Modeling structural change in French beef, poultry, and fish demand: a markov Switching AIDS model

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Abstract

Structural change in the French demand of beef, poultry and fish is originally investigated. Rather than applying the traditional switching AIDS (S-AIDS) model, we reconsider the analysis of structural change through the Markov switching AIDS (MS-AIDS). The main feature of this model is that the switching mechanism is controlled by an unobserved variable that follows a Markov chain. As such, it captures more complex dynamic patterns than does the S-AIDS model. The MS-AIDS and the S-AIDS are compared to determine which model provides the better explanation of beef, poultry,and fish dynamic demand. We find that a MS-AIDS displaying habit formation detects the two mad cow crises in 1996 and 2000 and may identify the structural changes emanating from nutritional recommendations.

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1 Introduction

It is commonly admitted that consumption patterns for meat and fish have changed considerably over the last decades. Generally, in west countries, shifts from red meats in favor to white meats and fish are observed. Many studies, such as Mangen and Burrel [2001], Moschini and Meilke [1989] and Rickertsen [1996] found that these changes are not fully due to change in relative prices and income, but are also partly explain by structural change.[1] The latter studies, following Ohtani and Katayama [1986], develop the Switching Almost Ideal Demand System (S-AIDS) to detect structural changes. In this model, structural change is approximated by an exogenous variable that modifies the parameter values according to the time period and the regime that prevail. Although this model is largely used, it is unable to represent many non linear dynamics such as asymmetry in variance and correlation. Moreover, it implies only a unique, irreversible and exogenous shift of regime at a fixed time, and it imposes that the structural change does exist, which overestimates and bias the occurrence of possible structural changes. First, this paper proposes to reconsider the analysis of structural changes in meat and fish demand: specifically, the Markov Switching model of Hamilton [1989] is applied to the AIDS. We call this model the Markov Switching AIDS (MS-AIDS). Second, it asks which of the S-AIDS or the MS-AIDS model better explains the dynamic pattern of French beef, poultry and fish consumption.

The Markov Switching model involves multiple structures (equations) that can characterize the evolution of behaviors in different regimes. Specifically, changes in mean, in volatility and in the autoregressive part of the equations can be easily developed. By permitting switching between these structures, this model is able to capture more complex dynamic patterns. The main feature of Markov Switching model is that the switching mechanism is controlled by an unobserved variable that follows a Markov chain. As such, a structure may prevail for a random period time, and it will be replaced by another structure when a switching takes place. Therefore, the model allows for frequent changes at random time points, and it is suitable for describing correlated data that exhibit distinct dynamic patterns during different periods. Moreover, it does not suffer from statistical biases that the Switching AIDS does since regime shifts are

[1] Health concerns are often cited to explain the shift in favor to white meats and fish.

stochastic, and so no determinist, and they are identified by the interactions between data and the unobserved variable, not by a *priori* inspection of data.

The MS-AIDS is applied to French consumption patterns for beef, poultry, and fish. This application is interesting since meat and fish demands follow a complex dynamic; France has known at least two sharp structural changes since the 1980s. First, nutritional recommendations emanating from heath authorities have provoked changes in preferences during the 1980s: consumers have been limiting red meat consumption, to the benefit of poultry and fish particularly. Second, France was stricken by two mad cow crises in March 1996 and in October 2000. For this complex dynamic, the MS-AIDS and the S-AIDS are compared to determine which model provides the better explanation of beef, poultry, and fish dynamic. The data are drawn from the French National Accounts over the period 1949-2001 (INSEE [2002]).[2] Various structures of MS-AIDS are employed to explain the evolution of beef, poultry and fish expenditures such as MS-AIDS with constant habit formation and MS-AIDS with shifting habit formation. We find that the dynamic of beef, poultry and fish is better explained by the MS-AIDS than by the S-AIDS, in all cases considered. Furthermore, introducing habit formation substantially improves the results. All MS-AIDS models establish substitutions between beef and poultry and beef and fish during mad cow crises, which is not always the case for the S-AIDS. Most of all, the MS-AIDS model characterized by habit formation and shifts in intercept would be able to precisely capture the two French mad cow crises and the gradual structural changes driven by health concerns.

The paper is organized as follows. In section 2, the MS-AIDS model is presented. Specifically, a comparison between the S-AIDS and the MS-AIDS, the estimation method and the optimal inference about regimes are developed. In section 3, the estimation results are presented. Section 4 concludes.

2 The Markov Switching AIDS

2.1 Markov Switching AIDS vs Switching AIDS

Deaton and Muellbauer [1980]'s almost ideal demand system (AIDS) is usually used to

[2] Generally, the AIDS model is employed to estimate micro data. Here, we use time series data, and the individual dimension cannot be studied. The effects estimated are average effects; we estimate the evolution through time of a representative household behavior.

estimate consumption patterns. The AIDS is such as the ith good's expenditure share at time t, denoted w_{it}, takes the form

$$w_{i,t} = \alpha_i + \sum_{j=1} \gamma_{ij}\, p_{j,t} + \beta_i \ln\left(\frac{x_t}{P_t}\right) + u_{i,t}, \quad t = 1,\ldots,T \text{ and } i = 1,\ldots,n \qquad (1)$$

where $\ln P_t$ is a log price index defined by

$$\ln P_t = \alpha_0 + \sum_{k=1} \alpha_k p_{k,t} + 0.5 \sum_{k=1}\sum_{j=1} \gamma_{kj}\, p_{k,t}\, p_{j,t} \qquad (2)$$

In equations (1) and (2), p_{kt} denotes the log per unit price of good k at time t, x_t is the total per capita expenditure of the n goods included in the system at time t and $u_{i,t}$ is a perturbation such as $u_{i,t} \to N(0,\sigma_i^2)$. Note that apart from the function $\ln P_t$ the system is linear and all the parameters are stable over time. Therefore, changes in preferences and in tastes, that may be induced by health concerns, attention to quality or new products, cannot be evaluated in the AIDS.

Various studies, such as Mangen and Burrel [2001], Moschini and Meilke [1989] and Rickertsen [1996] follow Ohtani and Katayama [1986] to take into account the possible structural changes in consumption patterns. The structural changes can be approximated by an exogenous variable h_t such as

$$\begin{aligned} h_t &= 0 \text{ for } t = 1,\ldots,\tau_1; \\ h_t &= \frac{t - \tau_1}{\tau_2 - \tau_1} \text{ for } t = \tau_1 + 1,\ldots,\tau_2 - 1; \\ h_t &= 1 \text{ for } t = \tau_2,\ldots,T; \end{aligned}$$

where τ_1 represents the end point of the first regime and τ_2 is the starting point of the second regime and where the transition path between the two regimes is linear. Note also that the change in regime can be gradual or abrupt, depending on the size of $\tau_2 - \tau_1$. Thus, the AIDS parameters α_i, γ_{ij}, β_i, in equations (1) and (2) becomes respectively $(\alpha_i + \tilde{\alpha}_i h_t)$, $\left(\gamma_{ij} + \tilde{\gamma}_{ij} h_t\right)$, and $\beta_i + \tilde{\beta}_i h_t$ to incorporate structural changes in the system. It is called the Switching AIDS (S-AIDS)

However, this kind of model has four restrictive implications on the nature of structural changes. First, the parameters are assumed to shift typically once and during a fixed period. Second, the occurrence of a structural break is supposed to exist. Yet, one can never say with certainty that a structural change exists in economic time series. And if one think a structural break has occurred because of some major economic event, this kind of structural change model can dramatically bias the inference towards finding breaks where none exist. Third, serial correlation between regimes is not possible. Four, volatility asymmetry is impossible to explain with the S-AIDS.

Hamilton [1989] developed a model in which parameters can change as the result of a regime shift-variable. Specifically, changes in regime are determined by the outcome of an unobserved state variable s_t. The variable s_t is assumed to follow a M-state Markov chain which evolves according to the following transition probabilities

$$P(s_t = m | s_{t-1} = l) = \pi_{lm}; \text{ for } l, m = 1, \ldots, M \tag{3}$$

The unknown transition probabilities π_{lm} are collected in the transition matrix $(M \times M)$ Π, where, for example, the row 2, column 1 element gives the probability that state 1 will be followed by state 2. In this paper, the theory of Markov Switching is applied to the AIDS. Thus, the popular AIDS is modelled in function of an unobserved variable s_t such as

$$w_{i,t} = \alpha_{i,s_t} + \sum_{j=1} \gamma_{ij,s_t} p_{j,t} + \beta_{i,s_t} \ln\left(\frac{x_t}{P_t}\right) + u_{i,t} \tag{4}$$

$$\begin{aligned} \ln P_t &= \alpha_{0,s_t} + \sum_{k=1} \alpha_{k,s_t} p_{k,t} + 0.5 \sum_{k=1} \sum_{j=1} \gamma_{kj,s_t} p_{k,t} p_{j,t} \\ s_t &= 1, 2, \ldots, M \text{ and } i = 1, \ldots, n \end{aligned} \tag{5}$$

and u_t, the n-vector composed of the $u_{i,t}$, is such as $u_t \sim N(0, \Omega_{s_t})$; where Ω_{s_t} is the $(n \times n)$ covariance matrix which depends on the shift-variable s_t and is composed of the σ_{ij,s_t} for $i = j = 1, \ldots, n$.

In the M regimes, $w_t = (w_{1t}, \ldots, w_{nt})$ keeps the same form, but the parameters (including those of the covariance matrix of the perturbation vector u_t) differ across regimes, and the changes in regime are stochastic, frequent and possibly serially correlated, whereas the S-AIDS admits only occasional and independent changes. This model is called the Markov Switching AIDS (MS-AIDS). The MS-AIDS is therefore suitable for describing correlated data that exhibit distinct dynamic patterns during different periods. Note also that possible changes in volatility are introduced contrary to the Switching AIDS. Moreover, MS-AIDS does not suffer from some statistical biases that the previous model does; the regime shifts are identified by the interaction between the data and the Markov chain, not by a priori inspection of the data as in the Switching AIDS. Furthermore, shifts in habit consumption can be incorporated in the MS-AIDS by including lagged expenditure shares in the demand system. Habit consumption effect reflects that the consumer only gradually adjust his consumption in response to structural changes and changes in prices and income. This model is interesting since sudden and sharp events may bring about changes in habit formation. The equation (4) becomes

$$w_{i;t} = \alpha_{i;s_t} + \sum_{j=1} \phi_{ij;s_t} w_{j;t-1} + \sum_{j=1} \gamma_{ij;s_t} p_{j;t} + \beta_{i;s_t} \ln \left(\frac{x_t}{P_t} \right) + u_{i;t} \tag{6}$$

Demand functions are characterized by properties such as adding-up, homogeneity of degree zero in prices, and total expenditure and Slutsky symmetry. In the MS-AIDS, these properties take the following parametric restrictions for each outcome of the regime shift-variable s_t

$$\sum_{i=1} \alpha_{i;s_t} = 1; \quad \sum_{i=1} \gamma_{ij;s_t} = 0; \quad \sum_{i=1} \beta_{i;s_t} = 0; \text{ and } \sum_{i=1} \phi_{ij;s_t} = 0, \ \forall i \text{ (adding-up)}$$
$$\sum_{j=1} \gamma_{ij;s_t} = 0; \ \forall i \text{ (homogeneity), and } \gamma_{ij;s_t} = \gamma_{ji;s_t}; \ \forall i;j \text{ (symmetry),}$$

An additional restriction imposed to avoid multicollinearity is $\sum_{j=1}^{n} \phi_{ij;s_t} = 0$. Restrictions to ensure concavity of the cost function are not imposed. However, we check the compensated own-price elasticities for a negative sign. It is a necessary condition for concavity.

The uncompensated own-price, $\eta_{ii;s_t}$, cross-price, $\eta_{ij;s_t}$, and the expenditure elasticities, $\varepsilon_{i;s_t}$ are given by

$$\eta_{ij;s_t} = -\delta_{ij} + \frac{1}{w_{i;t}} \left[\gamma_{ij;s_t} - \beta_{i;s_t} \left(\alpha_{j;s_t} + \sum_{j=1} \gamma_{ij;s_t} p_{j;t} \right) \right] \tag{7}$$

where δ_{ij} equals one when $i = j$ and zero otherwise, and

$$\varepsilon_{i;s_t} = 1 + \frac{\beta_{i;s_t}}{w_{i;t}} \tag{8}$$

The compensated price elasticities are calculated by

$$\tilde{\eta}_{ij;s_t} = \eta_{ij;s_t} + w_{j;t}\varepsilon_{i;s_t} \qquad (9)$$

Note that structural changes significantly affect the demand elasticities: it exists different own-price, cross-price, and expenditure elasticity values, for each regime.

2.2 Estimation and optimal inference about regimes

The population parameters that have to be estimated are those that describe the evolution of the vector w, governed by equations (3), (4), and (5). It consists of M matrix θ_{s_t}, composed of the $((n+2) \times 1)$ parameter vector $\theta_{i;s_t} = (\alpha_{i;s_t}; \gamma_{i1;s_t}; \ldots; \gamma_{in;s_t}; \beta_{i;s_t})$ for $i = 1; \ldots; n$, the $\frac{n(n+1)}{2}$ parameters of the M symmetric covariance matrix Ω_{s_t} and the various transition probabilities π_{lm} of the matrix Π. These parameters are collected in a vector Ψ, such as $\Psi = vec\,(\theta_{s_t}; \Omega_{s_t}; \Pi)$ for $s_t = 1; \ldots; M$, where the operator vec creates a column vector by stacking the columns of the matrix θ_{s_t}; Ω_{s_t}; and Π. If we set $N = n(n+2) + \frac{n(n+1)}{2}$, Ψ is a $Nparam = (M \cdot (N + (M - 1)) \times 1)$ parameter vector.[3] The difficulty here is that the evolution of the vector w_t depends on an unobserved variable s_t. Therefore, the occurrence of each regime at time t must be known to evaluate the log likelihood function. In this subsection, first the evaluation of the likelihood function and second an algorithm to calculate the probability that the tth observation was generated by the regime m are presented.

2.2.1 Evaluation of the likelihood function

Let X_t be a $((n+2) \times 1)$ vector of observed exogenous variables such as $X_t = (1; p_{1;t}; \ldots; p_{n;t}; \ln \frac{X_t}{P_t})$ and $W_t = (w_t; w_{t-1}; \ldots; w_1; X_t; X_{t-1}; \ldots; X_1)$ a vector containing all observations obtained through date t. From Bayes law and considering the above notations, the joint density-distribution function of w_t and s_t can be found by integrating

$$P(w_t; s_t = m|X_t, W_{t-1}; \Psi) = P(s_t = m|X_t; W_{t-1}; \Psi) \cdot f(w_t|s_t = m; X_t; W_{t-1}; \Psi) \quad (10)$$

for $m = 1; \ldots; M$, and $t = 1; \ldots; T$. $P(s_t = m|X_t; W_{t-1}; \Psi)$ denotes the probability that the tth observation was generated by regime m, conditioned on data obtained

[3] Note that the redundant parameters of the Matrix Π are omitted.

through date $t-1$, X_t, and the knowledge of the population parameters θ. This conditional probabilities are collected in a $(M \times 1)$ vector $\xi_{t|t-1}$. The conditional density $f(w_t|s_t = m; X_t; W_{t-1}; \theta)$ is given by[4]

$$f(w_t|s_t = m; X_t; W_{t-1}; \theta) = (2\pi)^{-\frac{n}{2}}|\Omega_m|^{-\frac{1}{2}} \exp\left(-\frac{1}{2}(w_t - X_t\mu_m)\Omega_m^{-1}(w_t - X_t\mu_m)'\right); \tag{11}$$

if the time series process over w_t is governed by regime m at date t. The conditional density of w_t is collected in a $(M \times 1)$ vector η_t. The density function of the observed vector w_t conditioned on past observable and the knowledge of the population parameters θ is found by summing (10) over all possible values of s_t, such as

$$f(w_t|X_t; W_{t-1}; \theta) = \sum_{m=1}^{M} P(w_t; s_t = m|X_t, W_{t-1}; \theta) = 1'(\xi_{t|t-1} \odot \eta_t) \tag{12}$$

where 1 represents an $(M \times 1)$ vector of 1s, and the symbol $\odot$ denotes element-by-element multiplication. The log likelihood function $\ell(\theta)$ for the observed data W_T evaluated at the value θ is such as

$$\ell(\theta) = \sum_{t=1}^{T} \ln f(w_t|X_t; W_{t-1}; \theta)$$

2.2.2 Optimal inference about regimes

The estimation of the parameter vector θ is obtained by numerically maximizing the log likelihood function $\ell(\theta)$.[5] However, the optimization is doable only if the probability vector $\xi_{t|t-1}$ can be implemented. Hamilton [1989] showed that the optimal probability vector and its forecast for each date t in the sample can be found by iterating on the following equations

$$\xi_{t|t} = \frac{(\xi_{t|t-1} \odot \eta_t)}{1'(\xi_{t|t-1} \odot \eta_t)} \tag{13}$$

$$\xi_{t+1|t} = P \cdot \xi_{t|t} \tag{14}$$

[4] It seems that the conditionnal density depends only on the current regime s_t, and not on the past regimes. This specication is not really restrictive since it is always possible to transform the density of w_t which depends on $(t + m + 1)$ two-state Markov chain $s^*_t; s^*_{t-1}; s^*_{t-m}$ into a density which depends only on a $(t + m + 1)$-state Markov chain s_t. Note that the transition matrix of s_t must also be adapted to the specication.

[5] The optimization is implemented by the procedure Optmum in GAUSS.

for $t = 1, \ldots, T$; where the mth element of the forecast $(M \times 1)$ vector $\xi_{t+1|t}$ is $P(s_{t+1} = m|W_t; \theta_{s_t})$. Thus, given a starting value $\xi_{1|0}$ and an assumed value for the population parameter vector θ, one can iterate on equations (13) and (14) for $t = 1, \ldots, T$ to calculate the values of $\xi_{t|t}$ and $\xi_{t+1|t}$ for each date t in the sample.[6] These probabilities are called the filtered probabilities. It is also possible to implement smoothed probabilities. Kim [1994] proposed to calculate these probabilities according to the following algorithm

$$\xi_{t|T} = \xi_{t|t} \odot \left[P' \cdot (\xi_{t+1|T} (\div) \xi_{t+1|t}) \right] \qquad (15)$$

where the sign $(\div)$ denotes element-by-element division. The smoothed probabilities $\xi_{t|T}$ are found by iterating on equation (15) backward for $t = T-1, T-2, \ldots, 1$. This iteration is started with the filtered probability $\xi_{T|T}$ which is obtained from equation (13) for $t = T$. The smoothed probabilities are based on the fact that we rarely do know which regime we are in (s_t is unobservable), but after the fact we can often identify which regime we were in with some degree of confidence.

3 The Data and the estimated MS-AIDS

3.1 The Data

The data are drawn from the French National Accounts over the period 1949-2001 (INSEE [2002]). The French National Accounts give the annual household consumption expressed in real terms (by volume) and in nominal terms (by value) and several general data like household disposable income, current taxes on income and French population figures. The household expenditures of three categories of food are studied: beef, poultry and fish. The choice of beef appears obvious given the defined regimes. Poultry and fish are chosen because it seems that the shifts from beef to these two goods are the highest levels of substitution compared to the other possible substitution levels. Moreover, the correlations between beef and poultry and beef and fish are strongly

[6] To see the basis of the algorithm, note from Bayes law that

$$\begin{aligned} P(s_t &= m|W_t; \theta) = P(w_t, s_t = m|X_t, W_{t-1}; \theta)/f(w_t|X_t, W_{t-1}; \theta) \\ &= f(w_t|s_t = m, X_t, W_{t-1}; \theta) \cdot P(s_t = m|X_t, W_{t-1}; \theta)/f(w_t|X_t, W_{t-1}; \theta) \end{aligned}$$

for $s_t = 1, \ldots, M$. Collect each value of $P(s_t = m|W_t; \theta)$ in the vector $\xi_{t|t}$ to obtain equation (13). The equation (14) directly follows from the properties of the Markov chain.

negative compared to the negative correlations between beef and other meat during the period 1980-2001.[7] Figure 1 illustrates the evolution of beef, poultry and fish consumption levels expressed in real terms. It shows the continuous decline of beef consumption since the middle of the 1980's that takes place to the benefit of poultry and, to the lesser extent, of fish. Nutritional recommendations emanating from health authorities may be responsible for this evolution (in France, the link between nutrition and health has grown since the beginning of the 1980s). Moreover, the negative effects of the two mad cow crises are easily detectable. In March 1996, the French consumers were informed of the link between Bovine Spongiform Encephalopathy (BSE) and the new variant Creutzfeldt-Jacob disease (nvCJD). In 2000, an other beef crisis occurred. It is observed that French demand shifts from beef to poultry and fish in both cases. From the data analysis, it may exist two regimes; one which is characterized by a low level of beef expenditure, $s_t = 1$; and an other one which is characterized by a higher level of beef expenditure, $s_t = 2$. So, M is equal to 2.

The empirical application required the constitution of several data. The total expenditure is constructed by summing annual beef, poultry and fish consumptions by volume. The total expenditure is expressed per capita given the population figures. Each budget share is calculated by dividing the corresponding consumption in real terms by the total expenditure. Prices indices are used and obtained by the ratio between consumption in nominal terms and consumption in real terms. Finally, a variable is required to correct the potential endogeneity of the total expenditure per capita (to be discussed later). We used the total household income per capita that is calculated by substracting the current taxes to the household disposable income and by dividing this result by the general price index and the population figures. Table 1 gives a description and summary statistics of the variables used in the estimations.

3.2 The estimated MS-AIDS

In the MS-AIDS all the parameters can vary over time and an high number of goods can be studied. However, this is not possible to implement due to the lack of degrees of

[7] Correlation measures the dependence over time between two series. A negative (positive) correlation between expenditures of two goods can be "interpreted" as goods that are substitute (complement) over time.

Table 1: Description of the data (INSEE source)

	Min	Mean	Max	STD
Budget share of beef	0.397	0.519	0.616	0.053
Budget share of poultry	0.181	0.282	0.413	0.069
Budget share of …sh	0.161	0.199	0.244	0.025
Total meat and …sh expenditures, 10^6 euros per capita	0.127	0.219	0.272	0.046

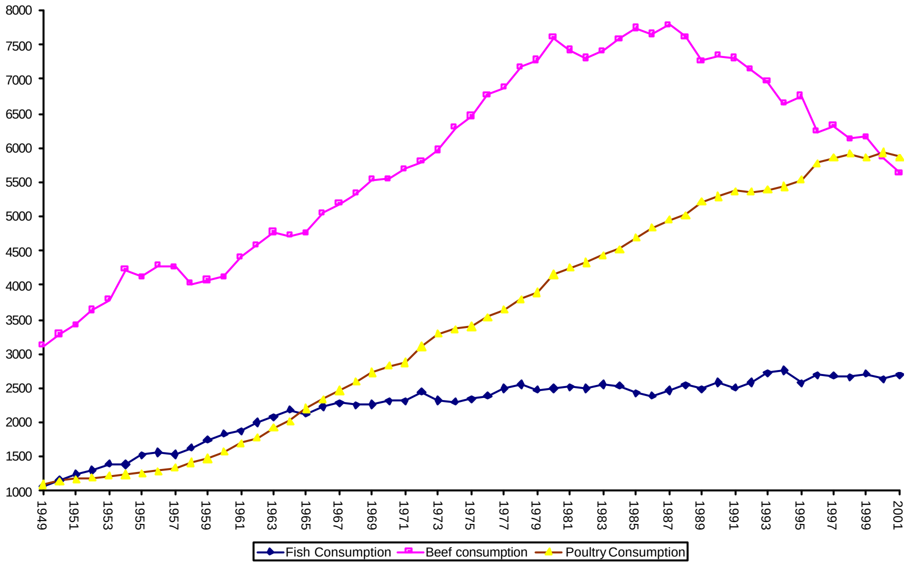

Figure 1: French beef, poultry and fish consumption levels

freedom implied by the annual data set used. In the MS-AIDS without habit formation, for each regime, there are n constants ®$_{s_t}$ and n coeffcient ¯$_{s_t}$, $\frac{n(n+1)}{2}$ price parameters if the symmetry constraint is imposed, $\frac{n(n+1)}{2}$ covariance matrix -$_{s_t}$ parameters, and the 2 transition probabilities compared to 53 annual observations. Thus, in all the application, it is assumed constant price and expenditure parameters over time[8] and the system of demand is restricted to beef, poultry and fish, $n = 3$.

As it was developed above, a demand system must fulfill properties such as adding-up, homogeneity of degree zero in prices, and total expenditure and Slutsky symmetry. These properties are integrated in the MS-AIDS estimation. The additivity property is

[8] An MS-AIDS with only changes in prices and income parameters was also estimated, but only one regime was consistent with data.

automatically respected in each regime since the dependant variables are expenditure shares, the sum of which is equal to one, and the explicative variables are the same in all equations, and in each regime. The homogeneity property is explicitly imposed in the MS-AIDS estimation by substituting in each regime the n absolute prices $p_{j;t}$ by the $n - 1$ relative prices $\frac{p_{j;t}}{p_{n;t}}$, where the reference price $p_{n;t}$ can be any $p_{j;t}$.[9] Under the null hypothesis, homogeneity property is respected, so the reference price has no statistical impact on expenditure shares. Therefore, homogeneity property is tested in each regime by introducing the reference price in each equation of the MS-AIDS, assessed in relative prices and if its parameter is significantly different from zero, the homogeneity property is rejected. Moreover, the symmetry property is also imposed in the MS-AIDS estimation under the respect of homogeneity hypothesis; the matrix Γ_{s_t} composed of the vectors $\gamma_{i;s_t} = (\gamma_{i1;s_t}; \dots; \gamma_{in;s_t})'$ for $i = 1; \dots; n$ and $s_t = 1; \dots; M$ is constrained to be a symmetric matrix. The algorithm proposed by Browning and Meghir [1991] to test the symmetry property is followed and applied in each regime. Specifically, the symmetry property is tested by checking that the distance between the parameter vector $\theta_{s_t;nc}$; estimated under the homogeneity constraint, and the parameter vector $\theta_{s_t;c}$; estimated under the homogeneity and the symmetry constraints is "statistically weak".

In the estimation of the MS-AIDS, it is also taken into account the possible correlation between the perturbation, $u_{i;t}$ and the total per capita expenditure, x_t.[10] The estimation with endogenous regressor developed by Blundell and Robin [1999] is followed. They proposed to substitute $u_{i;t}$ by the regression $\rho_i v_t + \varepsilon_{i;t}$ in the AIDS to correct and test the correlation, where ρ_i is a parameter, $\varepsilon_{i;t}$ is a perturbation independent of v_t and all explicative variables in the system, and v_t is the perturbation of the regression

$$x_t = Cz_t + v_t$$

where z_t is an instrumental variable vector composed of the per capita income, assumed

[9] The homogeneity property imposes that the sum of price parameters for each equation must equal zeros. Analytically, $\sum_{j=1}^{n-1} \gamma_{ij;s_t} = -\gamma_{in;s_t}; \forall i$ and therefore the first part of the ith MS-AIDS equation becomes $w_{i;t} = \alpha_{i;s_t} + \gamma_{i1;s_t}(p_{1;t} - p_{n;t}) + \dots + \gamma_{in-1;s_t}(p_{n-1;t} - p_{n;t}) + \dots$ and $\ln P_t$ is also modified to integrate the homogeneity property.

[10] Shocks over preferences that affect the total per capita expenditure affect good allocations: the determination of the total per capita expenditure and expenditure shares is realized at the same time. The correlation is due to this simultaneity.

correlated to total per capita expenditure and independent of u_t, and all the exogenous variables of the AIDS system, and C is an unknown parameter matrix. $\hat{\vartheta}_t$ is obtained from a least square estimation. In the rest of the paper, it is assumed that there exist only one regime for ρ_i. Therefore, the correlation correction presented in the AIDS can be easily applied to the MS-AIDS.

Finally, if changes in habit formation are included, the following MS-AIDS is estimated

$$w_{i,t} = \alpha_{i,s_t} + \sum_{j=1} \phi_{ij,s_t} w_{j,t-1} + \sum_{j=1}^{n-1} \gamma_{ij} \frac{p_{j,t}}{p_{n,t}} + \beta_i \ln\left(\frac{x_t}{P_t}\right) + \rho_i \hat{\vartheta}_t + u_{i,t} \qquad (16)$$

$$\begin{aligned} \ln P_t &= \alpha_{0,s_t} + p_{n,t} + \sum_{k=1}^{n-1} \alpha_{k,s_t} \frac{p_{k,t}}{p_{n,t}} + 0.5 \sum_{k=1}^{n-1}\sum_{j=1}^{n-1} \gamma_{kj} \frac{p_{k,t}}{p_{n,t}} \frac{p_{j,t}}{p_{n,t}} \qquad (17) \\ s_t &= 1, 2,\ i = 1, 2 \text{ and } u_t \sim N(0, \Sigma_{s_t}) \end{aligned}$$

and now $X_t = \left(1, w_{1,t-1}, \ldots, w_{n,t-1}, \frac{p_{1,t}}{p_{n,t}}, \ldots, \frac{p_{n-1,t}}{p_{n,t}}, \ln\left(\frac{x_t}{P_t}\right), \hat{\vartheta}_t\right)$, and the parameter vector $\theta_{s_t} = vec\left(\mu_{s_t}, \Phi_{s_t}, \Sigma_{s_t}, \rho_1, \rho_2, \pi_{11}, \pi_{22}\right)$, where Φ_{s_t} is a matrix composed of the habit parameters. Six types of structural changes can be estimated and tested: i) the constants can change and there is no habit consumption effect, ii) the constants and Σ_{s_t} can change and there is no habit consumption effect, iii) the constants can change and there is a stable habit consumption effect, iv) the constants and Σ_{s_t} can change and there is a stable habit consumption effect, v) the constants and the habit parameters can change, vi) the constants, the habit parameters and Σ_{s_t} can change.[11]

3.3 The results

In this section, the estimation of the standard AIDS model, the S-AIDS and MS-AIDS models with constant covariance matrix is presented: the MS-AIDS models with changes in the covariance matrix are not very informative since the considered expenditure share volatilities are very weak. Moreover, expenditure and price elasticities derived from the estimated models are presented. All the reported elasticities in this section are calculated for each regime with the corresponding fitted expenditure share

[11] By parameter changes, we mean that the cited parameters in the MS-AIDS take two different values: one in the regime 1 and other one in the regime 2.

and prices, evaluated at sample means. Moreover, several specification tests are implemented: the autocorrelation, the Markov specification, and the existence of habit formation are tested using Hamilton-White test and Lagrange multiplier test defined above. These tests are presented in appendix A. All the tests are implemented for the MS-AIDS in which homogeneity and symmetry constraints are imposed. Therefore, only two expenditure shares are considered to calculate the latter statistics.

3.3.1 S-AIDS and MS-AIDS

Estimated parameters, specification tests and structural changes identification

In this subsection, the standard AIDS, a S-AIDS and a MS-AIDS are estimated. In the latter models, only the intercept can take different values from a regime to the other one. In tables 2, 3 and 4 are respectively reported the maximum likelihood estimates and the value of the objective function ($\ell(\theta)$) for the three previous models.[12] The estimation results assume homogeneity and symmetry constraints fulfilled, although the two hypotheses are rejected for the three models.[13] Rejection could be due to possible omitted variables (Deaton and Muellbauer [1980]) or data errors. Even if symmetry and homogeneity (which are derived from the theory of individual consumer) do not hold at the level of aggregate demand, it is desirable to impose them as it reduces the number of parameters to be estimated and force the demand elasticities to be mutually consistent.

In these tables, all the coeffcients are significative at 0.05 significance level and the effect of prices on each expenditure share are intuitively coherent. Increasing $\ln\left(\frac{x_t}{P_t}\right)$ brings about a drop of poultry expenditure share and an increase of beef expenditure share, in the three models. As it will be confirmed below, beef seems to be a superior good, and poultry an inferior good. This second result is also intuitively reasonable. In

[12] In the S-AIDS, the search for the most likely break points involves estimating the S-AIDS for various combinations of break points. The end of the first regime τ_1, was allowed successively to be any observation in the data set from 1949 to 2000. For each τ_1, the starting point of the second regime, τ_2, was then allowed to be any subsequent period. The pair of break points that produced the lowest residual sum of squares was selected.

[13] In the standard AIDS model, the student statistic of the log fish price parameter is equal to 15.36 and -4.59 in the equations of beef and poultry respectively. In the MS-AIDS model the latter statistics are equal to 23.42 and -5.42. Moreover, the symmetry test is equal to 15.37 (P-value=0.00) in the standard AIDS model, and 9.80 (P-value=0.02) in the MS-AIDS.

the three models, a significative effect of $\hat{v}_t$ is estimated, which confirm the correlation between the perturbation and the total per capita expenditure. Moreover, the hypothesis of no autocorrelation in the MS-AIDS is strongly rejected by the Hamilton-White test. A statistic equal to 6.38 ($p-$value $= 0.000$) is obtained.

The main result of the subsection is that the no structural change hypothesis is strongly rejected in the S-AIDS and MS-AIDS. In the S-AIDS model, the values of the parameters defining the path of structural change that maximize the set of likelihood function are $\hat{\tau}_1 = 1964$ and $\hat{\tau}_2 = 1985$. This result suggest a gradual change of regime with a second regime starting when beef share expenditure definnitively drops (see figure 3). To investigate the significance of structural change, a likelihood ratio test (LR) for the hypothesis of constancy over time of the parameter vector is implemented. The hypothesis of no structural change is fully rejected at 0.01 significance level (see table 3).

In the MS-AIDS, the Hamilton-White test (see $HW\ Markov$ in table 4) is implemented to test the hypothesis of structural changes. The Markov specification cannot be rejected by the test; we find an Hamilton-White statistic for Markov specification equal to 0.897 and the corresponding $P-$value is equal to 0.415. The structural change dynamic of beef, poultry and fish expenditure shares is such as the estimated probabilities of staying in the same regime are equal to 0.919 for the regime of low beef expenditure level (regime 1, $s_t = 1$) and 0.924 for the regime of high beef expenditure level (regime 2, $s_t = 2$). In the figure 2, the smoothed unconditional probabilities of being in the low beef expenditure share regime for each period are represented. Meat and fish expenditures are in the low beef expenditure share regime during two periods (1959-1972 and 1993-2001). Thus, three regime shifts are estimated with this MS-AIDS model, whereas only one regime shift is estimated with a S-AIDS model. However, the 1996 and 2000 mad cow crises are identified by both the S-AIDS and the MS-AIDS.

Two criteria are used to select the model that better explain the observed French beef, poultry and fish consumption patterns. First, the mean square errors (MSE) for beef and poultry expenditure shares for each model are compared. Second, the errors of the S-AIDS and MS-AIDS to predict the evolution of beef and poultry expenditure

Table 2: Maximum likelihood parameter estimates for the standard AIDS model

	α	p_{beef}	$p_{poultry}$	p_{fish}	$\ln(x_t/p_t)$	ϑ_t
Beef[a]	0.566	−0.235	0.072	0.163	0.082	0.285
	(0.012)	(0.007)	(0.015)	(0.012)	(0.033)	(0.015)
Poultry	0.247	0.074	−0.044	−0.028	−0.088	−0.225
	(0.027)	(0.015)	(0.011)	(0.009)	(0.008)	(0.009)
$\ell(\theta) = 428.53$						

[a]Estimated standard errors are reported in parentheses

Table 3: Maximum likelihood parameter estimates for the S-AIDS model

	α	$\bar{\alpha}$	p_{beef}	$p_{poultry}$	p_{fish}	$\ln(x_t/p_t)$	ϑ_t
Beef[a]	0.502	0.125	−0.115	0.072	0.425	0.126	0.233
	(0.009)	(0.007)	(0.006)	(0.024)	(0.025)	(0.022)	(0.009)
Poultry	0.251	0.013	0.072	−0.050	−0.022	−0.075	−0.238
	(0.019)	(0.013)	(0.013)	(0.013)	(0.019)	(0.012)	(0.004)
$\ell(\theta) = 474.48$; LR test $= 91.9 < 0.000 >$ [b]							

[a]Estimated standard errors are reported in parentheses
[b]P-values are angular bracketed

shares are calculated and compared.[14] Table 5 displays the values of the different criteria used. For the two criteria and for each expenditure share, the MS-AIDS model is the model that better explain the dynamic of beef and poultry expenditure shares.

Expenditure elasticities and prices elasticities

In tables 6, 7 and 8, the estimated budget shares and expenditure and price elasticities are reported. In the three models and in each regime for the S-AIDS and MS-AIDS models, the expenditure elasticities are all positive and significant. In the standard AIDS and in the MS-AIDS, we estimate that beef and fish react more strongly to an increase in total expenditure than poultry. Furthermore in the latter models, beef is more elastic to expenditure than fish. As it is expected, beef and fish are superior goods in the standard AIDS and in the MS-AIDS. In the MS-AIDS model, we estimate a substitution effect of beef in favor to poultry and fish, when the MS-AIDS model goes from the high beef expenditure regime to the low beef expenditure regime: ta-

[14]Each studied models are estimated over the sub-sample 1949-1996. Then, the estimated parameter values are used to predict the beef and poultry expenditure shares for the period 1997-2001. The forcast errors are obtained by substracting the observed expenditure shares with the fitted expenditure shares. We assume that there are no regime change during the period 1997-2001, as it is estimated.

Table 4: Maximum likelihood parameter estimates for the MS-AIDS model

	α		p_{beef}	$p_{poultry}$	p_{fish}	$\ln(x_t/p_t)$	ϑ_t
	α_{s1}	α_{s2}					
Beef[a]	0.527 (0.008)	0.564 (0.009)	-0.061 (0.008)	0.028 (0.007)	0.033 (0.008)	0.064 (0.019)	0.252 (0.010)
	α_{s1}	α_{s2}					
Poultry	0.256 (0.015)	0.243 (0.015)	0.028 (0.010)	-0.029 (0.012)	0.001 (0.007)	-0.086 (0.007)	-0.208 (0.006)

$\ell(\theta) = 459.13$; HW Markov $= 0.897 < 0.415 >$ [b]

[a]Estimated standard errors are reported in parentheses and low beef expenditure regime variables are indexed by s1, and high beef expenditure regime variables are indexed by s2

[b]P-values are angular bracketed

Table 5: The mean square errors and the forcast error for S-AIDS and the MS-AIDS model

	M1[a]	M2[b]	M3[c]	M4[d]	M5[e]
MSE beef	0.00015	0.00006	0.000041	0.000019	0.000019
MSE poultry	0.00012	0.00009	0.000021	0.000018	0.000018
Error forecast beef	-1.666	-0.254	-0.4869	-0.049	-0.043
Error forecast poultry	1.5912	0.151	0.3539	-0.0039	-0.0041

[a]S-AIDS model

[b]MS-AIDS model with shift in constant

[c]S-AIDS model with habit formation

[d]MS-AIDS model with habit formation and shift in constant

[e]MS-AIDS model with shifts in constant and habit formation

ble 8 reports that the household respectively attributes 29% and 21.2% of his total expenditure[15] to poultry and fish during the low beef expenditure regime, whereas he respectively only allocates 27.6% and 18.9% of his total expenditure to poultry and fish during the high beef expenditure regime.

In the S-AIDS model, the previous results are not true. Especially, we estimate that fish expenditure share is less elastic to expenditure than poultry expenditure share, and fish is an inferior good, before and after structural change. Moreover, we are very surprised to estimate a substitution effect between fish and poultry when the S-AIDS goes from the high beef expenditure regime to the low beef expenditure regime: in table

[15]Here total expenditure refers to the sum of beef, poultry and fish expenditures for the representative agent.

7, it is estimated that fish expenditure share is higher during the high beef expenditure regime (0:224) than during the low beef expenditure regime (0:175). This result does not play in favor of the S-AIDS model and confirm our preference to the MS-AIDS model to explain French beef, poultry and fish expenditure share dynamics.

The comparison for each regime of the expenditure elasticity values has few sense since the β_i are not affected by structural changes. Given equation (8), the beef expenditure elasticities will always be higher in the low beef expenditure regime than in the high beef expenditure regime, since β_{beef} is positive. The same explanation can be driven for fish and poultry.

Table 8 reports the uncompensated prices elasticities of the MS-AIDS. Structural changes affects prices elasticities through the intercept and the fitted expenditure shares. All the uncompensated own-price elasticities are significant with the expected negative sign in the two regimes, and most of the uncompensated cross-price elasticities are positive and some are significantly positive, implying relations of substitution.[16]

Compare uncompensated own-price elasticities make sense since the α_i are affected by structural changes and is very instructive. In the low beef expenditure regime, beef expenditure share is the more elastic to its own-price expenditure shares. Whereas, in the high beef expenditure regime, it is the fish expenditure share. Thus, it is estimated that beef expenditure share is more sensible to a variation on its own-price during the low beef expenditure regime than during the high beef expenditure regime. Whereas, fish (poultry) price has more impact on fish (poultry) demand during high beef expenditure regime than during low beef expenditure regime. When agents are stricken by mad cow crisis, it is expected the same own-price effects. Specifically, when the poultry price increases, the drop of poultry demand should be lower during the mad cow crisis than that estimated during the high beef expenditure regime. Furthermore, when the beef price increases, consumers should reduce their consumption of beef more strongly during the mad cow crisis than they should do during the high beef expenditure regime.

Despite these good results, the MS-AIDS model is unable to detect the drop of beef expenditure share during the 1980's, observed in the figure 3, as the S-AIDS models

[16] Compensated cross-price elasticities estimated in the MS-AIDS model for the both regimes are all positive.

Table 6: Estimated expenditure shares and elasticities for the standard AIDS model

	Estimated shares	Expenditure elasticities	Price elasticities		
			Beef	Poultry	Fish
Beef[a]	0.520	1.158 (0.07)	-1.542 (0.06)	0.101 (0.03)	0.283 (0.03)
Poultry	0.282	0.688 (0.034)	0.43 (0.06)	-1.082 (0.04)	-0.037 (0.03)
Fish	0.198	1.029 (0.233)	0.807 (0.13)	-0.148 (0.42)	-1.688 (0.14)

[a]Estimated standard errors are reported in parentheses

detects in 1985. In the next subsection, lagged expenditure shares are included in the MS-AIDS model to capture both the habit formation and most of all the gradual structural changes of the 1980's.

3.3.2 MS-AIDS model with habit formation

Estimated parameters, specification tests and structural changes identification

Lagged expenditure shares of poultry and beef are included in each equation of the above MS-AIDS. From this way, habit formation is introduced: the consumer only gradually adjusts his consumption in response to changes in prices and expenditures because of already established habits. Moreover, structural changes may affect habits. In this subsection, the estimation results of the S-AIDS model with habit formation are not presented. As it is reported in table 5, the MS-AIDS models with and without change in habit formation better explain the expenditure share evolution than the S-AIDS with habit formation does. In this subsection, two MS-AIDS models with habit formation are considered: i) an MS-AIDS with no habit formation shift and ii) an MS-AIDS with habit formation shifts.

Tables 9 and 10 respectively report the maximum likelihood estimates, and the value of the objective function for the MS-AIDS with constant habit formation and with shifting habit formation. The results assume homogeneity and symmetry constraints fulfilled. Yet, Homogeneity is rejected for the both models and for the all goods. But, if homogeneity is imposed, the symmetry hypothesis is fully accepted.[17] The

[17]In the MS-AIDS model with constant habit formation, the student statistic of the log fish price parameter is equal to 8.33 and -4.35 in the equations of beef and poultry respectively. In the MS-

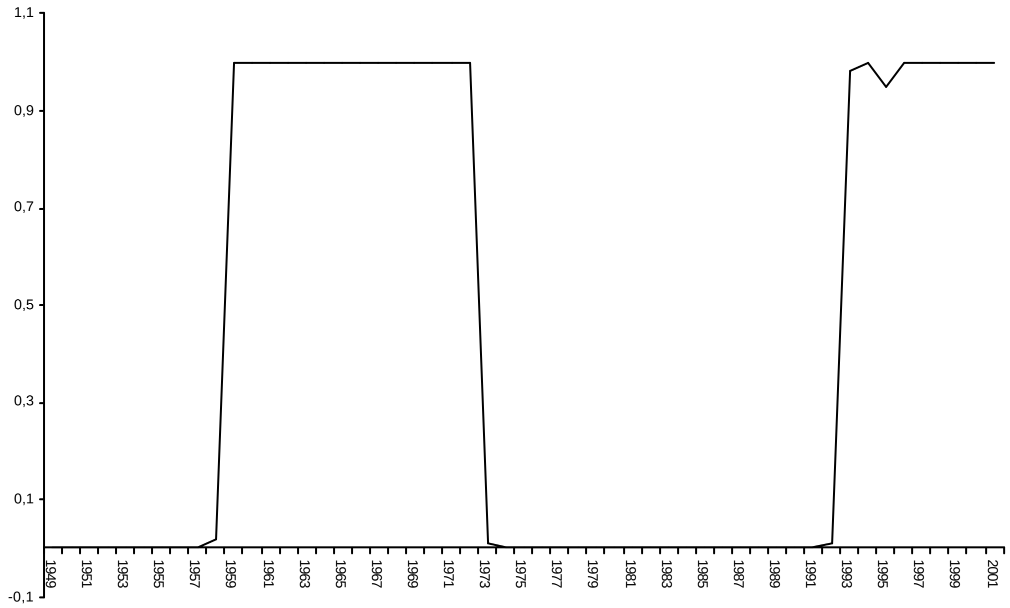

Figure 2: Smoothed probabilities of being in the low beef expenditure share regime.

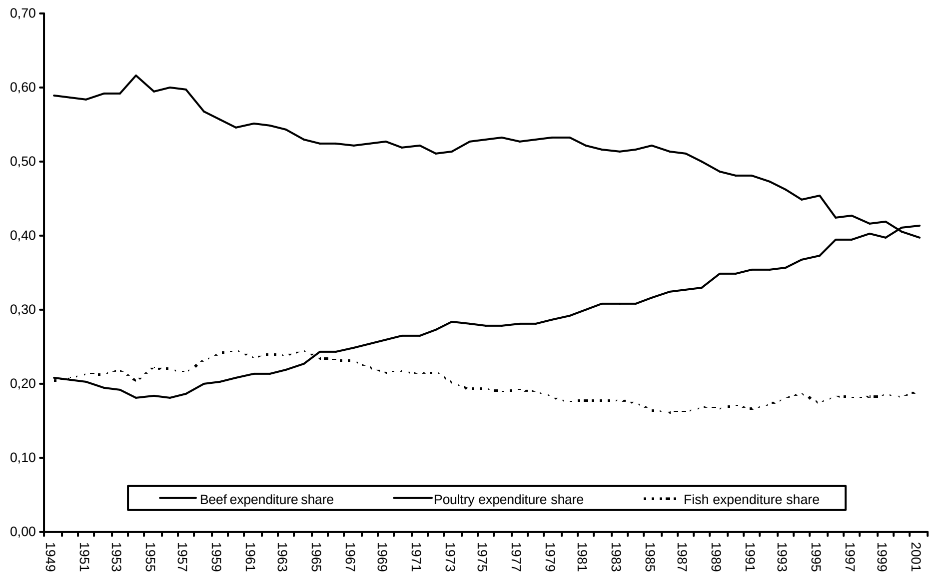

Figure 3: Beef, poultry, and fish expenditure shares (1949-2001)

Table 7: Estimated expenditure shares and elasticities for the S-AIDS model

	Estimated shares	expenditure elasticities	Price elasticities Beef	Poultry	Fish
Low beef expenditure regime $t \leq \tau_1 = 1964$[a]					
Beef	0.467	1.270	-1.417	0.085	0.062
		(0.065)	(0.06)	(0.06)	(0.05)
Poultry	0.358	0.792	0.334	-1.086	-0.04
		(0.025)	(0.05)	(0.05)	(0.05)
Fish	0.175	0.705	0.43	-0.050	-1.086
		(0.163)	(0.056)	(0.384)	(0.254)
High beef expenditure regime $t \geq \tau_2 = 1985$[b]					
Beef	0.575	1.220	-1.319	0.077	0.022
		(0.049)	(0.035)	(0.047)	(0.042)
Poultry	0.201	0.628	0.561	-1.168	-0.022
		(0.056)	(0.086)	(0.077)	(0.09)
Fish	0.224	0.770	0.314	-0.048	-1.037
		(0.173)	(0.069)	(0.272)	(0.168)

[a]Estimated standard errors are reported in parentheses
[b]Estimated standard errors are reported in parentheses

significative effects of own-prices, cross-price and $\ln\left(\frac{x_t}{P_t}\right)$ on expenditure shares are not presented in tables 9 and 10. But, the effects estimated in the sub-section above are also true; in the two MS-AIDS models considered, the effects of prices are intuitively coherent, and increasing $\ln\left(\frac{x_t}{P_t}\right)$ brings about a drop of poultry expenditure share and an increase of beef expenditure share. As above, beef seems to be a superior good, and poultry an inferior good. Tables 9 and 10 show a significative effect of ϑ_t on expenditure shares, which confirm the correlation between the perturbation and the total per capita expenditure.

A comparison of the habit estimated parameter values between the two MS-AIDS models is very informative. In the MS-AIDS model with constant habit formation, only beef habit marginal effect on beef expenditure share and poultry habit marginal effect on poultry expenditure share are significative in 5% level: the cross marginal effects of habit formation are rejected in each equation. In the MS-AIDS model with shifting habit formation, almost all the effects of habit formation are significative at

AIDS model with shifting habit formation the latter statistics are equal to 9.57 and -2.43. Moreover, the symmetry test is equal to 1.718 (P-value=0.190) in the standard AIDS model, and 1.323 (P-value=0.250) in the MS-AIDS.

Table 8: Estimated expenditure shares and elasticities for the MS-AIDS model

	Estimated shares	expenditure elasticities	Price elasticities		
			Beef	Poultry	Fish
Low beef expenditure regime[a]					
Beef	0.498	1.128 (0.04)	-1.191 (0.03)	0.025 (0.01)	0.038 (0.02)
Poultry	0.290	0.704 (0.02)	0.255 (0.039)	-1.029 (0.05)	0.07 (0.02)
Fish	0.212	1.103 (0.2)	0.101 (0.081)	-0.020 (0.21)	-1.184 (0.118)
High beef expenditure regime[b]					
Beef	0.535	1.119 (0.035)	-1.182 (0.03)	0.025 (0.0164)	0.202 (0.02)
Poultry	0.276	0.690 (0.022)	0.278 (0.04)	-1.034 (0.05)	0.066 (0.026)
Fish	0.189	1.116 (0.227)	0.109 (0.097)	-0.021 (0.231)	-1.204 (0.132)

[a]Estimated standard errors are reported in parentheses
[b]Estimated standard errors are reported in parentheses

5% level for the two regimes. Table 10 shows that the poultry habit effect on beef expenditure share is stronger during the low beef expenditure regime than during the high beef expenditure regime. Thus, the poultry habit effect brings about a larger drop of beef expenditure share during the low beef consumption regime than that estimated during the high beef consumption regime. When the effects of beef habit on poultry expenditure shares in each regime are compared, a very interesting result is obtained. Consume beef in the previous period brings about an increase of poultry consumption in the low beef consumption regime, but a drop of poultry expenditure share during the high beef consumption regime. These two previous results are intuitively coherent in mad cow crisis context. Surprisingly, beef habit effect on beef expenditure share is weaker during the regime of high beef consumption than that estimated during the other regime. Whereas, poultry direct habit effects are intuitively coherent as far as poultry habit effect on poultry expenditure share during low beef expenditure regime is stronger than that estimated during the high beef expenditure regime.

Moreover, in the two MS-AIDS models, the Hamilton-White test for autocorrelation provides evidence for no autocorrelation, whereas it was not the case in the estimated MS-AIDS of the previous subsection. We find an Hamilton-White statistic equal to

1:427 and 1:943 respectively. The corresponding P ¡ values are 0:18 and 0:05.

As in the above subsection, the Markov specification cannot be rejected; we find an Hamilton-White statistic for Markov specification equal to 0:827 (P ¡ value = 0:557) and 1:685 (P ¡ value = 0:154) for the MS-AIDS models with no change and change in the habit formation respectively. Moreover, tables 9 and 10 display the Lagrange Multiplier test (LM): the hypothesis of no habit formation is tested. We find statistics equal to 66:05 (P ¡ value = 0:00) and 62:94 (P ¡ value = 0:00) in the MS-AIDS with no change and change in habit formation, respectively. The hypothesis of no habit formation is strongly rejected by the LM test for the two MS-AIDS models. Moreover, table 5 shows that introducing habit formation improves the explanation of the dynamic of the expenditure shares; the errors forecast for beef and poultry are lower when habit formation is taken into account. This latter result is also true for the S-AIDS model, as it is displayed in table 5.[18] The two criteria, defined above, are used to select the MS-AIDS model which better explain beef, poultry and fish expenditure shares evolution. Table 5 reports that the MS-AIDS with no change in habit formation should be the model to choose to explain the studied expenditure shares.

Table 9: Maximum likelihood parameter estimates for the MS-AIDS model with constant habit formation

	®		W^{i1}_{beef}	$W^{i1}_{poultry}$	ϑ_t
Beef[a]	®$_{s1}$ 0:254 (0:0608)	®$_{s2}$ 0:273 (0:0612)	0:575 (0:074)	¡0:124 (0:0943)	0:168 (0:0294)
Poultry	®$_{s1}$ 0:046 (0:049)	®$_{s2}$ 0:041 (0:0496)	0:011 (0:066)	0:831 (0:075)	¡0:060 (0:0228)

`(ª) = 504:23; HW-Markov = 0:827 < 0:5571 >[b]; LM = 66:05 < 0:00 >

[a]Estimated standard errors are reported in parentheses and low beef expenditure regime variables are indexed by s1, and high beef expenditure regime variables are indexed by s2

[b]P-values are angular bracketed

Elasticities

[18]The hypothesis of no habit formation is strongly rejected in the S-AIDS. The LR statistic is equal 72:22 (p ¡ value = 0:0000)

Table 10: Maximum likelihood parameter estimates for the MS-AIDS model with shifting habit formation

	α		W_{beef}^{-1}		$W_{Poultry}^{-1}$		ϑ_t
	α_{s1}	α_{s2}	γ_{s1}	γ_{s2}	γ_{s1}	γ_{s2}	
Beef[a]	0.246 (0.0618)	0.348 (0.1102)	0.583 (0.075)	0.466 (0.144)	−0.194 (0.009)	−0.117 (0.014)	0.1715 (0.023)
	α_{s1}	α_{s2}	γ_{s1}	γ_{s2}	γ_{s1}	γ_{s2}	
poultry	0.044 (0.047)	0.118 (0.105)	0.015 (0.063)	−0.087 (0.140)	0.825 (0.074)	0.738 (0.131)	−0.047 (0.022)

$\ell(\theta) = 506.42$; HW Markov $= 1.685 < 0.154 >$ [b]; LM $= 62.94 < 0.00 >$

[a]Estimated standard errors are reported in parentheses and low beef expenditure regime variables are indexed by s1, and high beef expenditure regime variables are indexed by s2

[b]P-values are angular bracketed

Tables 11 and 12 report the estimated share, the expenditure and price elasticities for the MS-AIDS models without and with change in habit formation respectively. In both models and in each regime, the expenditure elasticities are all positive and significant. It is estimated, in the two MS-AIDS models, that beef reacts more strongly to an increase in total expenditures than poultry and fish. As previously, compare the expenditure elasticity values for each regime has few sense since the β_i are still constant across regimes.

In the tables 11 and 12, note also that all the uncompensated own-price elasticities are significant with the expected negative sign. As previously, fish and poultry (beef) are (is) more (less) sensible to their (its) own-price change during the high expenditure regime than during the low one. The uncompensated cross-price elasticities are almost all positive and some are significantly positive, implying relations of substitution between studied goods.[19]

We get very similar estimated smoothed probabilities for the two models. In the MS-AIDS with constant habit formation, expenditure shares stay in the low beef expenditure regime 6.8 years on average.[20] In the figure 4, the estimated smoothed probabilities to be in the low beef expenditure regime obtained in the MS-AIDS model with no shift in habits are represented. Below, in the figure 5 the beef, poultry and

[19]It is checked that all cross compensated price elasticities are all positive.

[20]The average duration is equal to $(1 - \hat{\pi}_{11})^{-1}$, where $\hat{\pi}_{11}$ is the estimated probability of staying in the low beef expenditure regime. Here, $\hat{\pi}_{11} = 0.8531$.

Table 11: Estimated expenditure shares and elasticities for the MS-AIDS model with constant habit formation

	Estimated shares	Expenditure elasticities	Price elasticities		
			Beef	Poultry	Fish
Low beef expenditure regime[a]					
Beef	0.508	1.035 (0.16)	-1.163 (0.08)	0.041 (0.05)	0.085 (0.14)
Poultry	0.298	0.955 (0.08)	0.114 (0.045)	-1.054 (0.03)	-0.015 (0.02)
Fish	0.194	0.973 (0.35)	0.244 (0.198)	-0.027 (0.08)	-1.190 (0.41)
High beef expenditure regime					
Beef	0.527	1.037 (0.16)	-1.158 (0.08)	0.040 (0.04)	0.082 (0.14)
Poultry	0.284	0.954 (0.08)	0.117 (0.05)	-1.055 (0.03)	-0.016 (0.02)
Fish	0.189	0.971 (0.37)	0.263 (0.21)	-0.029 (0.08)	-1.205 (0.44)

[a]Estimated standard errors are reported in parentheses

expenditure shares are represented. In these two figures, the vertical bars represent the switches between regimes (based on $P(s_t = 1|X_t; W_{t-1}; \hat{\theta}) = 0.5$) estimated in the MS-AIDS model with no change in habit formation. Six regime changes are estimated. The expenditure shares are in regime of high beef expenditure share from 1965 to 1985, and in the other regime from 1957 to 1964 and from 1986 to 2001, if the year 1995 is not considered. In the figure 5, the high beef expenditure regime correspond to a relative non decreasing dynamic of beef expenditure share, whereas beef expenditure share during the periods 1957-1964 and 1986-2001 substantially decreases, except in 1995.

As it was expected, introducing habit formation smooths the Markov Switching mechanism and permit expenditure shares to stay a longer time in the low expenditure regime. We might conclude that the gradual structural changes driven by nutritional recommendations can be captured by introducing habit formation in the MS-AIDS model. Therefore, it would appear that nutritional recommendations affect consumption pattern from 1986 according to our estimations. MS-AIDS models with habit formation may explain the two French mad cow crises and the structural change emanating from nutritional recommendations.

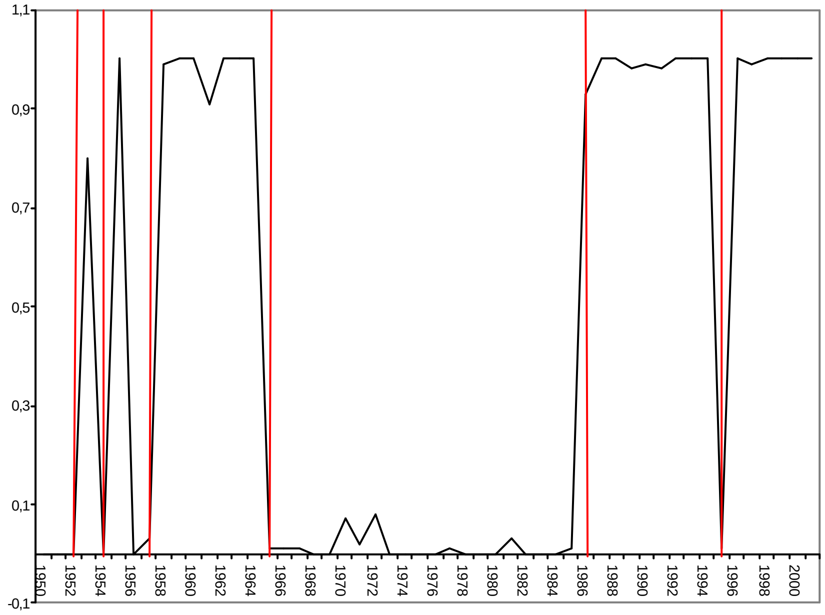

Figure 4: Smoothed probabilities to be in the low beef expenditure regime.

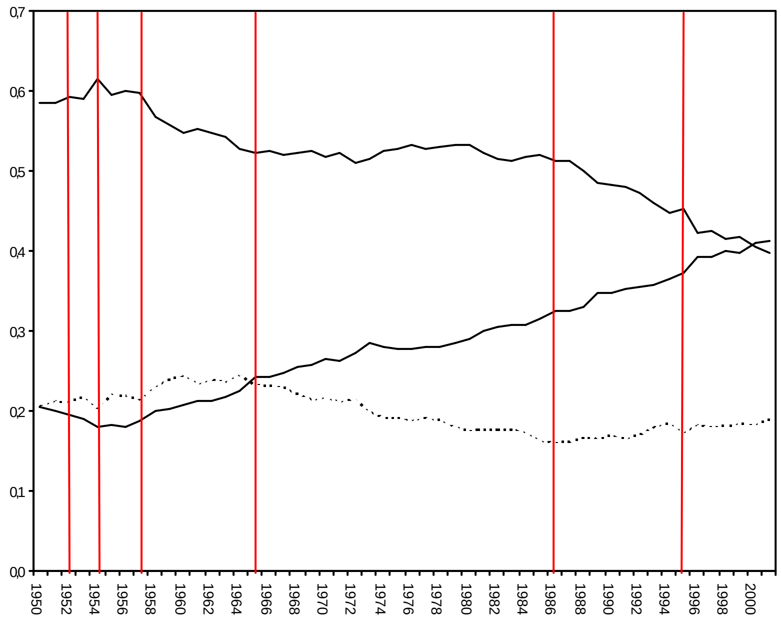

Figure 5: Beef, poultry and fish expenditure shares (1950-2001) and switches between regimes.

Table 12: Estimated expenditure shares and elasticities for the MS-AIDS model with shifting habit formation

	Estimated shares	Expenditure elasticities	Price elasticities		
			Beef	Poultry	Fish
Low beef expenditure regime[a]					
Beef	0.508	1.030 (0.154)	-1.156 (0.09)	0.046 (0.04)	0.077 (0.15)
Poultry	0.296	0.949 (0.087)	0.124 (0.05)	-1.053 (0.03)	-0.020 (0.02)
Fish	0.203	0.990 (0.353)	0.214 (0.20)	-0.040 (0.20)	- 1.163 (0.41)
High beef expenditure regime					
Beef	0.528	1.033 (0.188)	-1.151 (0.15)	-0.045 (0.05)	0.074 (0.23)
Poultry	0.285	0.948 (0.09)	0.127 (0.05)	-1.054 (0.03)	-0.021 (0.02)
Fish	0.188	0.989 (0.465)	0.232 (0.41)	-0.044 (0.1)	-1.177 (0.69)

[a]Estimated standard errors are reported in parentheses

4 Conclusion

In this paper, the analysis of structural changes in meat and fish demand model is reconsidered. The Markov Switching model of Hamilton [1989] is applied to the popular AIDS model. It involves multiple structures (equations) that can characterize the evolution of consumption patterns in different regimes. This model is used to simultaneously explain the beef, poultry, and fish expenditure evolutions in France. We find that the MS-AIDS models provide better and more precise estimations than those obtained in the commonly used S-AIDS to explain the dynamic of expenditure shares studied. Moreover, we find that a MS-AIDS model with habit formation captures the two French mad cow crises and the gradual structural changes driven by health concerns. We also estimate that nutritional recommendations affect consumers from 1986.

The introduction of habit formation to smooth the Markov Switching may appear not well adapted to gradual structural changes. To go through this limit, smoothed threshold autoregressive (STAR) models, initially developed by Tong [1983], Tong [1990] and Teräsvirta [1994], can be applied to demand systems. In these models the Switching mechanism is governed by the sign of the difference between an observed transition variable and the value of the threshold. Moreover, the transition from one regime to another one is formalized by a smoothed logistic function.[21] These models seem to be very fruitful to explain structural changes.

[21] The transition variable, the value of threshold and the value of the speed parameter in the logistic function are directly estimated.

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