | (0.098)       | (-0.56*)                | (-0.28*)             | (0.16)       | (-0.31)          |
| Other foodstuffes    | -0.38  | 0.15          | 0.01                    | 0.17                 | -0.15*       | 0.14             |
|                     | (-0.07) | (0.18*)       | (0.028)                 | (0.20)               | (-0.15)      | (-0.19)          |

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

1 The values of *a* ratio for each elasticity are obtained by dividing the correponding value by the approximate 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)* = *VAR (E)* - *A VAR(E)*, where *A* is a constant matrix, *VAR (b)* is the variance-covariance matrix of *b* (vector of estimated CBS model parameters). This procedure overestimates the *E* ratios of the corresponding elasticities for the respective 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 CIB 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 spill-over 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 specialized 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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The Structure of Food Demand in Tunisia: a Differential System Approach

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