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Abstract

In this paper we embed the Almost Ideal Demand System within a dynamic disequilibrium model, and derive a set of interrelated Euler equations which characterizes optimal consumption allocations under adjustment costs. It is argued that when applied to alcohol and tobacco expenditure, the proposed specification features the rational addiction hypothesis, as both forward-looking rational behaviour and habit formation are explicitly accounted for. The suggested estimation approach controls for potential nonstationarity in the underlying time-series. Results relative to UK tobacco and alcohol demand support the adopted specifications and highlight the degree of complementarity between addictive goods.

[1] A previous version of this paper circulated with the title: 'Back to the Future? Habits and Rational Addiction in UK Tobacco and Alcohol Demand'.

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Abstract

In this paper we embed the Almost Ideal Demand System within a dynamic disequilibrium model, and derive a set of interrelated Euler equations which characterizes optimal consumption allocations under adjustment costs. It is argued that when applied to alcohol and tobacco expenditure, the proposed specification features the rational addiction hypothesis, as both forward-looking rational behaviour and habit formation are explicitly accounted for. The suggested estimation approach controls for potential nonstationarity in the underlying time-series. Results relative to UK tobacco and alcohol demand support the adopted specifications and highlight the degree of complementarity between addictive goods.

1 Introduction

Rational addiction as defined by Becker and Murphy (1988) implies that consumption of addictive goods with negative health implications is still consistent with forward-looking maximization of utility from stable preferences. Addiction is rational in the sense that the consumer goes beyond the pure myopic behavior (habit persistence and reinforcement from past consumption), and anticipates the consequences of future consumption. This theory has allowed economists to treat demand for addictive goods, previously disregarded as irrational, and has been tested fairly successfully on alcohol and tobacco consumption. More recently, the rational addiction hypothesis has been tested on other goods than those commonly recognized as addictive, especially in relation to obesity and demand for unhealthy foods (Richards and Patterson, 2006). Empirical tests of the theory involve the estimation of demand models which allow for a response of demand to past levels of consumption and current and future prices (Becker, Grossman and Murphy, 1994; Chaloupka, 1991; Grossman and Chaloupka, 1998; Baltagi and Griffin, 2001). While some authors (Suranovic et al., 1999) have objected that such forward-looking behavior ignores future health adverse consequences, the persistence of unhealthy behaviors has been justified with adjustment and withdrawal costs that prevent consumers to switch to a healthier consumption bundle (Jones, 1999).

As argued in Decker and Schwartz (2000), understanding the connections between the consumption of more than one addictive good (e.g. cigarettes and alcohol) and incorporating their interrelationship into econometric consumption analyses is important for two reasons. First, if the two consumption goods are substitutes (or complements), then correctly specified consumption goods equations must include also the price of the other good and relevant policy variables as well. Second, a given policy might exert "cross" effect on the other market, hence the specification of such cross effect may provide useful policy guidance.

The rational addiction hypothesis is based on two fundamental assumptions: (i) forward-looking rational behavior, and (ii) habit formation. If it is hard to argue with the notion that cigarette and alcohol consumption is not subject to habit formation, a crucial point is whether consumers are forward-looking and take all the risks associated with addictive goods into consideration when making their choices.

In this paper we propose an approach to the joint modelling of alcohol and tobacco consumption expenditure which allows to capture (i) and (ii) above, and answer a number of questions which are of key importance for both fiscal and social policy: First, do habits play a role in the aggregate demand for alcohol and tobacco? Second, are alcohol and tobacco consumers forward-looking ? Third, are there significant interactions between expenditure on alcoholic drinks and tobacco expenditure?

To achieve this task, we embed Deaton and Muellbauer 's (1980) Almost Ideal Demand System (AIDS) within a dynamic disequilibrium model where consumers' behavior is governed by a system of Euler equations which characterizes optimal forward-looking allocations under adjustment costs. As the implied model captures both forward-looking behavior and habit formation, it features the rational addiction hypothesis. Although the rational habit hypothesis and forward-looking behavior have been explicitly introduced within an AIDS modeling framework in Alessie and Kapteyn (1991), Andrikopoulos et al. (1997), Weissemberg (1986) and Rossi (1987), to our knowledge no existing study relates the proposed specification to the joint modeling of consumption of addictive goods. Moreover, compared to Jones (1989) and Weissemberg (1986), the suggested specification embodies a more involved dynamic structure, as we detail in the paper.

On the econometric side, the estimable model which stems from our specification reads as an error-correcting system involving both forward and backward-looking behavior. The estimation approach we propose controls for potential nonstationarity in the underlying time-series. More specifically, we propose a simple two-stage procedure, where cointegration techniques are applied in the first stage to obtain consistent estimates of the static (long-run) parameters in the AIDS relationship.[1] Having fixed the parameters of the AIDS at their super-consistent estimates, in the second stage Generalized Method of Moments (GMM) techniques are implemented to obtain the parameters governing the system of interrelated Euler equations. Any existing econometric package can be used to implement the proposed method.

Our application investigates aggregate consumption of alcoholic beverages and tobacco in the UK over the 1963-2003 period, using quarterly data. Accounting for interaction between alcohol and tobacco demand through a systemwise approach is not a trivial extension, since it is acknowledged that the cross-price effect in alcohol and tobacco demand might be quite relevant and complementarity between the two goods is a likely outcome (Decker and Schwartz, 2000).

Obviously, the estimation of models which embody the rational addiction hypothesis based on aggregate data, poses formidable challenges. In general, it is not clear whether all the necessary aggregation conditions are met when dealing with alcohol and tobacco expenditure. The use of aggregate data may blur the fact that decisions on tobacco and alcohol consumption at any point in time are the result of a complex flow among individuals who start and quit. Furthermore, as it is well known, aggregate price data often significantly underestimate the amount of price variation experienced by individuals at the local level. However, there is a strand of literature, to which this paper is related, where the empirical investigation of addictive consumption goods is tackled successfully by means of aggregate data, see, *inter alia*, Jones (1989), Goel and Morey (1995), Olekalns and Bardsley (1996), Bask and Melkersson (2003, 2004), Duffy (2002, 2003) and Richards and Patterson (2006).Our results show that despite the above mentioned difficulties, a number of issues on tobacco and alcohol expenditure can be investigated empirically, and policy questions addressed.

The paper is organized as follows. Section 2 presents the model, disentangling the long run specification (Section 2.1) from the disequilibrium adjustment dynamics (2.2). Section 3 discusses the estimation procedure, and Section 4 provides the empirical analysis based on quarterly UK alcohol and tobacco data. Section 5 draws some conclusions.

2 The model

We consider a representative consumer who undertakes a two-stage decision process. In the first stage he decides the optimal (target) expenditure allocation across the different goods. In the second stage this target behavior is embedded into a quadratic cost of adjustment-disequilibrium framework.

2.1 Long-run equilibrium

The target level of consumption is assumed to follow the linear approximation of the static and flexible AIDS model of Deaton and Muellbauer (1980). This implies that the long-run equilibrium is free from habits and expectations and reflects the Marshallian demand function derived from an utility-maximizing consumer with a price-independent generalized logarithmic (PIGLOG) expenditure function. The equilibrium relationship is given by the following system of demand equations:

$$w_{it}^{*} = \gamma_{i0} + \sum_{j=1}^{n} \gamma_{ij} \log P_{jt} + \lambda_i \log\left(\frac{Y_t}{P_t}\right) + \delta_i t \qquad (1)$$

$$i = 1, ..., n \ \ , \ \ t = 1, ...T$$

where n is the number of goods, w^*_{it} is the aggregate target level for the i-th expenditure share as predicted by consumer theory,

$$w_{it} = (P_{it}Q_{it} / \sum_{j=1}^{n} P_{jt}Q_{jt}) = (P_{it}Q_{it}/Y_t)$$

is the actual expenditure share for good i at time t, P_{jt} is the price of good j at time t, Q_{it} is the quantity of good i purchased at time t, Y_t is the total expenditure at time t and the non-linear price index P_t can be adequately approximated by the Stone index $\log P^*_t = \sum_{h=1}^{n} w_{kt} \log P_{ht}$. A linear trend with coefficient δ_i was included in the model to capture systematic trends (e.g. smooth structural changes) in demand patterns.

System (1) is linear in the preference parameters γ_{i0}, γ_{ij} and λ_i and is obtained under the assumption of intertemporal separability. In order to respect the underlying theoretical assumptions, the following restrictions must hold in (1):

$$\sum_{i=1}^{n} \gamma_{i0} = 1, \quad \sum_{i=1}^{n} \gamma_{ij} = 0, \quad \sum_{i=1}^{n} \lambda_i = 0, \quad \sum_{i=1}^{n} \delta_i = 0 \tag{2}$$

$$\sum_{j=1}^{n} \gamma_{ij} = 0 \tag{3}$$

$$\gamma_{ij} = \gamma_{ji}. \tag{4}$$

These constraints represent respectively the adding up, homogeneity and symmetry assumptions from microeconomic theory. Given (2) the demand system is singular by construction. In order to avoid the related econometric problems, the usual procedure consists in dropping one equation from the system[2].

Following Ng (1995) and using some algebra the model can be parameterized as

$$w_{it}^{*} = \sum_{j=1}^{n-1} \gamma_{ij} \log\left(\frac{P_{jt}}{P_{nt}}\right) + \gamma_i^h \log(P_{nt}) + \lambda_i \log\left(\frac{Y_t}{P_t}\right) + \gamma_{i0} + \delta_i t \tag{5}$$

where $\gamma_i^h = \sum_{j=1}^{n} \gamma_{ij}$ and equilibrium expenditure shares are expressed in terms of relative prices and real total expenditure. The advantage of this formulation is that the homogeneity constraint (3) here corresponds to the restriction $\gamma_i^h = 0$. For the rest of the discussion we rewrite compactly (5) as:

$$w_t^{*} = \Gamma z_t + \gamma + \delta t \tag{6}$$

where $w_t^{*} = (w_{1t}^{*}, ..., w_{mt}^{*})'$, $m = n-1$, $z_t = (p_{1t}, ..., p_{mt}, p_{m+1t}, y_t)'$, $p_{jt} = \log\left(P_{jt}/P_{nt}\right)$, $j = 1, ..., m$, $p_{nt} = \log\left(P_{nt}\right)$, $y_t = \ln\left(Y_t/k_t P_t\right)$, $\Gamma = [\gamma_{ij} \vdots \gamma_i^n \vdots \lambda_i]$, $i = 1, ..., m$, $j = 1, ..., m-1$ is a $m \times (m+2)$ matrix and $\gamma = (\gamma_{10}, ..., \gamma_{m,0})'$, $\delta = (\delta_1, ..., \delta_m)'$ are $m \times 1$ vectors.

2.2 Dynamic disequilibrium model

System (6) defines the baseline AIDS share equations. However, a number of modifications are desirable before model (6) can be applied to data on alcohol and tobacco expenditure, as argued in Jones (1989).

Following Weissemberger (1986), we posit that consumers are generally unable to achieve equilibrium in each time period, due to habit persistence, and the costs of adjusting the consumption bundle to meet future expectations. Let $\widetilde{w}_{t+j} = w^{*}_{t+j} + e_{t+j}$, where w^{*}_{t+j} corresponds to the equilibrium expenditure share (6), and e_{t+j} is an $m \times 1$ error term which captures stochastic deviations from the static AIDS.

In each time period, the representative consumer solves the following cost-minimization problem

$$\min_{\{w_{t+j}\}} E_t \sum_{j=0}^{\infty} \rho^j [(w_{t+j} - \widetilde{w}_{t+j})' D_0 (w_{t+j} - \widetilde{w}_{t+j}) + \\ + \Delta w_{t+j}{}' D_1 \Delta w_{t+j} + \Delta^2 w_{t+j}{}' D_2 \Delta^2 w_{t+j}] \tag{7}$$

where w_t, w_{t-1} and w_{t-2} are given at time t. In (7) $E_t \cdot = E(\cdot \mid \Omega_t)$ is the expectation operator conditional on the information set available at time t, $\Omega_{t-1} \subseteq \Omega_t$, $\Delta w_t = w_t - w_{t-1}$, $\Delta^2 w_t = \Delta w_t - \Delta w_{t-1}$, ρ $(0 < \rho < 1)$ is a time-invariant discount factor and D_0, D_1 and D_2 are $m \times m$ symmetric positive definite matrices. It is assumed that $\{w_t, w_{t-1}, ... z_t, z_{t-1}, ... e_t, e_{t-1}...\} \subseteq \Omega_t$

and that $E_t e_{t+j} = 0$ for $j \geq 1$.

The first addendum in (7) measures the cost of not attaining the long run target w^*_{t+j}, i.e. disequilibrium costs and the second and third addenda measure respectively the costs of changing w_t and Δw_t. In the rational addiction context, the dis-utility of adverse health consequences from consumption is accounted for in the first addendum, while the costs of adjustment (withdrawal) discussed by Jones (1999) are modelled in the remaining two terms.

If D_0, D_1 and D_2 are specified as non-diagonal matrices, cross-adjustment and cross-disequilibria costs arise. It is worth noting that differently from Weissemberger (1986), it is assumed that adjustment costs in (7) originate from quarterly rather than yearly changes in consumption allocations. This choice is motivated by the nature of consumption decisions we investigate in Section 4. It is reasonable to assume, indeed, that alcohol and tobacco consumers process new information more than only once a year.

The first-order necessary conditions to solve (7) are given by the system of (second-order) interrelated Euler equations (Fanelli, 2006)

$$\rho^2 D_2 E_t \Delta^2 w_{t+2} - \rho[D_1 + 2D_2] E_t \Delta w_{t+1} + [D_1 + 2\rho D_2]\Delta w_t + D_2 \Delta^2 w_t + D_0(w_t - \widetilde{w}_t) = 0_{m\times 1}. \tag{8}$$

Using (6) and simple algebra, the Euler equations can be written as the expectations-based error-correcting model

$$E_t\Delta w_{t+2} = \rho^{-1}\Psi_1 E_t\Delta w_{t+1} - \rho^{-2}\Psi_2\Delta w_t - \rho^{-2}\Delta w_{t-1} - \rho^{-2}\Upsilon(w_t - \Gamma z_t - \gamma - \delta t) + \varphi_t \tag{9}$$

where $\Psi_1 = [\Psi + (2+\rho)I_m]$, $\Psi_2 = [\Psi + 2\rho I_m]$, $\Psi = D_2^{-1}D_1$, $\Upsilon = D_2^{-1}D_0$ and $\varphi_t = \rho^{-2}\Upsilon e_t$. The matrices Ψ_1, Ψ_2 and Υ in (9) need not to be symmetric, and the term $(w_t - w_t^*) = (w_t - \Gamma z_t - \gamma - \delta t)$ is the vector of expenditure share disequilibria, i.e. deviations of actual expenditure shares from the equilibrium levels that would prevail in the absence of frictions.

System (9) can be further manipulated in the form

$$\Delta w_t = \rho\Psi_2^{-1}\Psi_1 E_t\Delta w_{t+1} - \rho^2\Psi_2^{-1}E_t\Delta w_{t+2} - \Psi_2^{-1}\Upsilon(w_t - \Gamma z_t - \gamma - \delta t) + \Psi_2^{-1}\Delta w_{t-1} + \varphi_t^* \tag{10}$$

where $\varphi_t^* = \rho^2\Psi_2^{-1}\varphi_t$. This formulation shows that the expenditure shares at time t depend on: (i) expected changes in expenditure shares one and two periods (quarters) ahead (forward-looking behavior); (ii) deviations of actual expenditure shares from equilibrium levels (disequilibria); (iii) changes in lagged expenditure shares (myopic habit persistence).

As Ψ_1, Ψ_2 and Υ are generally not diagonal, the pattern of expenditure shares for the i-th good depends on its own dynamics as well as on the dynamics of all goods in the system. In particular, the Υ matrix contains the own and cross-adjustment coefficients, i.e. the parameters in each row measure how expenditure shares react to the own disequilibrium as well as to the disequilibria involving the other goods. For simplicity, considering the case $m = 2$ (a three demand system $n = 3$ with $m = n - 1 = 2$ two modelled expenditure shares); then the Υ matrix is given by

$$\Upsilon = \begin{bmatrix} \omega_{11} & \omega_{12} \\ \\ \omega_{21} & \omega_{22} \end{bmatrix}$$

where e.g. the structural parameter ω_{11} measures how Δw_{1t}, react to the own two periods lagged disequilibrium $(w_{1t-2} - w^*_{1t-2})$, whereas ω_{12} indicates whether Δw_{1t} react to the two periods lagged disequilibrium $(w_{2t-2} - w^*_{2t-2})$ characterizing the other expenditure share.

Apparently, the specified system seems to neglect a role to expected future prices and total expenditure. Actually, by solving the model (9) forward, it can be shown that the system is consistent with a dynamic specification where consumers react to lagged disequilibria and future expected changes of prices and total expenditure. To see this without going too much into technical details, we focus on the case where the D_2 matrix in (7) is zero, i.e. when consumers face first-order adjustment costs only. When $D_2 = 0_{m\times m}$ model (9) collapses to the system of (first-order) interrelated Euler equations

$$\Delta w_t = \rho E_t \Delta w_{t+1} - \Pi(w_t - \Gamma z_t - \gamma - \delta t) + \xi_t \qquad (11)$$

where $\Pi = D_1^{-1} D_0$ and $\xi_t = \Pi e_t$. By imposing a suitable transversality condition, (11) can be solved forward and manipulated to yield the optimal error-correcting decision rule (Fanelli, 2006*b*)

$$\Delta w_t = (I_m - \Lambda)(w_{t-1} - \Gamma z_{t-1} - \widetilde{\gamma} - \delta t) + \sum_{j=0}^{\infty} (\rho\Lambda)^j (I_m - \Lambda)\Gamma E_t \Delta z_{t+j} + \zeta_t \quad (12)$$

where Λ is a $m \times m$ matrix whose elements are opportunely related to that of Π in (11), $\zeta_t = (I_m - \rho\Lambda)(I_m - \Lambda)e_t$ and $\widetilde{\gamma} = \gamma + \delta$. It is evident that changes in expenditure shares in (12) depends on the lagged disequilibria and expectations on future expenditure shares, prices and expenditure levels. This model represents a process of "rational" habit formation, as the consumer depicted by (12) is forward as well as backward-looking.

Two further points about the specification outlined in this section should be noticed. First, model (9) embodies both the hypotheses of forward-looking behavior and convex adjustment costs, therefore it results in a tight dynamic structure.[3] Second, Heien and Durham (1991) argue that the habit effects modelled through lagged dependent variables are likely to be overstated when aggregate time-series data are used, as information about consumers heterogeneity is ignored in aggregated time series data and omitted variables result in higher residual autocorrelation, ultimately and incorrectly captured by the habit effect. This is also part of the usual aggregation argument, as individual behaviors are not necessarily reflected in aggregate models. Although this is certainly true, as most of the empirical research and policy analysis is based on aggregated time series data, it is certainly desirable to conduct a specification search to improve habit formation and rational addiction modeling.

3 Estimation procedure

The unrestricted parameters of the system of Euler equations (9) are contained in (Γ, γ, δ, ρ, Ψ, Υ). In particular, (Γ, γ, δ) refers to the long-run AIDS, and (ρ, Ψ, Υ) to the dynamic adjustment structure. We propose a simple two-step procedure for estimating model (9), which hinges on the super-consistency result guaranteed by the presence of non-stationary cointegrated variables, see Phillips (1991) and Johansen (1991).

First step

We assume that w_t and z_t are I(1) and cointegrated such that the term $d_t = (w_t - \Gamma z_t - \gamma - \delta t)$ is I(0). Under these assumptions, the efficient estimation of (Γ, γ, δ) can be carried out through cointegration methods. Tests of the hypotheses of homogeneity and symmetry involve the elements in Γ and are characterized by chi-squared distributions.[4]

The recent literature on the cointegrated AIDS model can be split into two main research flows according to the estimation method. The first bulk of works stems from Ng (1995) and Attfield (1997)[5], who adopt a triangular vector error correction (TVEC) representation of the demand system and implement Dynamic Ordinary Least Squares (DOLS), see e.g. Stock and Watson (1993). The alternative modelling procedure is the Johansen (1996) full information maximum likelihood (FIML) technique, based on a Vector Error Correction (VEC) representation of the demand system as in e.g. Ben Kaabia and Gil (2001). In comparing empirically the two approaches, Fanelli and Mazzocchi (2002) show that the VEC has the advantage of providing a "natural" framework for testing (and framing) some of the hypotheses underlying the cointegrated AIDS, such as the exogeneity of prices and total expenditure.

Second step: GMM

Once the matrix Γ, which contains the AIDS preference parameters, is replaced with its super (order T) consistent maximum likelihood (ML) estimates obtained in the first step, the estimation of system (9) can be accomplished either through ML or GMM. Estimation through a VAR-based ML approach is discussed in Fanelli (2006a) for the case $\varphi_t = 0$ ("exact" model), and in Binder and Pesaran (1995) for the more technically involved case $\varphi_t \neq 0$ ("inexact" model). Below we focus on the GMM approach, given its computational simplicity compared to "full-information" methods.

Using the decomposition $\Delta w_{t+2} = E_t \Delta w_{t+2} + \eta_{t+2}$, where the rational expectations forecast error η_t is such that $E_t \eta_{t+2} = 0$ and $E_t \eta_{t+1} = 0$, by lagging the model by two time periods, system (9) can be rewritten as

$$\Delta w_t = \rho^{-1}\Psi_1 \Delta w_{t-1} - \rho^{-2}\Psi_2 \Delta w_{t-2} - \rho^{-2}\Delta w_{t-3} - \rho^{-2}\Upsilon\ \widehat{d}_{t-2} + u_t \tag{13}$$

where $u_t = \eta_t - \rho^{-1}\Psi_1\eta_{t-1} + \varphi_{t-2}$ and $\widehat{d}_t = (w_t - \widehat{\Gamma} z_t - \widehat{\gamma} - \widehat{\delta} t)$ is the estimated disequilibria term obtained in the first-step. The matrices Ψ_1 and Ψ_2 are restricted as in (9).

Under the above hypotheses on the order of integration of variables, the model (13) involves stationary variables and reads as an error-correcting system, non-linear in the parameters. The substitution of the "true" disequilibria $d_t = (w_t - \Gamma z_t - \gamma - \delta t)$ with the estimated $\widehat{d}_t$ does not affect the asymptotics (order $\sqrt{T}$) of the estimators of $(\rho,\ \Psi,\ \Upsilon)$, due to the above mentioned super-consistency result.

It is assumed that the rational expectations forecast error η_t and the disturbance e_t are homoskedastic, and $E(\eta_t e_t') \neq 0_{m\times m}$, implying that $E(\eta_t \varphi_t') \neq 0_{m\times m}$. In this case, the disturbance term u_t in (13) follows a MA(2)-type process, hence it holds the condition

$$E(u_t \mid \Omega_{t-3}) = 0_{m\times 1}. \tag{14}$$

The orthogonality conditions in (14) represent the basis for the GMM estimation of (13). Let $\theta = (\rho,\ vec(\Psi)',\ vec(\Upsilon)')'$ be the $a \times 1$ $(a = 1 + 2m^2)$ vector containing the unrestricted parameters of (13), and θ_0 the "true" value of θ. From (14) it turns out that for any (stationary) vector s_t of dimension $q \times 1$ such that $s_t \in \Omega_{t-3}$ (i.e. for any vector containing variables dated $t-3$ and earlier) and $mq \geq a$,

$$E\left[h_t(\theta_0)\right] = 0_{mq\times 1} \tag{15}$$

where $h_t(\theta_0) = u_t(\theta_0) \otimes s_t$ and $u_t(\theta)$ denotes the vector of disturbances of (13).[6] The orthogonality conditions (15) can be employed to form a GMM estimator of θ by choosing $\widehat{\theta}_T$ as the solution to

$$\min_{\theta} \; h_T(\theta)' \; W_T \; h_T(\theta)$$

where $h_T(\theta) = \frac{1}{T}\sum_{t=1}^{T} h_t(\theta)$ is the $mq \times 1$ vector of sample moments and W_T is the weighting matrix. An optimal GMM estimator can be computed by employing an heteroscedasticity and autocorrelation consistent (HAC) estimator of the covariance matrix, as in Andrews (1991) or Newey and West (1994).[7] The over-identifying restrictions test statistic, $J_T = T \; h_T(\widehat{\theta})' \; \widehat{W}_T \; h_T(\widehat{\theta})$, is χ^2 distributed with $mq - a$ degrees of freedom.

The system of Euler equations (13) is linear in parameters aside from the discount factor ρ. However, as it is generally difficult to estimate the discount factor within the class of forward-looking models we consider here, we adopt a grid search for ρ, fixing a set of economic plausible values and then selecting the one which minimized the GMM objective function.[8]

4 Results

The empirical analysis is based on a time series of T=161 quarterly observations of UK consumer expenditure on alcoholic beverage and tobacco over the period 1963:1 to 2003:1. All data are freely supplied on-line by the UK Office for National Statistics (www.statistics.gov.uk). Data on aggregate UK household consumer expenditure on alcoholic beverages are based on volume of sales and average prices of individual types of alcoholic beverages for "off-licence" trades. This information is obtained from a continuous survey of retail outlets. Estimates for tobacco are based on data obtained from Her Majesty's Customs & Excise (HMCE) relating to the quantities of tobacco released for sale within the UK. Quarterly household aggregated expenditure is obtained from several independent sources, including the Retail Sales Inquiry and the Expenditure and Food Survey (which merges the previous Family Expenditure Survey and the National Food Survey). Prices series are the Retail Price Index (RPI) for alcoholic beverages, tobacco and the all-item RPI. Prices and expenditure time series were scaled to be 1 at the mean point to reduce the bias from the Stone Index approximation.

The system includes two expenditure share equations, respectively for alcoholic beverages (w_{1t}) and tobacco (w_{2t}), while a numeraire equation (w_{3t}) for all remaining goods was dropped from estimation to overcome the singularity problem ($\sum_{i=1}^{3} w_{it} = 1$); hence $m = n - 1 = 3 - 1 = 2$. The information required to estimate the system is completed by the prices of alcoholic beverages, tobacco and all other goods p_{1t}, p_{2t} and p_{3t} and total expenditure y_t, after deflation through the Stone index. Prices and total expenditure are collected in the vector $z_t = (p_{1t}, p_{2t}, p_{3t}, y_t)'$.

Figure 1 shows the overall trend in alcohol and tobacco consumption (real expenditure at 1995 prices) over the sample period and the expenditure shares w_{1t} and w_{2t}. UK household consumption of alcohol has risen at a fairly constant rate, even if the expenditure share does not show the same trend due to the aggregate expenditure increase. The fall in tobacco consumption, especially from the 1980s, is evident from both the real expenditure and expenditure share graphs.

The first-step of our procedure starts with the estimation of the cointegrated AIDS (6). We used a VEC for $X_t = (w_{1t}, w_{2t}, z_t')'$ and the Johansen method (Johansen, 1996). The VEC included a liner trend restricted to the cointegration space, and three centered seasonal dummies to capture deterministic seasonal patterns characterizing expenditure shares. The lag length was fixed at 5 as suggested by standard information criteria (AIC, SC, HQ), and residuals diagnostic tests.[9]

Before computing the Johansen Trace test for cointegration rank, we examined the roots of the characteristic polynomial associated with the VEC. The eigenvalues of the companion matrix associated with the VEC suggest the presence of unit roots at the long run frequency (as expected).[10] The Trace test is reported in Table 1 and indicates the presence of four unit roots in the six-dimensional system X_t, corresponding to two cointegrating relations. Given the cointegration rank $r = m = 2$, the FIML estimates of the preference parameters (Γ, γ, δ), are reported in Table 2.

The symmetry and homogeneity constraints characterizing the elements in the Γ matrix were tested through a likelihood ratio (LR) statistic and not rejected. This is an encouraging results, in contrast with many applied studies, which could reflect a specification improvement. The weak and strong exogeneity of prices and total expenditure with respect to the structural parameters of the AIDS were sharply rejected.[11] The long-run relationships also show a negative and significant trend for both products, a shift of preferences away from the two addictive goods possibly due to increased information and health concerns.

Table 3 reports the estimates of the long-run Marshallian elasticities for the homogeneity and symmetry constrained system. Some results are striking, albeit plausible and consistent with previous studies. Demand for alcohol in the UK is quite price-elastic (-1.23) and there is clear evidence of complementarity between alcohol and tobacco consumption, as in the study by Jones (1999) for the UK and Decker and Schwartz (2000) on US individual data. In the long-run, there is also a very high expenditure elasticity, which contrasts the negative trend observed in preferences, as increasing incomes lead to higher consumption. Duffy (2003) also finds some complementarity between tobacco and spirits and a high expenditure elasticity for spirits. However, his higher level of disaggregation allows to distinguish across alcoholic beverages, and beer and wine are found to be substitutes of tobacco. For tobacco consumption, our results differ from Duffy (2003), as the Marshallian long-run own-price and expenditure elasticities are non-significant, showing a consumer whose long-run consumption equilibrium is independent from the traditional economic factors. Habits and addiction are the main determinants of changes in consumption levels.

After replacing the preference parameters of the AIDS (Γ, γ, δ) with the estimates of Table 1, we next moved to the second-step estimation procedure. The reference model is the system of interrelated Euler equations (13). Details of the econometric specification are as follows. For GMM estimation, the set of stationary instruments was $s_t = (\Delta_4 w_{1t-3}, \Delta_4 w_{2t-3}, \Delta p_{1t-3}, \Delta p_{2t-3}, \Delta p_{3t-3}, \Delta w_{1t-4}, \Delta w_{2t-4}, \Delta p_{1t-4}, \Delta p_{2t-4}, \Delta p_{3t-4}, \Delta y_{t-4}, \Delta w_{2t-5})'$ where for a given (logged) variable, v_t, $\Delta_4 v_t = v_t - v_{t-4} = (1 - L^4)v_t$ generates yearly changes.[12] It can be recognized that s_t belongs to the information set a time $t-3$ and earlier. The weight matrix was estimated through a HAC procedure with Bartlett weights and Newey and West's (1994) criterion for bandwidth. From the selected grid, the values of the discount factor that minimizes the GMM objective function is equal to 0.98, consistently with a quarterly average real discount rate of 2% (i.e. a real yearly rate of about 8%).

GMM estimates are summarized in Table 4 along with the J_T statistic for over-identifying restrictions, whereas in Table 5 we summarized Shea's (1997) measures of instrument relevance.[13] It turns out that the partial correlation among the right-hand side variables of system (13) and the list of instruments selected for GMM estimation range from 30% to 53% which appears reasonable for variables which are expressed in first differences (growth rates).

The estimates of Table 4 can be summarized in two important results. First, the estimated interrelated dynamic structure of adjustment suggests both backward and forward-looking behavior. Second, besides the complementarity of alcohol and tobacco discussed above, a further relevant link emerges in the consumption of these two additive good. Alcohol and tobacco adjust not only to their own past disequilibria, but also to each other's ones as suggested by the estimated Υ matrix.

5 Conclusions

Understanding the role that uncertainty - other than risk aversion - plays in determining consumption decisions of addictive goods has important policy implications. Individuals often face significant price uncertainty about future tax policies for such kind of goods. State governments sometimes try to change behavior by announcing policies that may be implemented in the future. These announcements may be effective if the permanently change the beliefs that individuals hold about future prices, whereas they may have modest effects on individual and aggregate consumption if they are perceived to be temporary. Tax policies thus not only affect prices in the period that they are announced and enacted, but also beliefs about future prices if they are perceived to be credible and agents are forward-looking.

Our paper suggests a dynamic specification for the Almost Ideal Demand System which is consistent with both backward and forward-looking behavior. The proposed set-up has been used to model alcohol and tobacco decisions in a joint dynamic framework, which admits an interpretation in terms of rational addiction. Estimation is based on a two-step strategy, where cointegration techniques are used for estimating the long run demand system that would prevail in the absence of frictions, and GMM techniques for estimating the implied interrelated system of adjustment towards equilibria.

The empirical application, based on a 40-years long time series of UK alcohol, tobacco and other goods expenditure supports the specification choice and leads to four relevant results: (i) the joint backward and forward-looking specification is consistent with the proposed application; (ii) the theoretical restrictions of homogeneity and symmetry, often rejected in time series-based AIDS models, are also valid within the adopted specification; (ii) exogeneity of prices and total expenditure in the long-run relationship is strongly rejected and the proposed method allows to account for endogeneity, overcoming a relevant limit of most empirical applications; (iv) as few empirical studies have investigated before, there is a strong complementarity between alcohol and tobacco consumption behavior, not only in terms of price reactions, but also in adjusting to past cross-disequilibria.

Our study raises a couple of relevant theoretical and empirical issues which still need to be addressed; first, one may wish to check for the impact on results of alternative cost-adjustment structures; and second, it may be difficult to generalize the results of an aggregate time-series study, as addictive behavior are known to vary significantly across socio-demographic segments and a panel data extension (as in Baltagi and Griffin, 1995) is desirable. The encouraging results of the proposed application suggest that dynamic issues deserve a careful even if complex treatment when addictive goods are considered and further study addressing the above limitations is desirable.

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FIGURES AND TABLES

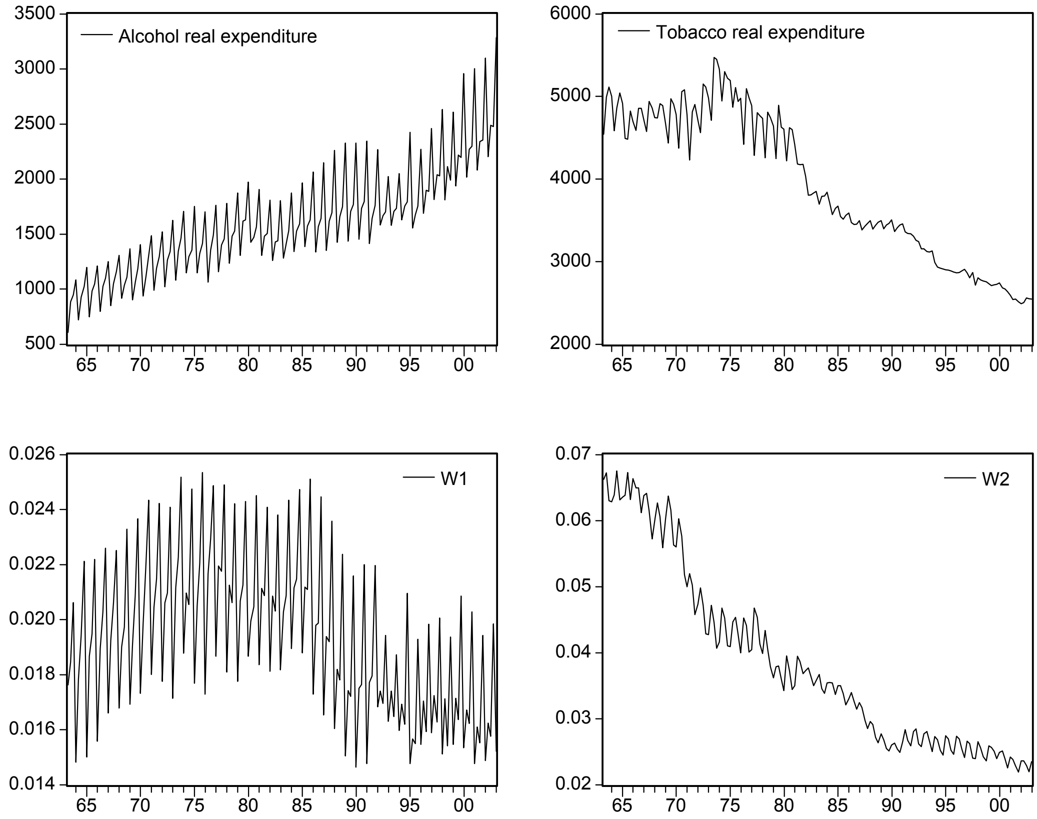

Fig. 1. Trends in alcohol and tobacco aggregate consumption; UK quarterly data.

Table 1
Johansen's Trace test for cointegration rank based on the VEC with 5 lags, three centered seasonal dummies and a restricted linear trend.

Number of unit roots	Rank (r)	Trace	5% c.v
6	0	125.2	114.9
5	1	90.9	89.9
4	2	59.7	62.6
3	3	32.7	42.2
2	4	13.4	24.4
1	5	4.7	12.4

Notes: 5% asymptotic critical values in the last column are taken from Table 15.4 in Johansen (1996).

Table 2

Upper panel: FIML estimates of the parameters of the AIDS (7) with homogeneity and symmetry imposed. Lower panel: Likelihood ratio (LR) tests for the hypotheses of homogeneity and symmetry and on the weak and strong exogeneity of prices and total expenditure.

Commodity	p_{1t}	p_{2t}	p_{3t}	y_t	tr
w_{1t}^* (Alcohol)	-0.003 (-0.25)	-0.020 (-5.0)	0.024	0.054 (3.9)	-0.0003 (33.3)
w_{2t}^* (Tobacco)	-0.020 (-5.0)	0.039 (16.2)	-0.019	-0.039 (-6.5)	-0.0002 (-50.0)
LR: homogeneity and symmetry	$\chi^2(3)$=2.45 [0.48]				
LR: weak exogeneity of z_t	$\chi^2(8)$=40.20 [0.00]				
LR: strong exogeneity of z_t	$\chi^2(40)$=82.77[0.00]				

Notes: the cointegration rank is fixed at 2 consistently with the results in Table 1;

t-statistics in parentheses, p-values in square brackets.

Table 3
Marshallian Long-Run Elasticities.

	Elasticities			
Commodity	Alcohol	Tobacco	Other Goods	Expenditure
w_{1t}^* (Alcohol)	-1.23 (0.42)	-1.16 (0.05)	1.21	3.80 (0.56)
w_{2t}^* (Tobacco)	-0.50 (0.01)	0.01 (0.01)	-0.48	-0.01 (0.02)

Note: Standard errors in parentheses.

Table 4
GMM estimates of the parameters of the system of Euler equations (13) with J_T test for over-identifying restrictions.

GMM estimates of system (13)

$$\rho = \underset{\text{fixed}}{0.98}\ , \quad \widehat{\Psi}_1 = \begin{bmatrix} \underset{(10.34)}{1.48} & \underset{(5.38)}{1.03} \\ \underset{(-10.83)}{-1.62} & \underset{(-15.13)}{-0.88} \end{bmatrix}\ , \quad \widehat{\Psi}_2 = \begin{bmatrix} \underset{(10.34)}{0.46} & \underset{(5.38)}{1.03} \\ \underset{(-10.83)}{-1.62} & \underset{(-15.13)}{-1.90} \end{bmatrix}$$

$$\widehat{\Upsilon} = \begin{bmatrix} \underset{(-2.96)}{-0.004} & \underset{(-1.50)}{-0.117} \\ \underset{(-2.49)}{-0.005} & \underset{(-2.95)}{-0.244} \end{bmatrix}\ , \quad J_T = \underset{[0.70]}{12.57}$$

Alcohol equation:	Tobacco equation:
$R^2 = 0.93$	$R^2 = 0.63$
s.e. =0.005	s.e. = 0.006

Note: the first row in the matrices $\widehat{\Psi}_1$, $\widehat{\Psi}_2$ and $\widehat{\Upsilon}$ refers to the alcohol equation, and the second row to the tobacco equation; the vector of instruments is $s_t = (\Delta_4 w_{1t-3}$, $\Delta_4 w_{2t-3}$, Δp_{1t-3}, Δp_{2t-3}, Δp_{3t-3}, Δw_{1t-4}, Δw_{2t-4}, Δp_{1t-4}, Δp_{2t-4}, Δp_{3t-4}, Δy_{t-4}, $\Delta w_{2t-5})'$ and includes three deterministic seasonal dummies; t-statistics in parentheses; the p-value associated with the J_T test is in square brackets and is computed from a χ^2 distribution with $mq - a$ =16 degree of freedom, where m =2, q =15 is the number of instruments in s_t (including the deterministic seasonal dummies), and $a = 14$ is the number of free estimated parameters.

Table 5
Shea's (1997) $\overline{R}_p^2$ partial measures of instrument relevance, see footnote 17 for details.

Regressors of system (13)	$\overline{R}_p^2$
Δw_{1t-1}	0.48
Δw_{2t-1}	0.53
Δw_{1t-2}	0.31
Δw_{2t-2}	0.49
$\widehat{d}_{1t-2}$	0.49
$\widehat{d}_{2t-2}$	0.30

Notes: the vector of instruments is $s_t = (\Delta_4 w_{1t-3}, \Delta_4 w_{2t-3}, \Delta p_{1t-3}, \Delta p_{2t-3}, \Delta p_{3t-3}, \Delta w_{1t-4}, \Delta w_{2t-4}, \Delta p_{1t-4}, \Delta p_{2t-4}, \Delta p_{3t-4}, \Delta y_{t-4}, \Delta w_{2t-5})'$ and includes three deterministic seasonal dummies.

Notes

[1]Starting with the work of Johnson et al. (1992), the error-correcting nature of demand systems is perceived as a key feature when variables are non-stationary. Cointegrated demand system have often proved consistent with the underlying theoretical restrictions, otherwise subject to frequent rejection (see Keuzenkamp and Barten, 1995).

[2]As known, maximum likelihood estimates are invariant to the choice of the equation to be dropped (see Barten, 1969).

[3]Quadratic costs can be restrictive, albeit mathematically convenient, therefore rejection of the model should not be intended as a clear cut evidence against the rational habit formation hypothesis as rational habit formation might still hold under a different dynamic structure.

[4]Phillips (1991) and Johansen (1991) discuss the theoretical conditions under which efficient estimators that belong to the locally asymptotically mixed normal (LAMN) class can be obtained.

[5]See also Duffy (2002) for an application to alcohol demand.

[6]In principle, one can consider different sets of instruments for the m equations of the dynamic demand system.

[7]The estimation of model (13) through GMM leads to conventional questions about instrument choice, and "weak identification" issues, which are well beyond

the objectives of this paper; the interest reader is referred to Stock et al. (2002).

[8]Clearly, plausible values of ρ are close to (but less than) one. Most studies find that variations in ρ do not significantly affect estimates of the other parameters.

[9]Computations were performed through PcGive10.0 and E-Views 4.0.

[10]The eigenvalues of the companion matrix associated with the VAR suggest also the possibility of unit roots at the seasonal frequency (Hylleberg et al., 1990). A throughout time series analysis of the seasonal pattern of UK tobacco and alcohol consumption goes beyond the purposes of the present paper. However, if the dynamics of the VEC is correctly specified, the possible presence of unit roots at the seasonal frequencies does not pose any additional issues on the usual cointegration tests at the zero frequency (Lee and Syklos, 1995), as well as on the estimation of long run relationships (Johansen and Schaumburg, 1999).

[11]The "endogeneity" of total expenditure can be easily justified if one realizes that (the antilog of) y_t represents by construction the denominator of expenditure shares. Observe that the violation of the weak exogeneity of z_t implies that the efficient estimation of the AIDS through Dynamic OLS (DOLS) should be performed by including a number of leads of Δz_t in addition to lags in the regression of w_t on z_t, see Ng (1995) and Fanelli and Mazzocchi (2002).

[12]The filter $(1 - L^4)$ removes all unit roots characterizing v_t at all frequencies. Three centered seasonal dummies where included on the right hand side of (13) (and in the instrument list) to account for deterministic seasonal patterns characterizing the variables of the demand system. For the sake of simplicity, estimates of

coefficients associated with seasonal dummies are not reported in Table 3.

[13]In models with one explanatory variable, the R^2 obtained from regressing the endogenous (explanatory) variables on the instrument vector can be considered a useful measure of instrument relevance. In multivariate models, however, one cannot measure relevance by simply regressing each explanatory variable on the instrument vector in turn; indeed, if instruments are highly collinear the R^2 might result high for each explanatory variable even when instruments are actually "weak". Shea's (1997) simple method allows to compute, for each explanatory variable, partial R^2 measures of instrument relevance, $\overline{R}_p^2$, by correcting opportunely for the correlation among instruments. Observe that in Table 5 we did not report partial $\overline{R}_p^2$ for deterministic seasonal dummies.